IMPROVING BIM AUTHORING PROCESS REPRODUCIBILITY WITH ENHANCED BIM LOGGING

Suhyung Jang
Building Informatics Group, Dept. of Architecture and Architectural Engineering, Yonsei University, Republic of Korea

Ghang Lee
Professor, Department of Architecture and Architectural Engineering, Yonsei University, Republic of Korea

ABSTRACT: *This paper presents an enhanced BIM logger designed to capture both geometry and attribute changes of building element geometries, thereby offering a transparent source of representation of the BIM authoring process. The authors developed the logger and reproduction algorithm using the Revit C# API based on the analysis of information required to define building elements and associated attributes. The enhanced BIM log was evaluated through a case study of Villa Savoye designed by Le Corbusier. Despite negligible discrepancies, the results show that the enhanced BIM log can accurately represent the BIM authoring process capturing and reproducing 92.45% of the building elements from the original BIM model. Future research can focus on expanding the scope of logging and probing the potential of automating the BIM authoring process using these enhanced BIM logs.*

KEYWORDS: *Building information modeling (BIM), BIM log mining, BIM authoring software, Custom BIM log, Authoring process reproducibility.*

1. INTRODUCTION

The architecture, engineering, construction, and operation (AECO) industry has experienced a transformational shift with the widespread adoption of BIM technology. The shift has not only enhanced productivity but also improved informed decision-making within the sector (Sacks et al., 2018). Although BIM models—products of the BIM process—display the finalized decisions of a project, they encapsulate a wealth of insights due to the extensive decision-making endeavors underpinning their authoring. Consequently, the BIM authoring process can serve as a valuable knowledge repository for understanding the decision-making process.

BIM log mining seeks to extract these insights by examining the BIM logs in detail. BIM logs serve as invaluable data reservoirs, capturing sequential events recorded during BIM software usage (Jang et al., 2023). Previous studies have explored various aspects of the BIM authoring process, from design authoring patterns (Yarmohammadi et al., 2017), productivity (Shin, 2023; Shin et al., 2022), and collaboration patterns (Zhang & Ashuri, 2018), to the specific roles of modelers (Forcael et al., 2020).

Researchers have emphasized the significance of incorporating data attributes to elucidate the as-happened process within the log to attain reliable results from the analysis (Bose et al., 2013; Suriadi et al., 2017). Nonetheless, the BIM logs produced by prevailing BIM software overlook modifications in building elements undertaken during the BIM authoring phase because they were originally developed for maintenance operations (Autodesk, 2022). Consequently, such logs often miss the depth required to accurately capture the BIM authoring narrative (Jang et al., 2023; Yarmohammadi & Castro-Lacouture, 2018). Even though efforts have been made to enhance these logs through custom loggers (Gao et al., 2021; Jang et al., 2021; Kouhestani & Nik-Bakht, 2020; Pan & Zhang, 2021; Yarmohammadi & Castro-Lacouture, 2018), these adaptations still are not able to capture critical geometric nuances like shapes, scales, and locations—details pivotal to understanding the evolution and decision making involved in the BIM authorship.

To address the issue, this paper introduces an improved BIM logger capable of capturing comprehensive details for the precise replication of the BIM authoring process. The methodology behind this advanced logger includes analyzing the essential data needed to describe building elements in Autodesk Revit, followed by the design of a custom BIM logger to record this crucial information. In addition, a reproduction algorithm was developed to evaluate the logger's accuracy in representing the BIM authoring process. The reproducibility of the logger was further validated through a case study.

The paper is structured as follows. Section 2 reviews previous custom BIM loggers proposed in the literature, and Section 3 describes the research methodology employed in this study. Section 4 reviews the minimum information

Referee List (DOI: 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Suhyung Jang, Ghang Lee, *Improving BIM Authoring Process Reproducibility with Enhanced BIM Logging*, pp. 508-514, DOI 10.36253/979-12-215-0289-3.49

requirements to define BIM elements in Revit, and Section 5 outlines the development of the enhanced BIM logger and reproduction algorithm. Section 6 evaluates the reproducibility of the enhanced BIM logger through a case study, and Section 7 concludes the paper.

