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THE BIM MATURITY PROCESS TO THE DIGITAL TWIN FOR LEAN STRATEGIC FACILITY MANAGEMENT

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Abstract

Digital twins are increasingly popular in the built environment for addressing unique challenges through tailored use cases. One such application is in decision support and management for strategic facility management. Employing a Design Science Research (DSR) strategy, this research proposes a digital twin framework for Lean strategic facility management, which explores the integration of Building Information Modelling (BIM) process maturity. The findings present a structured approach that enables organisations to achieve enhanced decision support, efficient decision management, and combined Lean management. Organisations can enhance their performance in strategic facility management by utilising the proposed framework. This paper offers practical guidance for organisations seeking to adopt Lean management in strategic facility management by providing a BIM maturity process for a Lean strategic facility management digital twin. Embracing this approach enables organisations to fully harness the potential of digital twins, driving customer value improvements.

Introduction

Strategic facility management involves effectively balancing a business's present and future needs, ensuring the support of core functions and anticipating future requirements. (Barrett, 2000). Information management is vital in strategic facility management, enabling organisations to make informed decisions and optimise their operations. However, many facility management organisations still need to adopt a strategic approach to gathering, analysing, and utilising facility operation data (Greibach, 2021). Unfortunately, information usage is often limited to reactive maintenance or compliance activities, with little connection to core business objectives (Greibach, 2021; IFMA, 2021; RICS, 2014). This lack of timely access to comprehensive and relevant information hinders executives from effectively managing their built assets and making data-driven decisions (buildingSmart, 2021). Therefore, there is a growing need for improved information management practices to unlock business value and revolutionise strategic facility management.

Information management needs accurate, up-to-date, and accessible data that aligns with business objectives (RICS, 2011). BIM is proposed as a Lean solution in the construction industry, with its adoption benefiting from a proactive Lean approach (Demirdöğen *et al.*, 2020). BIM and Lean processes mutually reinforce each other, maximising benefits and improving overall productivity and performance (Andújar-Montoya *et al.*, 2020).

Digital twins complement BIM models in facility management by providing real-time data handling and analytical and autonomous capabilities (Lu et al., 2020; Trombadore et al., 2020). Lean management applied to BIM for facility management can facilitate the achievement of core business value, emphasising the integration and exchange of information across divisions and services within an organisation (Wanigarathna *et al.*, 2019). This approach aligns with an overall organisational strategy to transform into a Lean enterprise. A Lean enterprise is an integrated organisation that efficiently delivers value to stakeholders through Lean management.

This paper explores the BIM maturity process within the digital twin framework for Lean strategic facility management. Organisations can improve their decision-making, optimise operations, and enhance customer value and facility management performance by utilising these strategies.

Literature review

In a world increasingly becoming digital, organisations must transform to remain efficient and competitive by using digital technologies to develop new business processes, culture, and customer experiences, or to modify existing ones, to meet shifting business and market requirements. With digital transformation in organisations, significant investments have been made in digitising-built assets, but the anticipated return on investment has yet to materialise. (Kennedy, 2022). The conventional mainstream digital tools and solutions do not consider the facility's strategic needs, therefore limiting proper strategic decision-making approaches (Demirdöğen *et al.*, 2020); instead, it is concerned with operations and maintenance; as a result, the organisation cannot use them to improve decision-making capacities in core business (Gnanarednam *et al.*, 2013). Furthermore, siloed work contributes to a gap between operations and information management, leading to a lack of evidence and digital business tools to link facility management activities with organisational performance. Facility managers are thus dealing with facilities that are too costly to operate and cannot control costs very well; timely information for decision-making is rare, leading to poor-quality in-service provision (Yalcinkaya & Singh, 2014).

Information management can aid in breaking the silos, thus providing maximum business performance and improving communication links (Mbabu *et al.*, 2022). Integrating BIM with facilities management information improves facility information management operations, making information more trustworthy and strategically sound (FMN, 2020). Facility owners, operators, and users can acquire new operational and performance-related benefits when asset information requirements align with the core organisational strategy and deliver through standardised information management and the openBIM approach (Zahra, 2022). Facility management based on OpenBIM standards may help to speed the integration of BIM into facility management procedures as a platform for collaboration, and interoperable data transmission offers an opportunity for improved quality data flow, automated mapping, and information management. (Zahra, 2022).

