ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume X-M-2-2025
30th CIPA Symposium “Heritage Conservation from Bits:
From Digital Documentation to Data-driven Heritage Conservation”, 25–29 August 2025, Seoul, Republic of Korea

Bridging Heritage Knowledge and Digital Models: An HBIM Integration Framework

Xi Wang [1], Cong Wu [1], Xiao Zhang [1], RuolinPan [1]

[1] School of Architecture, Tianjin University, NO. 92 Weijin Rd, Nankai District, Tianjin, P. R. China – wangxi88love@tju.edu.cn, wucong@tju.edu.cn

Keywords: HBIM, KSQI Route, Pattern Book Tooling Solution, Semantic-driven Modelling, Data-model Decoupling and Re-coupling.

Abstract:

Architectural heritage conservation demands the integration of precise physical documentation and interpretative design knowledge, yet current HBIM approaches remain fragmented: ‘scan-to-BIM’ prioritizes geometric accuracy at the expense of semantic richness, while “rule-based reconstruction” emphasizes idealized logic over as-built evidence. To bridge this gap, this study introduces the KSQI paradigm (Knowledge-Semantics-Quantities-Image), a novel framework that systematically connects domain expertise with digital modelling to balance spatial accuracy and architectural semantics. The research develops an *as-recognized modelling* or *semantic-driven modelling* through (1) a conservation cycle-guided information indexing system for semantic-driven knowledge integration, (2) a data-model decoupling workflow that teams from different disciplines maintain their working habits, handling data and models separately, then recoupling data-model by BIM team, and (3) a pattern book tooling solution including check forms for hierarchical investigation, algorithm modelling generator. By linking physical attributes (quantities/images) with design logic (semantics/knowledge), KSQI enhances information management, supports iterative knowledge updates, and facilitates informed conservation decisions. Case studies demonstrate its effectiveness in encoding both as-built conditions and historical, traditional design/construction principles, reinforcing the ‘H’ (history/heritage knowledge) in HBIM. This framework advances heritage documentation toward the smart metric survey, ensuring models serve as dynamic, semantically rich assets for conservation, research, dissemination, and digital twin applications.

1. Introduction

1.1 Background: Four Aspects of Heritage Documentation

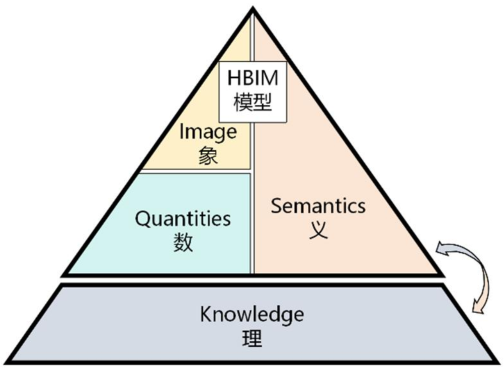

Figure 1. The KSQI relationship.

Shape/Image, Values of Quantity, and Semantics which are referred to as ‘Image’, ‘Quantities’, and ‘Semantics’, along with ‘Knowledge’, are collectively referred to as ‘KSQI’: the four aspects of heritage documentation(Figure 1). Details are as follows.

(1) Image refers to the visual characteristics of the surveyed object, including its external image, spatial form, detailed modelling, color, and texture, as well as the visualized form resulting from the attribution of meaning(Banfi, 2019; Bosché et al., 2015; Capone and Lanzara, 2019; Laing et al., 2015; Stanga et al., 2019; Tang et al., 2010).

(2) Quantity values refer to the magnitude of quantities expressed by numbers and units, such as the dimensions, coordinates (position), and RGB values of color.

(3) In addition, the objectives of the metric survey include semantic recognition, which involves the functions, images, specifications, materials, and colors of the constituent elements of the surveyed object, as well as the spatial-structural relationships between them, reflecting the architectural typology and the logic and regularities of design and construction.

(4) Knowledge refers to the expertise in site selection, design, construction, and conservation within the field of architectural heritage preservation.

Metric survey is not only a common method for recording but also a foundational, holistic, and forward-looking task. It provides detailed basic data and opportunities for breakthroughs in the study of ancient architecture.

These four aspects should be integrated in HBIM, which means bridging heritage knowledge and digital models. Thus ‘KSQI’ is also the four essential elements of modelling. This integration framework consists of the general objective, the technical route, and workflow and phase requirements.

1.2 Literature Review

Currently, there are two primary technical approaches for HBIM (Heritage Building Information Modelling), each rooted in either metric survey or architectural expertise.