2. LITERATURE REVIEW

BIM log mining is a data analysis approach that utilizes process mining techniques to explore BIM event logs collected during a BIM software operation. Process mining includes various techniques for automated process discovery, social network analysis, process optimization, case prediction, and history-based recommendations (Aalst et al., 2011). However, event log imperfections can lead to unreliable results, and researchers have introduced an incremental approach to evaluating event log fitness and a methodology to guide process mining execution (Bose et al., 2013; Suriadi et al., 2017).

While improving event log quality has received significant attention, several studies have focused on enhancing the information included in the BIM logs. These include custom Revit logger which extracts element identifiers and bounding boxes (Yarmohammadi & Castro-Lacouture, 2018), IFC loggers which capture snapshots and identify the changes made between different versions of BIM models (Kouhestani & Nik-Bakht, 2020; Pan & Zhang, 2021), and command-object graphs to notate the geometric modeling sequence (Gao et al., 2021) to improve the understanding on modeling patterns. However, these custom logs still grapple with reproducing the BIM authoring process due to missing information to represent the geometric shape and attributes of the building elements.

The BIM authoring process is often defined as a process in which 3D software is used to develop a BIM model based on criteria that are important to the translation of the building's design (Messner et al., 2019). Accordingly, this process includes the addition, deletion, and modification of the geometry of building elements and their associated properties (Kouhestani & Nik-Bakht, 2020; Lin & Zhou, 2020). Through BIM authoring, building elements are refined to meet the level of development (LOD)—the information necessary to depict the building elements—within the BIM model. However, the BIM model only reflects the end result of the comprehensive BIM authoring process. Concurrently, the design decisions made during this process can be a rich and invaluable reservoir of information, encapsulating real-time design decision-making. Documenting these design decisions can also aid in extracting the design knowledge of architects, especially when paired with recently emerging data-based analysis techniques (Jang et al., 2023). In this context, this study aims to develop a custom logger designed to capture essential information, enabling the reproduction of the BIM authoring process.

3. METHODOLOGY

This study developed a three-step methodology to enhance the reproducibility of BIM logs as depicted in Fig. 1. The methodology involved developing a customized BIM authoring logger, implementing a BIM authoring process reproducer, and evaluating the reproducibility of the enhanced BIM log through a case study.

Fig. 1: Research flowchart.

To capture sufficient information in the BIM log to reproduce the BIM authoring process, the authors analyzed the minimum inputs required to represent building elements in Revit. As building elements are represented using classes in an object-oriented programming model, the information required for each class corresponding to a specific category of elements was analyzed. The log captures the geometric shape and attribute values to represent the building elements in a comma-separated value (CSV) format. The reproduction algorithm developed in this study iterates through the events recorded in the BIM log, identifies the command type (i.e., "ADDED," "MODIFIED," or "DELETED"), and executes them with reference to the "Comments" property (i.e., copied "ElementID") of the building elements.

The evaluation phase of this study involved modeling Villa Savoye designed by Le Corbusier for the case study, during which the BIM authoring logger recorded the authoring process (Fig. 2). The events recorded in the enhanced BIM log were iterated using the BIM authoring process reproducer, and the reproducibility of the developed model was evaluated based on the volumetric center distances and volume differences between elements, as well as visual analysis of plans, elevations, sections, and 3D views.

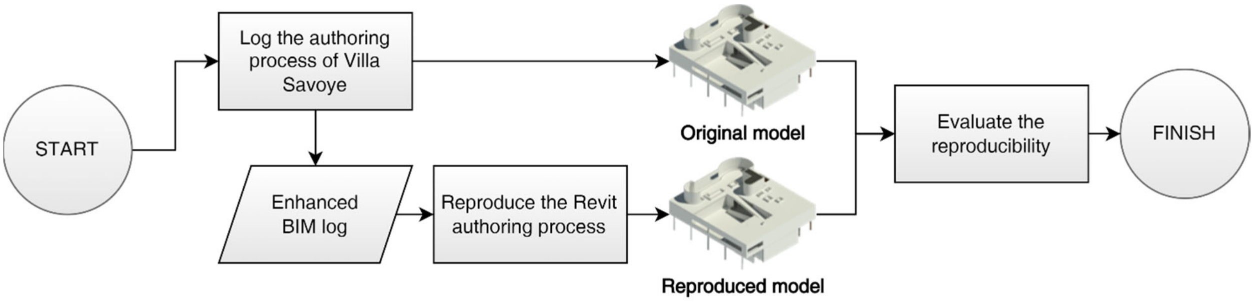

Fig. 2: Evaluation of BIM authoring logger and BIM authoring log reproducer.

