MORE WORDS FROM FACILITY OPERATION MANAGERS: TEXT-BASED BUILDING INFORMATION FOR INCLUSIVE ACCESSIBILITY

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Abstract. In the domain of Facility Management (FM), the implementation of Building Information Modelling (BIM) poses significant challenges for the Facility Operation Manager (FOMr) in terms of effective integration into their regular workflow. Employing the Soft Systems Methodology (SSM), this study highlights a conducive environment that enhances the usability of BIM for the FOMr. By expanding the application scenarios of BIM within the FM field, we contribute to completing the lifecycle of building models. We introduce 'Text-based Building Information' (TxBI), a system designed to complement Industry Foundation Classes (IFC) while emphasizing a text-centric approach. TxBI strategically focuses on systematically integrating Mechanical, Electrical, and Plumbing (MEP) components, which are pivotal for daily FM operations. It generates a simple yet versatile dataset derived from the as-built BIM deliverable, channeling it to Computerized Maintenance Management Systems (CMMS) and streamlined 3D systems. The utility of TxBI is exemplified through its application in commercial software environments, showcasing the creation of lightweight digital twins of completed buildings. Significantly enhancing FOMrs' access to building information, TxBI establishes a more versatile data environment for all building stakeholders. The accumulation of comprehensive information throughout the Operation and Maintenance (O&M) phase culminates in enhanced asset management and extended longevity of buildings.

Keywords. BIM for FM, operation and management, facility operation managers, text-based building information, long-life building, real time visualization from text, digital twins.

1. Introduction

Building Information Modelling (BIM) has been expected to play an increasingly critical role in the domain of facility management (FM), enhancing the effectiveness of Life Cycle Management (LCM) among other benefits (Wijeratne et al., 2023).

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However, the utilization of BIM in FM is not as active compared to the design and construction phases (Rogage and Greenwood, 2020). This ongoing issue is compounded by challenges such as the limited awareness of building owners and discontinuity of BIM management after the hand-over (Cavka et al., 2017). For most medium to large-scale buildings, Facility Operations Managers (FOMrs) are the individuals who grapple with the daily operational issues of building once it is handed over from the builders. It should be noted that many FOMr lack the adequate BIM operational skills due to various reasons, including a lack of adequate funding, resources, and time for training. (Ashworth et al., 2016).

Presently, BIM for FM software and related research typically assume the exchange of building information via the Industry Foundation Classes (IFC), a format that various BIM software can commonly output (Lai and Deng, 2018). While the creators of these models have easy access to the IFC contents, the same cannot be said for FOMr. A significant drawback for FOMr is typically their limited operational skills with BIM-related software and their unfamiliarity with the model contents (Ashworth et al., 2016). Consequently, improving the means for non-BIM stakeholders to access informational contents of building asset is a meaningful step toward realizing the active utilization of the BIM-based data sets in the day-to-day operations by the FOMr.

2. Research Objective

Given the paramount importance of extending the building service life in today's context, the digital transformation of operations exerts a profound influence on the entire building life cycle (Wijeratne et al., 2023). Throughout the Operation and Management (O&M) phase, which constitutes the majority of a building's lifespan, it is crucial that building information remains readily accessible (Carvalho et al., 2023). More importantly, operational records should be systematically accumulated in a database and form an integral part of the building information asset. The research objective of this paper is predicated on a system proposal that addresses the aforementioned challenges and facilitates high accessibility for a wider range of building stakeholders throughout the extended building lifespan.

Numerous prior studies have addressed this issue. For example, Altohami et al. (2021) have utilized IFC data within a Semantic Web environment to facilitate seamless integration of BIM with the Internet of Things (IoT) devices. Kim et al. (2018) have enhanced the interoperability and accessibility of FM data through the Semantic Web. Katsigarakis et al. (2022) have proposed an environment that converts IFC to OBJ files and leverages the Resource Description Framework (RDF) format to promote diverse data integration. However, as previously mentioned, the challenges associated with handling the model itself remain unresolved. One of the most accessible, lean, and human-readable datasets is structured text, such as comma-separated values (CSV). This research specifically addresses use cases by FOMr, proposing a concept of text-based information enriched with relevant facility-related details and its case studies.