A Lean management approach will enable a streamlined and seamless deployment of BIM to address the concerns of variability and waste in facility management (Terreno et al., 2019); however, BIM for facility management faces some challenges as it does not work with real-time data (Burgess et al., 2020a; Haghig Khajavi et al., 2019; Lu et al.,2020), making information flow between real-time operations and monitoring systems and the BIM model more difficult to handle (Hoang et al., 2020). In addition, BIM in facility management is not as analytic and automated (Terreno *et al.*, 2019); for example, BIM facility management information capture in the built asset life cycle is not always adequate and wealthy by lacking decision support and management capability to update facility management (Dixit *et al.*, 2018; Tsay *et al.*, 2022).

A digital twin is a virtual representation of a physical object or process that can collect information from its real-world environment to represent, validate, and simulate the physical twin's current and future behaviour (Botín-Sanabria *et al.*, 2022). Digital twins are replacing these historical, data-driven, conventional tools and solutions for strategic digital decision-making (CNBC, 2023). In addition, digital twins can enable greater interoperability and collaboration by ensuring that different systems and platforms can work together seamlessly. This provides for digital decisions, providing a powerful means of constantly improving your operations, which is critical to the success of your organisation.

Digital twins can bring your decisions to the forefront and provide you with the fine-grained control you require. They, too, have the potential to model and monitor how people, business processes and technology interact with the built environment in real-time, providing a more comprehensive context about the built environment (Godager *et al.*, 2021) through a cyber-physical linkage reciprocally and synchronised in real-time through interconnected sensors and devices.

Research can be found on BIM maturity to digital twin and Lean integration for the construction phase; however, less attention has been paid to facility management or strategic facility management. Sacks et al. (2020) introduced digital twin construction as a data-centric approach to construction management that employs information and monitoring technology in a Lean, closed-loop planning and control system. Sacks et al. (2020) affirm that Lean provides principles for an effective production planning and control model that may take advantage of the data supplied by the digital twin's monitoring and interpretation components to improve processes. As BIM technology is maturing into the digital twin, it can be found that there is a need for research on the potential of digital twin and Lean integration in strategic facility management to enable Lean strategic facility management, optimised business performance, whole-life performance and reducing waste in business and built assets lifecycle operations.

This research finds a limitation in the availability of frameworks in BIM maturity to digital twin for strategic facility management. Godager et al. (2021) identified the need for frameworks to support BIM in optimising core business management in demonstrating BIM value. In contrast, Botín-Sanabria et al. (2022) indicated that the implementation of digital twins is limited and yet to reach its full potential due to a scarcity of frameworks for digital twin implementation (Botín-Sanabria *et al.*, 2022). Therefore, this research aims to solve a problem that is both practical and theoretically significant in investigating digital twin strategic facilities management connections to enable Lean strategic facility management. A conceptual framework is proposed to represent and define the fundamental elements/constructs/concepts to be examined visually, i.e., strategic planning, BIM delivery, digital twin platform, decision support and management, and Lean management assumed relationships between them. This paper is part of more extensive research to propose a digital twin framework for Lean strategic facility management.

The proposed conceptual framework introduces the BIM maturity process as a vital component of the Lean strategic facility management digital twin. Facility management organisations can fully utilise the potential of BIM to aid in strategic decision-making and Lean management by integrating the BIM maturity process into the digital twin framework.

Research Methodology

Design Science Research (DSR) is knowledge-creating prescriptive research that focuses on improving facets of the built environment (Voordijk, 2009). Design science outlines a cyclical development and evaluation process that initially begins with an outline of an issue in the built environment, subsequently proposes that a new process or technology could solve this issue, and ultimately evaluate whether the novel solution is successful for its envisioned users and in its envisioned setting (Hevner et al., 2004b;

Johannesson & Perjons, 2012; Kehily &, 2015; Voordijk, 2009). The solution to a field problem takes the form of an artificial construct or 'artefact,' which is defined as an artificial object constructed by people to solve practical problems. (Johannesson and Perjons, 2012). Artefacts can be physical items, drawings, guidelines, or information and communication technology solutions. In design science, a framework could be described as an 'artefact' based on that notion.