4. ENHANCED BIM LOGS

This section provides a detailed overview of how building elements are defined in Revit and how the enhanced BIM log captures the necessary information to accurately represent the BIM authoring process. The study utilized Autodesk Revit 2023 and Revit C# API for the implementation of the enhanced BIM log. Building elements in Revit are represented using classes in an object-oriented programming model that has a hierarchical structure that reflects the physical structure of the building. Each class corresponds to a specific type of building element, such as walls, floors, roofs, doors, and windows. Fig. 3 illustrates the geometric shape and attribute values recorded for each building element category.

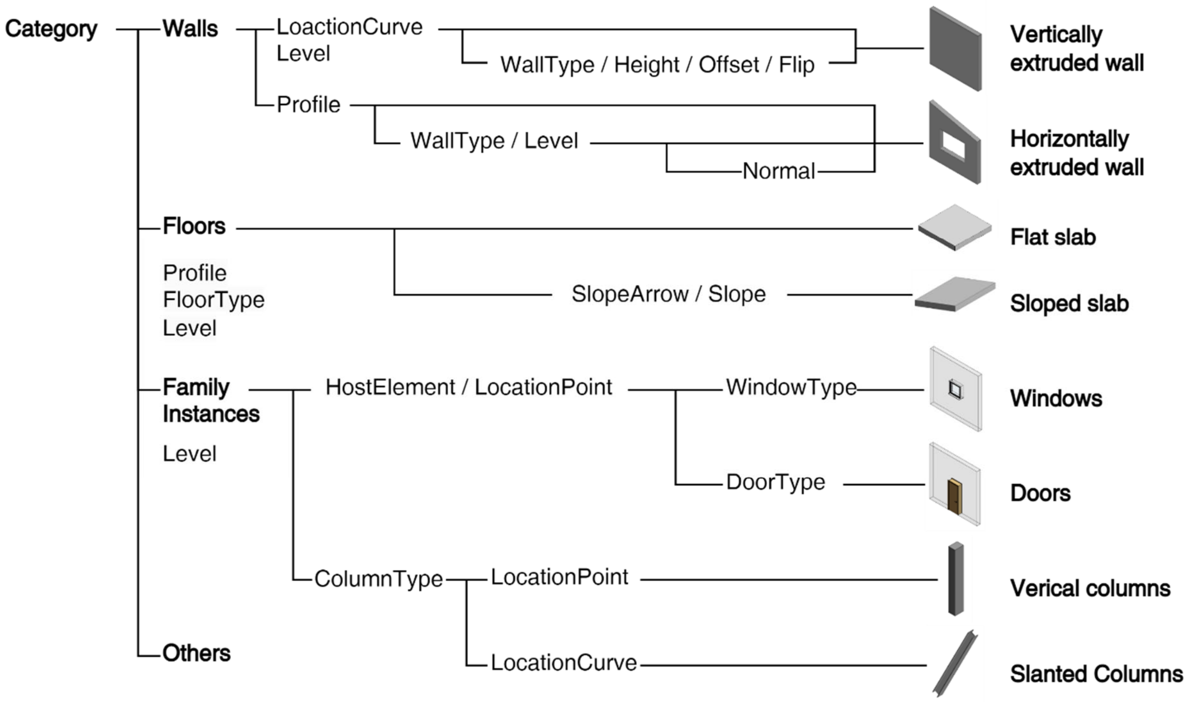

Fig. 3: Geometric shape and attribute values recorded within the enhanced BIM log.