3. Method

This study employs the Soft Systems Methodology (SSM), a framework designed for the analysis of complex and ambiguous problems (Checkland, P and Poulter, 2006). The subsequent sections adhere to the structure of SSM as follows. In Section 4, we will identify system issues and propose a conceptual model. This model will then be validated through case studies in Subsection 4.4. The ensuing sections will encompass a discussion, limitations of this paper, and the conclusion. Figure 1 illustrates the correspondence between this workflow and the SSM framework.

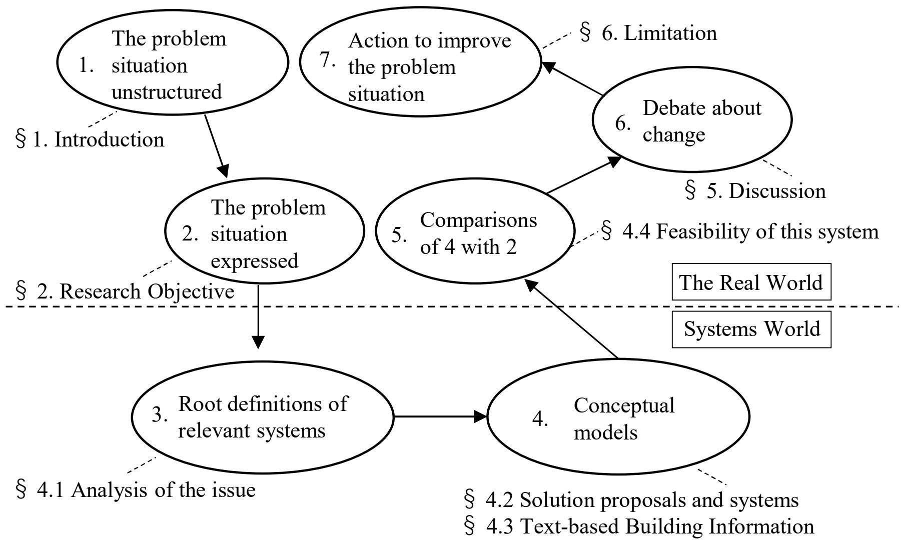

Figure 1. The research methodology based on the seven stages of Soft Systems Methodology.

4. Analysis

4.1. ANALYSIS OF THE ISSUE

In this section, we address the deficiencies of the current system and establish a fundamental definition for the ideal system. When transmitting BIM information as text data, converting BIM to IFC format has the advantage of allowing data sharing in the consistent format from various BIM software, thereby facilitating system standardization (Dhillon et al., 2014). Furthermore, BIM geometry often encapsulates building-specific shapes such as floors and walls, which can sometimes be of irregular complex shapes, making IFC a beneficial format for preserving such shapes. However, IFC primarily serves as an intermediary format for BIM and Construction Information Modeling (CIM), and the software capable of processing it still encounters numerous challenges. Custom software that can process IFC format necessitates users to learn specific operational methods (Pärn et al., 2017), thereby prolonging the learning period for BIM creators and FOMr, consequently lengthening post-construction preparation tasks.

Moreover, whether BIM information is correctly output in IFC format depends on the applications. Although IFC is a unified format convertible from various BIM software, some applications cause information conversion losses in IFC format (Lai and Deng, 2018). While BIM creators can reconcile these potential discrepancies by cross-referencing BIM with IFC, FOMrs, who often face challenges in utilizing BIM software as highlighted by Lin et al. (2022), may find it difficult to verify the accuracy of IFC format against the as-built structure. Consequently, FOMrs face challenges in determining whether losses occurred during the conversion of BIM to IFC, or if they were due to elements originally not included in the BIM.