A conceptual framework is associated with the abstraction or understanding of a situation that leads to a specific goal (Shehabuddeen *et al.*, 1999). A conceptual framework further defines, either graphically or narratively, the essential elements to be examined, including key components, constructs, or variables and the assumed relationships between them. Conceptual frameworks can be simple or complex, theory-driven, or common-sense descriptive or causal (Kalaa *et al.*, 1994). This research aims to propose a digital twin as a solution to enabling Lean strategic facility management. For this research, a model is ideal for presenting the constructs to the framework. In contrast, the conceptual framework would be suitable for understanding the relationships between its constructs towards meeting Lean strategic facility management.

The initial stage involves performing theoretical literature studies to find practical problems with research potential. The primary issue is a need for more evidence and business tools for integrating facility management with the core business and an effective strategic decision-making strategy that considers the client's strategic requirements; to enhance core business and support decision management and support capabilities. This is followed by the second stage, in which the researcher derives extant knowledge constructs for the problem. Finally, the research assembles known knowledge to build an artefact solution to the problem, represented through an initial proposed digital twin framework to enable Lean strategic facility management. The initial proposed framework is produced in the second phase by linking the knowledge constructs and their relationships.

The third stage is evaluation, which involves finding how effective the proposed solution is in addressing the problem in its environment. This calls for an evaluation survey in the third stage of the research process to evaluate the research problem, the research solution's potential and the proposed solution's efficacy. The research chose an online questionnaire survey that involved 30 respondents of diverse expertise and experience within the built environment.

The fourth stage follows the third: research exploration through semi-structured interviews. This stage comprised 16 interviews with diverse participants, from facility operators and information solution developers to information managers. In the research evaluation, the researcher gathered and analysed data to better understand the problem-solving process, tools, and methods used in the industry to co-create an evolved conceptual framework for the problem.

In the fifth stage, the researcher will undertake research evaluation via expert panel discussions to verify the proposed framework. The expert panel evaluation will assess the framework's fruitfulness, prudence, quantification, scope, progressiveness, and internal and external consistency. The expert evaluation findings will be used to refine the proposed framework to generate a final framework. The final stage is the contribution of research. The final stage is research contribution. The research aims to contribute to theory by providing prescriptive knowledge, which includes solution constructs, representation of the proposed framework, methods, and limitations. This paper presents findings from the second to fourth stages of Design Science Research.

Results and Discussion

The BIM maturity process to a Lean strategic facility management digital twin illustrated in Figure 1 involves four levels, starting from strategic planning at level 0 and progressing to the establishment of a dynamic digital twin through BIM delivery at level 1, data source onboarding and integration at level 2, data modelling at level 3, and decision automation at level 4. Each level builds upon the previous one, leading to increased functionality to enhance the capabilities and functionality of the digital twin.

Level 0: Strategic planning

At Level 0 of the BIM maturity process, organisations embark on strategic planning and develop a robust digital twin strategy. This level sets the foundation for the successful implementation and utilisation of the digital twin throughout Strategic facility management.

Strategic planning involves thoroughly assessing the organisation's goals, objectives, and key stakeholders. It is crucial to understand the specific needs and requirements of the enterprise to ensure that the digital twin aligns with the overall strategic direction. This may involve engaging with various departments, such as engineering, operations, and maintenance, to gather insights and identify the pain points the digital twin can address.

During this phase, organisations also define the scope and boundaries of the digital twin implementation. This includes determining which assets, systems, and processes will be integrated into the digital twin platform. Additionally, performance targets and metrics are established to assess the success and effectiveness of the digital twin strategy.

Developing a digital twin strategy is a critical component of Level 0. It outlines the roadmap for implementing the digital twin and defines the key objectives, milestones, and timelines for each stage of the maturity process. The strategy should consider data management, digital twin