Wall elements in Revit are classified into two categories—rectangular profile walls and nonrectangular profile walls—following the different creation methods for each type. Floor elements are classified into two types, flat floors, and sloped floors, and are created using different attributes depending on the type. Windows, doors, and columns are classified as "FamilyInstances," and their representation is based on the placement of predefined instances on the selected base geometry. "FamilyInstances" have different categories based on the "FamilySymbol" used, such as "WindowType," "DoorType," and "ColumnType." Windows and doors require a "LocationPoint" and “HostElement,” while columns can be placed without a “HostElement,” depending on whether the representation of the slope is required.

In addition to recording other required information items as string formats, the enhanced BIM log captures geometric bases, such as “LocationPoint,” “LocationCurve,” and “Profile,” and their respective subclasses, such as “Line,” “Arc,” “CylindricalHelix,” “Ellipse,” “HermiteSpline,” and “NurbsSpline.” The information required for each geometric base and its string format representation is presented in Table 1. The enhanced BIM logger records the geometric bases of the building elements represented during the BIM authoring process in the described format.

Table 1: Definition of geometric classes.

Classes	Subclasses	Input Requirements	String Formats
Location Point	XYZ	(X coordinate, Y coordinate, Z coordinate)	(double, double, double)
Location Curve	Line	(endPoint1, endPoint2)	[Line, XYZ, XYZ]
	Arc	(plane, radius, startAngle, endAngle)	[Arc, XYZ, double, double, double]
	CylindricalHelix	(basePoint, radius, xVector, zVector, pitch, startAngle, endAngle)	[CylindricalHelix, XYZ, double, XYZ, XYZ, double, double, double]
	Ellipse	(center, xRadius, yRadius, xAxis, yAxis, startParameter, endParameter)	[Ellipse, XYZ, double, double, XYZ, XYZ, double, double]
	NurbsSpline	(degree, knots, controlPoints, weights)	[NurbsSpline, int, IList<double>, Ilist<XYZ>, Ilist<double>]
	HermiteSpline	(controlPoints,periodic,tangents)	[HermiteSpline, Ilist<XYZ>, bool, HermiteSplineTangents]
CurveLoop	CurveLoop	(LocationCurve$_1$, …, LocationCurve$_n$)	{CurveLoop, LocationCurve$_1$, …, LocationCurve$_n$}
Profile	Profile	(CurveLoop$_1$, … ,CurveLoop$_n$)	Profile, CurveLoop$_1$, … ,CurveLoop$_n$

Furthermore, multiple attribute values in Revit can be modified to better represent each building element. For instance, recording whether it was flipped was important in representing vertically extruded walls because the sequence of the wall layer can be positioned opposite. Meanwhile, a normal vector that the wall is facing is critical in the horizontally extruded walls. The initial values and modifications of the attributes are also recorded in the enhanced log, providing information on how the building elements were defined and developed during the BIM authoring process.

5. REPRODUCTION ALGORITHM

The authors implemented a reproduction algorithm to iterate through the events in the enhanced BIM log and repeat them, as illustrated in Fig. 4. The algorithm begins by identifying the command type of events. If the command type is “ADDED,” the algorithm adds an element of the recorded category and applies the recorded attribute values, while adding the “ElementID” of the event to the “Comments” attribute of the newly created BIM element. If the command type is “MODIFIED,” the algorithm queries the element with the “ElementID” recorded in the Comments value and applies the corresponding modification. If the command type is “DELETED,” the algorithm queries the elements with the “ElementID” recorded in the “Comments” value and deletes the element.