Conversely, what if we could directly output structured text data from the original BIM data without going through IFC? Text data, being lightweight and versatile, not only facilitates easier integration with existing systems but also enables the visualization of such data in formats familiar to FOMrs, such as spreadsheets, which are openly accessible. This adaptation significantly reduces the verification burden on FOMrs. This shift from a model-centric to a text-centric approach increases the likeliness that the system could be utilized throughout the building lifecycle.

4.2. SOLUTION PROPOSALS AND SYSTEMS

Here, we explore a text-based system with a focus on the high-priority areas of O&M, particularly Mechanical, Electrical, and Plumbing (MEP). Unlike architectural and structural components, MEP elements exist as parts of a continuous system. Each component is simple enough in form to estimate its shape from text information alone. Figure 2 illustrates the representation of the BIM geometry's shape using attributes. For instance, consider piping: given that pipes are cylindrical, knowing the total length and cross-sectional area allows for an approximate understanding of their external shape. However, due to the characteristic of MEP components being segmented and connected, the coordinates indicating their position become critical. It is also possible to obtain height information from reference points or centers. For instance, if a reference point on a site has three-dimensional coordinates (x, y, z), then the geometry's coordinates can be transformed into relative coordinates from this reference point ($x+\alpha$, $y+\beta$, $z+\gamma$). Clarification of the coordinate information pertaining to the central or reference points of each geometry facilitates the accurate acquisition of positional data in relation to other components within a system.

Notably, while MEP systems encompass components with complex shapes, such as various equipment, converting most of these components to simpler structures does not significantly impact the actual use of FM. Any irregularly shaped components can be effectively accommodated by incorporating approximate dimension information as additional attributes. Consequently, this allows for a direct conversion of MEP components from BIM software to text data, without necessarily going through IFC conversion. Leveraging these MEP characteristics, we propose Text-based Building Information (TxBI) that facilitates the linkage of BIM to FM software without IFC intermediation, utilizing text information.

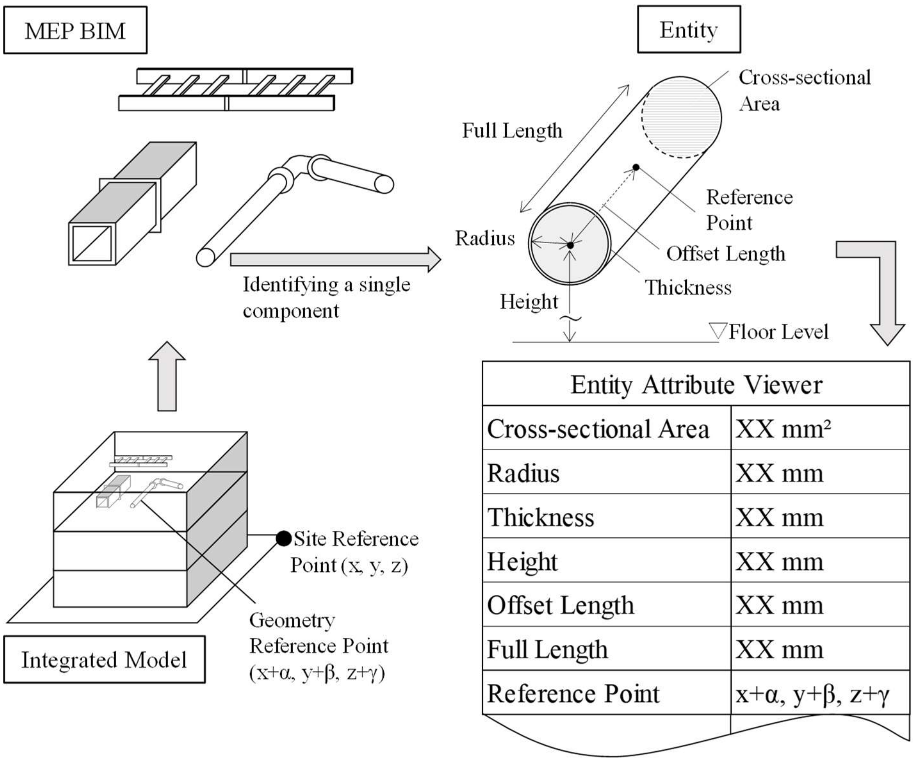

Figure 2. The representation of the BIM geometry shape using attributes.