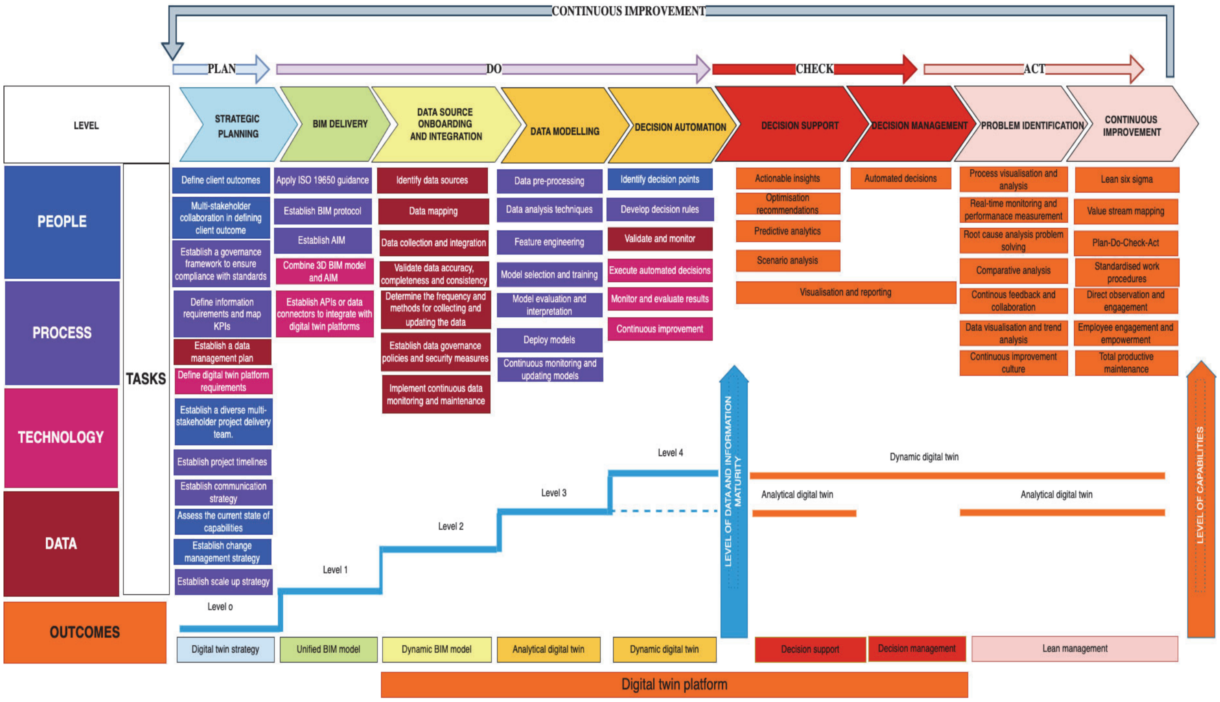

Figure 1: Evolved digital twin framework to enable Lean strategic facility management.

platform infrastructure, communication, and stakeholder engagement.

Organisations can ensure alignment and a shared understanding of digital twin implementation outcomes and benefits among stakeholders by creating a clear digital twin strategy. This fosters team collaboration and communication and enables a more holistic approach to facility management.

The benefits of strategic planning and a well-defined digital twin strategy are manifold. Firstly, it enables organisations to comprehensively view their assets, systems, and processes, fostering a more informed decision-making process. Secondly, strategic planning enhances collaboration and coordination among various departments and stakeholders. When teams establish a common vision and goals, they can collaborate effectively to accomplish their intended results. This leads to improved communication, streamlined workflows, and better resource allocation.

Furthermore, the digital twin strategy provides a framework for managing risks and challenges associated with the implementation process. It allows organisations to identify potential barriers, develop mitigation strategies, and allocate resources effectively. This proactive approach minimises disruptions and ensures a smoother transition to subsequent levels of BIM maturity.

Finally, a well-defined digital twin strategy sets the stage for future scalability and adaptability. As technology evolves and new opportunities emerge, organisations can leverage their strategic plan to incorporate additional functionalities, data sources, and advanced analytics. This enables continuous improvement and optimisation of the digital twin ecosystem, keeping the organisation at the forefront of innovation.

Level 1: Establishing a unified digital twin through BIM delivery.

Level 1 of the BIM maturity process involves inputs from the design, construction, and handover stages, ensuring that the digital twin encompasses the entire life cycle of the built asset. During the design stage, the organisation engages with architects, engineers, and designers to develop a detailed BIM model that represents the physical and functional characteristics of the asset. This includes capturing geometric data, such as the building's layout, dimensions, and structural elements, as well as non-geometric data, such as materials, specifications, and equipment details. The BIM model serves as a central reference for all stakeholders involved in the project, facilitating coordination and collaboration throughout the design process.

As construction commences, the BIM model becomes an invaluable tool for managing construction activities and ensuring that the project adheres to the design intent. Contractors and subcontractors utilise the BIM model to visualise the construction process, identify potential clashes or conflicts, and optimise the construction sequencing. This integration of BIM with construction operations allows for better project control, improved resource utilisation, and enhanced communication among the construction team.