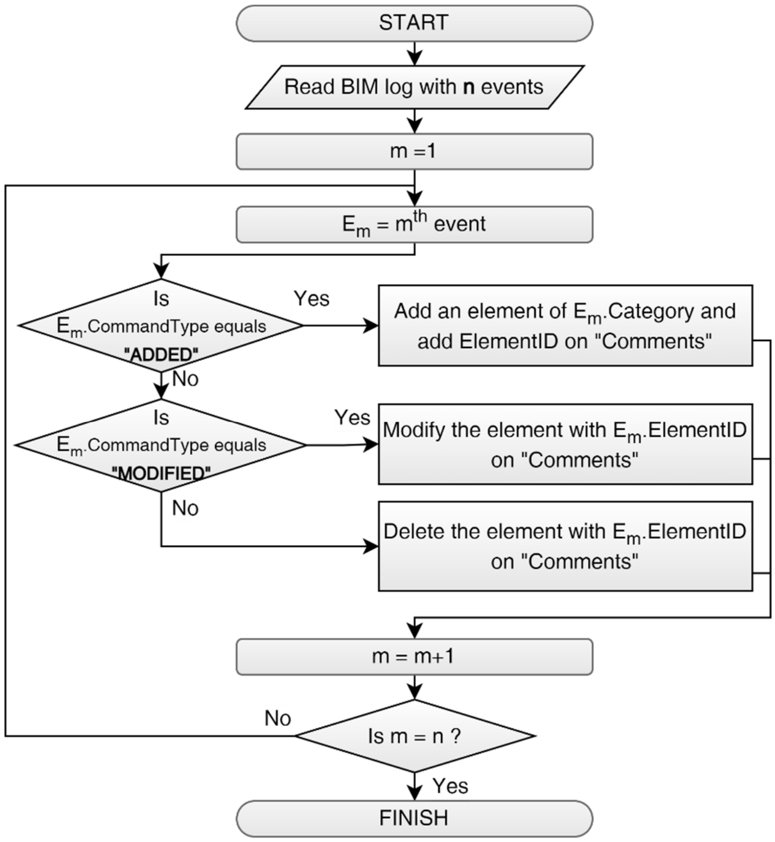

Fig. 4: Reproduction algorithm.

6. EVALUATION OF REPRODUCIBILITY

To assess the enhanced log and its ability to be reproduced, the authors of this study carried out a case study of Villa Savoye, designed by Le Corbusier. Using the BIM log from the authoring process, a reproduced BIM model was generated using the reproduction algorithm, as depicted in part (a) of Fig. 5.

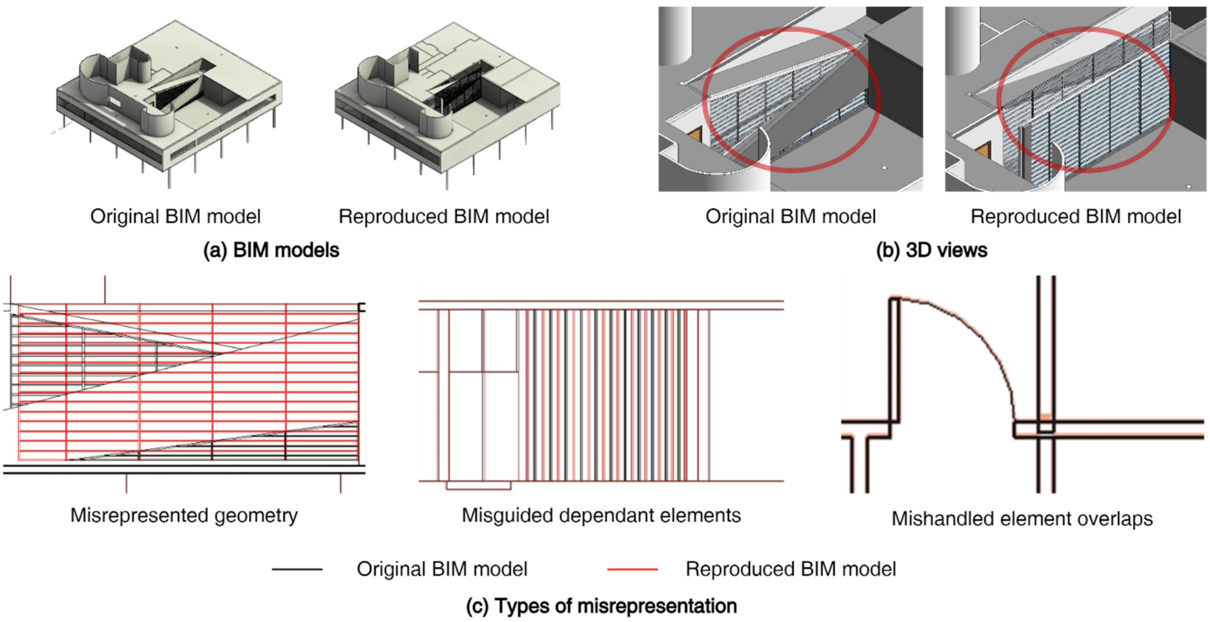

Fig. 5: Comparison between the original BIM model and reproduced BIM model.