4.3. TEXT-BASED BUILDING INFORMATION (TXBI)

As a concrete solution, we propose a conceptual model: TxBI system, which is predicated on text data as the primary means of information conversion. The detail of concept is illustrated in Figure 3. The assumed situation is that the as-built project models, mostly created by the project BIM specialists during the design and construction phases, are fully succeeded to the owner and the FOMr in the post-construction and O&M/FM phases.

A. Separating BIM into MEP BIM

When architectural, structural and MEP are initially coordinated within a federated model, it becomes necessary to segregate the MEP components from the rest. This critical task of separation should be undertaken by the project BIM personnel to accurately distinguish and categorize these distinct components within the model.

B. Outputting Text from MEP BIM Model

Text data, which includes the shape information and coordinates linked to each attribute of the MEP BIM geometry, is exported using the attribute export functionality. Numerous modeling software incorporated capabilities for exporting structured text data in universal data formats such as CSV. Even in cases where BIM software does not possess a native text export feature, the add-on program or tailor-made script will be able to fulfill this need.

C. Transfer of Text Data from BIM to TxBI: Before completion

Prior to construction completion, project BIM manager hands over the text data extracted from BIM to the FOMr. The FOMr then conducts a thorough verification of this data on the TxBI platform, ensuring that no critical information pertinent to O&M or FM is omitted. Post-completion, in the absence of a BIM operator, the FOMr assumes the responsibility of adding or modifying information directly on TxBI. This strategy effectively eliminates the necessity for the FOMr to engage with the BIM system both before and after the project's completion. The TxBI interface will become familiar to many project stakeholders because it behaves as if a standard spreadsheet, facilitating straightforward data input and manipulation for the FOMr. Moreover, it is anticipated that TxBI will enable the import of information into the BIM system at any stage post-completion. Additionally, unique identifiers derived from BIM geometry, potentially linked to attributes via a Globally Unique Identifier (GUID), will be managed (Kang and Hong, 2015). To enhance the precision in identifying individual components, multiple identifiers, such as the BIM creation date and the creator's details, might be utilized.

D. Integration with CMMS

TxBI will be then seamlessly integrated into a computerized maintenance management system (CMMS). This integration facilitates the utilization of BIM-derived information during the FM phase. The FOMr predetermine the specific information that is required within the CMMS, ensuring that only this designated information is exported from the TxBI system. A reciprocal interaction between TxBI and CMMS is established, allowing data input into CMMS to be correspondingly reflected back into TxBI.

E. Simple Visualization System

Now we delineate the real-time visualization from the text. A process of simple re-modeling can be undertaken by utilizing the exported information. The re-modeling process involves calculating the shape representation based on geometric coordinate points, including dimensions like diameters and cross-sections. This approach addresses the inherent limitations of textual descriptions, such as the challenges in intuitively grasping shapes, by enabling shape reconstruction from text without the necessity for IFC.

Previous studies have documented the use of BIM in web browsers for 3D visualization and FM application (Wijeratne et al., 2023). However, in our focus on MEP systems, further simplifications are achievable in comparison to other scenarios. For instance, a 2D representation with additional height information or the use of pins to mark specific locations can be employed for a more simplified visualization. Such simplifications not only facilitate digital twin applications on the web but also enable their practical implementation onsite through Augmented Reality (AR) technologies.