Upon completion of the construction phase, the BIM model transitions to the handover stage, becoming an asset for facility management. The as-built BIM model, enriched with accurate data and documentation from the construction phase, is handed over to the facility management team. This includes detailed information about the installed systems, equipment specifications, maintenance schedules, and operational parameters. The facility management team can use this comprehensive digital representation to operate, maintain, and manage the facility throughout its life cycle.

During Level 1, the organisation ensures that the BIM model aligns with the established information requirements and protocols. The BIM execution plan (BEP) outlines the responsibilities and deliverables from the design, construction, and handover stages, ensuring that all stakeholders contribute to developing a unified digital twin. The BIM protocol within the BEP governs the collaboration and data exchange among the different parties, establishing explicit information sharing and coordination guidelines.

The BIM model is continuously validated and updated throughout the design, construction, and handover stages to ensure data accuracy and quality. Quality checks are conducted to verify the model's integrity and address any discrepancies or inconsistencies. This validation process includes verifying the alignment of the BIM model with the physical construction, capturing as-built changes, and updating the data as required. This ensures that the BIM model accurately represents the physical asset and facilitates seamless facility management.

Throughout Level 1, effective communication and coordination among stakeholders play a crucial role. Regular meetings, workshops, and coordination sessions are conducted to address design issues, resolve conflicts, and ensure that the BIM model accurately reflects the intended design and construction requirements. Effective communication channels are established to facilitate information exchange, feedback sharing, and decision-making among the design, construction, and facility management teams.

Establishing a central platform for BIM collaboration and data management enables seamless integration between the different stages. Design data, construction updates, and handover information are stored and accessed through a CDE, ensuring the BIM model remains a dynamic and up-to-date asset representation. The CDE may incorporate cloud-based storage, version control mechanisms, and collaboration tools to enable stakeholders to work together efficiently.

As Level 1 concludes, the organisation has successfully achieved a unified digital twin incorporating inputs from various stages, including design, construction, and handover. The culmination of these inputs results in a unified BIM model that captures the built asset's physical and functional characteristics. The unified BIM model serves as a central repository of information, encompassing the geometric data representing the asset's layout, dimensions, and structural elements and the non-geometric data comprising materials, specifications, equipment details, maintenance schedules, and operational parameters. This comprehensive representation gives stakeholders a holistic view of the built asset, facilitating effective decision-making and analysis throughout its life cycle. To ensure seamless integration with other data sources, such as sensors or systems, the unified BIM model must establish data connectors, such as APIs, that enable data synchronisation and interoperability.

Level 2: Establishing a dynamic BIM model through data source onboarding and integration.

At Level 2 of the BIM maturity process, the focus shifts towards creating a dynamic BIM model through data source onboarding and integration. This level involves identifying relevant data sources, mapping data elements to the BIM model, collecting and integrating data, and ensuring data accuracy and quality.

To begin, it is essential to identify the various data sources that can contribute to the digital twin. These sources may include sensors, IoT devices, core business systems, asset databases, maintenance logs, and other relevant data sources. Each source brings valuable information that can enhance the understanding and management of the facility.

Once the data sources are identified, the next step is to map each source's data element to the BIM model's corresponding parameters. This mapping ensures that the collected data aligns with the digital twin's model, allowing for effective integration and analysis. Establishing clear guidelines and protocols for this mapping process is crucial to maintain consistency and standardisation across the data.

With the mapping process complete, the focus shifts to collecting and integrating the data into the digital twin platform. This involves implementing data storage capabilities, establishing data connectors or APIs for seamless data synchronisation, and ensuring data accuracy, completeness, and consistency. Data validation processes are implemented to identify and resolve any discrepancies or errors within the collected data.

Real-time data streaming capabilities are often implemented at this stage to enable the digital twin to receive and process data in near real-time. This ensures that the digital twin reflects the most up-to-date information about the facility, allowing for timely decision-making and responsiveness to changes or events.

Data governance policies and security measures play a vital role in maintaining the integrity and privacy of the collected data. Establishing protocols for data access, sharing, and ownership is essential to ensure compliance with regulations and protect sensitive information. Regular audits and reviews of data governance practices help to maintain data quality and mitigate risks associated with data management.

Continuous monitoring and maintenance of the integrated data become crucial at this level. Data quality checks, data cleansing, and data enrichment processes are implemented to enhance the accuracy and effectiveness of the digital twin. Regular updates and maintenance activities ensure that the digital twin remains a reliable and trusted source of information for facility management.