The BIM model comprised 158 elements, which included 97 walls, 8 slabs, 8 windows, 19 doors, and 27 columns, with 2,836 events logged during the process. The reproduced model captured every element present in the original. A comparison revealed minimal average distances between the volumetric centers of the elements: 3.6440E-07 for walls, 2.1470E-07 for floors, 1.4760E-07 for windows, 1.6139E-07 for doors, and 1.4380E-07 for columns. Volume differences were also analyzed, with disparities noted as 0.1876% for walls, 0.0198% for floors, and 0.0433% for columns, with no discrepancies for windows and doors. The variations in distance and volume displayed a near-perfect reproduction. It is postulated that such differences may arise from metric and imperial unit conversions.

The models were contrasted visually in 3D, along with elevation, section, and plan views. The manual analysis allowed the authors to pinpoint inaccuracies in the reproduced model. As highlighted by the red ellipses in part (b) of Fig. 5, the curtain wall profiles were inaccurately depicted. Part (c) of Fig. 5 overlays drawings from the original and reproduced BIM models, delineated by black and red lines respectively. The comparison revealed three main types of inaccuracies:

Custom attributes: In this version of the implementation, custom attributes, such as distances between vertical mullions, were not supported. This omission led to mullions in the reproduced model being placed with default values. The issue was observed in four curtain wall elements.

Automatically connected elements: In instances where building elements overlapped, their placements varied occasionally. The function in Revit that automatically joins closely placed elements generates minor discrepancies in the lengths of the automatically joined elements, depending on how far apart the joined elements were initially. The issue was observed in two interior wall elements.

Unknown reasons: There were instances where the wall elements with specific profiles did not align precisely with the original design. These discrepancies may be attributed to limitations within the logging and reproduction algorithm. This issue was observed in six profile wall elements.

In summary, 12 of the 159 elements (or 92.45%) in the reproduced BIM models were inaccurately represented–all being wall elements. Despite these discrepancies, the enhanced BIM logger effectively logged most of the necessary information to recreate the BIM authoring process.

7. CONCLUSION

This study developed an enhanced BIM logger that captures the necessary information to reproduce the BIM authoring process. By analyzing the information requirements of five representative building elements in Revit, the authors developed a custom logger that records geometric shapes and attribute values. The study also developed a reproduction algorithm to repeat the BIM authoring process. The effectiveness of the enhanced log was evaluated in a case study of Villa Savoye designed by Le Corbusier, which showed that the enhanced BIM logger provides a valuable tool for capturing and reproducing 92.45% of the building elements generated and modified within the BIM authoring process. While minor discrepancies and misrepresentations were observed, the results of the case study demonstrated the potential of the enhanced BIM logger.

Looking ahead, avenues for improvement lie in broadening the spectrum of building element categories or attribute values to augment reproducibility. Additionally, the applications of enhanced BIM logs beckon exploration, as does the prospect of analyzing the as-happened BIM authoring process (Shin et al., 2022; Yarmohammadi & Castro-Lacouture, 2018) and automating the BIM authoring process using such logs (Pan & Zhang, 2020). Overall, the enhanced BIM logger presented in this study can contribute to elevating the transparency and efficiency of the BIM authoring process, serving as an invaluable data source for its enhancement.

8. ACKNOWLEDGMENTS

This work was supported in 2023 by a Korea Agency for Infrastructure Technology Advancement (KAIA) grant funded by the Ministry of Land, Infrastructure, and Transport (Grant RS-2021-KA163269).

REFERENCES

Aalst, W. van der, Adriansyah, A., Medeiros, A. K. A. de, Arcieri, F., Baier, T., Blickle, T., Bose, J. C., Brand, P. van den, Brandtjen, R., & Buijs, J. (2011). Process mining manifesto. *International Conference on Business Process Management*, 169–194.