F. Transferring Text Data from TxBI back to BIM

In the context of renovation projects, BIM models developed during the initial construction phase are repurposed to generate detailed renovation plans. Consequently, the extensive data accumulated in TxBI during O&M phases can seamlessly integrated back into the BIM environment. This integration effectively incorporates crucial FM information into the existing BIM model, thereby enhancing its utility and accuracy for future renovation activities.

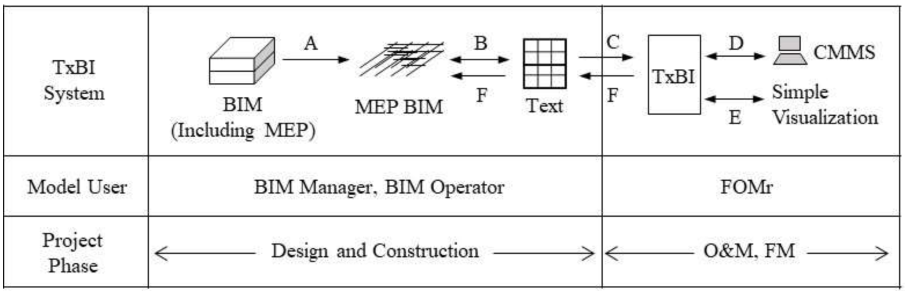

Figure 3. The workflow and task allocation of TxBI's system.

4.4. FEASIBILITY OF THIS SYSTEM

We validate the feasibility and plausibility of the proposed system by presenting a practical implementation. A commercial BIM environment named Pinspect is designed as an Augmented Reality application (ARapp) which integrates BIM with the AR system in the mobile environment as the building digital twins. Figure 4 illustrates the concept diagram of the Pinspect system.

The software efficiently uploads key points of geometry coordinates and essential management attributes from BIM software to the cloud, circumventing the need for IFC. This data is then accessible via the mobile ARapp, where pins representing the coordinates are displayed. These pins, embodying both coordinate information and attributes, facilitate the onsite verification of BIM data within the actual building structure. By superimposing these pins onto their real-world counterparts, inspectors can validate the BIM input's precision directly at the construction site. The pins also support the addition of attributes, such as the project's progress status, enabling real-time feedback to the BIM system through cloud technology.

Empirical trials, conducted with the involvement of the first author who was a member of the development team, have shown that this app potentially reduces time spent on construction site management by approximately 70% (M.SOFT Co., Ltd., 2021). In the context of O&M, the pre-emptive identification and AR visualization of critical MEP components via the app can significantly mitigate the risk of oversight during onsite inspections. These pins can serve as the representation of issues recorded during the on-site inspection, which can be easily transferred to CMMS after the hand-over. This case study underscores that even a simplified digital twin, derived from textual data, can be effectively leveraged for building management.

Moreover, the integration of TxBI with CMMS is further streamlined by the conventional practice of importing text data, such as CSV files, into CMMS. This connection establishes a seamless flow of data between TxBI and CMMS.

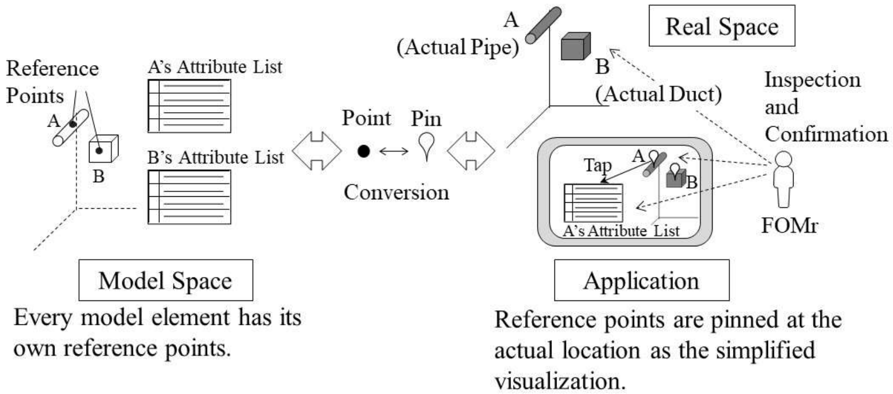

Figure 4. Pinspect system concept diagram.