Throughout this level, the focus is on integrating disparate data sources and establishing a dynamic BIM model that reflects the facility's current state. Facility managers can obtain a complete understanding of their facility's performance, maintenance requirements, energy consumption, and occupant behaviour, among other pertinent factors, by consolidating data from various sources.

The dynamic BIM model created at Level 2 serves as a foundation for further analysis and insights in subsequent levels of the maturity process. It provides a holistic view of the facility, enabling decision-makers to identify patterns, trends, and anomalies. This comprehensive understanding of the facility sets the stage for data-driven decision-making and optimisation in the higher levels of the maturity process.

Level 3: Establishing an analytical digital twin through data modelling.

At Level 3 of the BIM maturity process, the focus shifts towards establishing an analytical digital twin by leveraging data modelling techniques. This level aims to derive insights from the integrated data and utilise them to make informed decisions and predictions about the facility's performance and future scenarios.

First, the integrated data from various sources, such as sensors, IoT devices, core business systems, and asset databases, serve as the foundation for analysis. This data is pre-processed and analysed using statistical analysis, machine learning algorithms, predictive modelling, clustering, or time series analysis. The objective is to uncover patterns, relationships, and trends within the data that can provide valuable insights.

One crucial step in this process is feature engineering, which involves selecting, transforming, and combining the relevant data features to optimise them for modelling. Data scientists apply domain knowledge and statistical techniques to identify the most informative features contributing to the desired outcomes. This step helps improve the accuracy and performance of the models.

Once the data is prepared, suitable models are selected and trained based on the specific objectives of the digital twin and the facility management challenges at hand. Machine learning algorithms, such as regression, classification, or clustering algorithms, may be employed depending on the nature of the data and the desired insights. The models are trained using historical data and validated to ensure their effectiveness and reliability.

The results obtained from the models are then evaluated and interpreted to derive actionable insights. Facility managers can better understand the facility's behaviour, performance trends, and potential risks or inefficiencies. These insights can help identify improvement opportunities, optimise maintenance schedules, predict equipment failures, and make informed decisions regarding energy consumption, occupant comfort, or space utilisation.

Integrating the models within a digital twin platform enables real-time data flow and provides continuous monitoring and analysis of the facility's performance. The digital twin acts as a central hub where the analytical models are deployed, allowing stakeholders to access and interact with the insights and predictions generated by the models.

An analytical digital twin is a valuable tool for facility managers, enabling them to address issues, optimise operations, and improve decision-making proactively. For example, facility managers can adjust HVAC settings or implement energy-saving measures to optimise energy usage by predicting future energy consumption patterns based on historical data and weather forecasts. They can also simulate different scenarios and evaluate the potential impact of changes in occupancy patterns or space reconfigurations on energy consumption and comfort levels.

Additionally, the analytical digital twin can support long-term planning and resource allocation. Facility managers can make informed decisions about facility expansion, equipment upgrades, or maintenance strategies by simulating different scenarios and assessing the impact of various factors. The insights derived from the digital twin's data modelling capabilities empower facility managers to optimise resource allocation, reduce costs, and improve the overall efficiency and sustainability of the facility.

Continuous improvement is a vital aspect of Level 3. As new data becomes available and the models are retrained, the digital twin's insights and predictions become more accurate and reliable. This iterative process ensures that the facility management strategies evolve and adapt to changing conditions, maximising the benefits derived from the digital twin.

Level 4: Establishing a dynamic digital twin through decision automation.

At Level 4 of BIM maturity, the focus shifts towards establishing a dynamic digital twin incorporating decision automation capabilities. This level builds upon the foundation of the previous levels, where a unified digital twin has been established through BIM delivery, a dynamic BIM model has been created through data source onboarding and integration, and an analytical digital twin has been developed through data modelling.

Decision automation in the context of the digital twin involves identifying decision points within the facility management process where automated decisions can be made based on the insights derived from the analytical digital twin. For example, these decisions can range from optimising energy usage and resource allocation to predicting maintenance needs and occupancy planning.

The first step in establishing decision automation is identifying key decision points. This requires a thorough understanding of the facility management processes, challenges, and objectives. Some examples of decision points are energy management, space utilisation, scheduling preventive maintenance, and emergency response planning.