Autodesk. (2022). *About Journal Files*. Autodesk REVIT 2022 Help. https://help.autodesk.com/view/RVT/2022/ENU/?guid=GUID-477C6854-2724-4B5D-8B95-9657B636C48D

Bose, R. J. C., Mans, R. S., & van der Aalst, W. M. (2013). Wanna improve process mining results? *2013 IEEE Symposium on Computational Intelligence and Data Mining (CIDM)*, 127–134.

Forcael, E., Martinez-Rocamora, A., Sepulveda-Morales, J., Garcia-Alvarado, R., Nope-Bernal, A., & Leighton, F. (2020). Behavior and Performance of BIM Users in a Collaborative Work Environment. *Applied Sciences-Basel*, *10*(6), 2199. https://doi.org/10.3390/app10062199

Gao, W., Wu, C., Huang, W., Lin, B., & Su, X. (2021). A data structure for studying 3D modeling design behavior based on event logs. In *Automation in Construction* (Vol. 132). https://doi.org/10.1016/j.autcon.2021.103967

Jang, S., Lee, G., Shin, S., & Roh, H. (2023). Lexicon-based content analysis of BIM logs for diverse BIM log mining use cases. *Advanced Engineering Informatics*, *57*, 102079. https://doi.org/10.1016/j.aei.2023.102079

Jang, S., Shin, S., & Lee, G. (2021). Logging Modeling Events to Enhance the Reproducibility of a Modeling Process. *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction*, *38*, 256–263.

Kouhestani, S., & Nik-Bakht, M. (2020). IFC-based process mining for design authoring. In *Automation in Construction* (Vol. 112, p. 103069). https://doi.org/10.1016/j.autcon.2019.103069

Lin, J.-R., & Zhou, Y.-C. (2020). Semantic classification and hash code accelerated detection of design changes in BIM models. In *Automation in Construction* (Vol. 115). https://doi.org/10.1016/j.autcon.2020.103212

Messner, J., Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Leicht, R., Saluja, C., & Zikic, N. (2019). *BIM Project Execution Planning Guide (v. 2.2)*. Computer Integrated Construction Research Program, Pennsylvania State University. https://openlibrary-repo.ecampusontario.ca/jspui/handle/123456789/768

Pan, Y., & Zhang, L. (2020). BIM log mining: Learning and predicting design commands. *Automation in Construction*, *112*, 103107. https://doi.org/10.1016/j.autcon.2020.103107

Pan, Y., & Zhang, L. (2021). A BIM-data mining integrated digital twin framework for advanced project management. In *Automation in Construction* (Vol. 124). https://doi.org/10.1016/j.autcon.2021.103564

Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). *BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers*. John Wiley & Sons.

Shin, S. (2023). *A BIM object-based BIM modeling productivity measurement method using BIM log mining*. Yonsei University.

Shin, S., Jang, S., Roh, H., & Lee, G. (2022). *A Critical Review of Measuring the Modeling Productivity of Building Information Modeling*. Proceedings of the 19th International Conference on Computing in Civil & Building Engineering (ICCCBE), Capetown, South Africa. https://doi.org/10.1007/978-3-031-35399-4_33

Suriadi, S., Andrews, R., ter Hofstede, A. H., & Wynn, M. T. (2017). Event log imperfection patterns for process mining: Towards a systematic approach to cleaning event logs. *Information Systems*, *64*, 132–150.

Yarmohammadi, S., & Castro-Lacouture, D. (2018). Automated performance measurement for 3D building modeling decisions. In *Automation in Construction* (Vol. 93, pp. 91–111). https://doi.org/10.1016/j.autcon.2018.05.011

Yarmohammadi, S., Pourabolghasem, R., & Castro-Lacouture, D. (2017). Mining implicit 3D modeling patterns from unstructured temporal BIM log text data. *Automation in Construction*, *81*, 17–24. https://doi.org/10.1016/j.autcon.2017.04.012

Zhang, L., & Ashuri, B. (2018). BIM log mining: Discovering social networks. *Automation in Construction*, *91*, 31–43. https://doi.org/10.1016/j.autcon.2018.03.009