5. Discussion

TxBI represents a significant advancement in the field of BIM for FM, highlighting the potential for direct text exportation from BIM for use with tools such as CMMS and Realtime Visualization from Text in O&M applications. The system, intentionally simplified to a text-based format, is specifically designed to facilitate frequent usage by the FOMr with minimal technical expertise requirements.

The primary objective of TxBI is to challenge and reevaluate the conventional assumptions set by traditional BIM approaches for FM, thereby promoting a more widespread adoption and utilization of BIM data by the FOMr. This initiative bridges the gap between their O&M expertise and BIM, transitioning from a design and construction-centric model to an information model-focused approach during the maintenance phase. The emphasis here is not on an extensive, comprehensive information source, but rather on providing lighter, more accessible alternatives.

The centralization of BIM attribute management and O&M records within TxBI significantly amplifies the value derived from BIM in FM, particularly through the application of Artificial Intelligence (AI) analysis. This technology has the potential to facilitate comparative assessments of challenges and best practices encountered in various facilities globally against the actual buildings under management. A key application involves linking BIM's coordinate data and component quantities with FOMr's inspection records and response history to enable enhanced O&M strategies. For instance, given a scenario involving critical server equipment adjacent to piping and HVAC units. When a leakage occurs on piping and endangers the server, the detailed actions should be taken by FOMrs in response along with the components' specific coordinate data and quantities, are ultimately recorded and linked in TxBI. AI analysis of this data can then promptly suggest remedial actions for similar occurrences and provide advance warnings of potential O&M issues during the integration of BIM into TxBI, based on coordinates and quantities. Additionally, leveraging insights from facilities where exemplary management practices have optimized Life Cycle Costs (LCC) could facilitate recommendations for optimal equipment placement and management strategies, informed by similar coordinate and quantity data. This approach not only fosters improvements and training but also could appropriately recognize and motivates FOMrs who demonstrate exceptional performance, thus encouraging superior outcomes.

When the utilization of BIM in numerous buildings is further increased, even marginally, and its economic benefits are widely recognized, appropriate incentives for BIM creation and its application in FM may subsequently emerge. Therefore, it is imperative to develop systems tailored to the needs of FOMrs who actively engage with BIM data in FM. Our advocacy should extend beyond promoting the utility of BIM; it should also involve actively incorporating the perspectives of FOMrs, fostering collaborative dialogues about the practical applications of BIM in FM.

6. Limitation

It is acknowledged that the scope of information required may vary depending on specific cases. Thus, the development of case studies tailored to these varying needs will be essential in the future.

Furthermore, we posit that the BIM for FM in architectural and structural realm necessitates distinct approaches compared to MEP. Simplifying major components such as walls, columns, floors, and beams into text form can present a significant challenge in architectural BIM context. While MEP is composed of a series of simple elements forming a system, the architectural and structural ones show complexity due to their substantial size, the diversity of shapes, and the custom adjustments made onsite, such as components cut to specific dimensions or shapes freely formed with concrete. For detailed polygons, accurately replicating their shape is contingent on knowledge of the number of vertices and the vectors from a central point.

Therefore, this task poses a greater challenge than the simpler modeling typically associated with facilities management. Recent studies have explored the use of voxels for the simplified modeling of BIM (Khan et al., 2023). While voxels, as aggregates of cubes, offer a potentially more straightforward path to text conversion, they also highlight the possibility that architectural and facility information might be represented in disparate formats.

7. Conclusion

This study introduces TxBI, a novel approach that facilitates the direct utilization of BIM for FM without the reliance on intermediary formats. TxBI strategically focuses on connecting with the most critical information necessary for O&M tasks, adopting a text-centric methodology. This approach embodies a concept where, BIM that reflects more words from FOMrs, thus greatly contributes to the longevity and sustainable management of buildings.

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