Once the decision points are identified, the next step is to develop decision rules. Decision rules can be based on various factors, such as data modelling insights, predefined thresholds, optimisation objectives, or advanced machine learning algorithms. These rules serve as the foundation for automating decision-making within the digital twin.

The benefits of decision automation within the digital twin are significant. Firstly, it enables decision-makers to make data-driven decisions in real or near real-time. Facility managers can respond quickly to changing conditions, optimise operations, and distribute resources efficiently by automating decision-making with accurate and current information.

Secondly, decision automation can help in optimising resource allocation. One example of what a digital twin can do is analyse patterns of energy consumption. It can identify inefficiencies and then automatically adjust settings or suggest actions to minimise energy waste. This leads to cost savings and contributes to sustainability efforts by minimising the facility's environmental footprint.

Thirdly, decision automation enhances preventive maintenance planning. The digital twin can continuously monitor equipment performance, analyse data trends, and predict maintenance needs. Facility managers can improve equipment maintenance by automating scheduling and receiving alerts for potential issues. This proactive approach can reduce downtime and extend the lifespan of the equipment.

Furthermore, decision automation supports risk assessment and emergency response planning. The digital twin can analyse data from various sensors, detect anomalies or safety hazards, and automatically initiate appropriate responses. This capability enhances the facility's resilience and helps mitigate risks by enabling quick and efficient emergency responses.

Another benefit of decision automation is improved occupancy planning. The digital twin can analyse space utilisation patterns, track occupancy levels, and optimise seating arrangements or room allocations based on demand. This capability is particularly valuable in facilities where efficient space utilisation is crucial for productivity and cost-effectiveness.

Monitoring and evaluation of automated decisions are essential for continuous improvement. Facility managers need to monitor the outcomes of the automated decisions to ensure they align with the desired objectives and deliver the expected benefits. Regular evaluation helps identify improvement areas and fine-tune the decision automation process.

As decision automation evolves within the digital twin, it becomes a powerful tool for facility management. The digital twin platform can capture feedback and monitor the outcomes of previous automated decisions. Self-learning is enabled by pattern recognition and making predictions based on existing data. This can enable organisations to analyse the effectiveness of different actions and learn from past experiences and makes predictions to improve enterprise and operational performance.

Facility managers can rely on the digital twin's capabilities for data-driven decision-making, resource optimisation, risk assessment, and occupancy planning. Decision automation with the digital twin enables a proactive approach to facility management, where potential issues can be identified and addressed before they impact operations. This reduces reliance on subjective judgment and promotes evidence-based decision-making, improving outcomes and optimised resource allocation.

Ultimately, establishing a dynamic digital twin with decision automation capabilities empowers facility managers to optimise their operations, enhance efficiency, reduce costs, improve occupant satisfaction, and improve the overall performance of their facilities. It is a valuable tool for strategic decision-making and supports long-term facility management strategies.

The process of automating decisions is ongoing and allows for constant improvement. This involves refining decision rules, updating data models, and incorporating new knowledge or changes in facility management requirements. This iterative improvement process ensures that decision automation capabilities evolve alongside the organisation’s strategic objectives.

Conclusions

This paper discussed the BIM maturity process to a strategic facility management digital twin. It consists of four levels, from strategic planning to establishing a dynamic digital twin. Each level builds upon the previous one, enhancing the capabilities and functionality of the digital twin. Strategic planning sets the foundation for successful implementation and aligns the digital twin with the organisation's strategic direction. Establishing a unified digital twin through BIM delivery ensures that the model encompasses the entire life cycle of the built asset. Data source onboarding and integration create a dynamic BIM model by collecting and integrating data from various sources. Finally, decision automation enables the digital twin to support data-driven decision-making and automate facility management processes.

The evolved proposed framework that comprises the BIM maturity process to Lean strategic facility management offers several benefits, including improved decision-making, enhanced collaboration among stakeholders, risk mitigation, and scalability. Organisations can obtain a clear view of their assets, improve their workflows, and maximise resource allocation by utilising BIM as a digital twin. Integrating real or near real-time data modelling and automation capabilities enables proactive facility management and enhances operational efficiency. Future research directions focus on evaluating the proposed framework through expert evaluation.

In conclusion, integrating the BIM maturity process with a strategic facility management digital twin provides a robust framework for organisations to unlock the full potential of their built assets. Organisations can improve their operations, decision-making, customer outcomes, and facility management performance by implementing these approaches.

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