As mentioned before, due to differences in professional backgrounds, academic disciplines, and target applications, the HBIM technology route has two distinct directions: Scan-to-BIM and Rule-based reconstruction. Scan-to-BIM tends to emphasize the differences in the current state (Aftab et al., 2023; Croce et al., 2023; Gustavo et al., 2020; Kang, 2023; Laing et al., 2015), establishing an ‘as-built BIM’ (a model representing coordinates), with a greater focus on the precision of coordinates, while lacking effective methods for expressing semantic relationships.

This approach involves semantic segmentation of point clouds at the component level, aligning point clouds with models during modelling, and using the deviation between point clouds and models as an evaluation metric for assessing model completion. While an idealized 'as-designed BIM' (Shao et al., 2024) is also established (a model that expresses semantics), it merely adds semantic information to the former and provides some validation functions, without an effective method for integration. The advantage of this technical approach is its ability to accurately record the geometric details of physical objects. However, it lacks effective methods for the division and combination of model units, the sorting of structure-type relationships, and the recording and expression of knowledge. This technical approach is more commonly seen in related research dominated by metric survey and mapping professionals internationally (Aftab et al., 2023; Banfi, 2019; Bosché et al., 2015; Bosche and Haas, 2008; Brilakis et al., 2010; Capone and Lanzara, 2019; Croce et al., 2023; Gustavo et al., 2020; Kalyan et al., 2016; Kang, 2023; Khalid and Hani Ismaeel, 2020; Kim et al., 2013; Laing et al., 2015; Maiezza, 2019; Pătrăucean et al., 2015; Rebolj et al., 2017; Shao et al., 2024; Stanga et al., 2019; Tang et al., 2010; Xiong et al., 2013; Zhang et al., 2016).

The technical approach of regularized reconstruction also employs photogrammetry and 3D laser scanning to obtain measured data, but it involves a certain degree of abstraction and simplification based on these data. It summarizes the 'structure-type' relationships of components based on constructive logic, using as few parameters as possible to describe as many patterns as possible. These patterns represent the form and construction logic information of the architecture. Identifying these patterns from measured data and documenting and expressing them require a high level of knowledge and practical experience from the operator. This approach is more commonly seen in China led by architectural studies (HAN et al., 2022; Liu et al., 2019; WANG et al., 2019; WU et al., 2016).

In practice, these two approaches are not mutually exclusive and can be flexibly combined. Scan-to-BIM focuses on documenting the preservation status of physical objects, and semantic segmentation of point clouds can record high-precision real textures, particularly suitable for organic forms, irregular components, or artistic elements such as sculptures, carved decorations, prunus branch lattice windows, wooden, brick, and stone components with carvings, and caisson ceilings, as well as structures whose construction logic cannot be easily expressed through mathematical formulas (Aftab et al., 2023; Croce et al., 2023; Kang, 2023). On the other hand, Rule-based reconstruction emphasizes recording idealized and standardized practices, summarizing patterns based on measured data, and incorporating detailed dimensions from manual measurements, making it particularly applicable to wooden components such as columns, beams, and rafters, as well as model units with clear construction logic.

These approaches are based on recording coordinate relationships for existing conditions and expressing ideal semantic relationships, respectively. Each method has its strengths and weaknesses, and combining them could lead to more efficient and convenient solutions. By leveraging knowledge to guide the process, using a 'knowledge graph' to oversee information, integrating multi-source heterogeneous data, and embedding it into every stage of the HBIM workflow, information transfer pathways can be optimized, enabling more flexible and efficient information management. This would result in an improved technical approach. Therefore, to better serve metric survey and heritage conservation, integrating knowledge into HBIM modeling and developing a reproducible technical framework is highly necessary.

1.3 Key Contributions

This paper aims to discuss a method that establishes and verifies the technical route of Rule-based reconstruction, and forms a fusion route in combination with 'Scan-to-BIM'. The original data forms information after concept combing and logic extraction. The information becomes knowledge after structured processing. Knowledge can solve problems. If only the status data of the physical object is recorded, the relevant information on the image characteristics and construction logic will be missing, and the 'structure type' information will be missing only as the spatial position data of the 3D model expression components. How to improve the integration degree of knowledge and model, based on 'reverse mining' regular knowledge, 'forward rebuild' regularized model, that is, to improve the content of 'H' in the HBIM model, and to find the optimal route between expression regularity and expression difference at the knowledge level, is the first problem to be solved, and the follow-up work can be carried out only when the route is correct.

Key contributions include: A semantics-centered fusion route for heritage recording; The KSQI framework resolves knowledge integration and tool optimization challenges; Improved operability, lower knowledge barriers, and higher modeling efficiency.

2. The KSQI Integration Framework

The KSQI paradigm includes overall objectives, the technical route, workflow, and delivery requirements.

2.1 Overall Objectives

The overall objective is to establish an information indexing framework for the full life cycle of heritage conservation, providing information management and knowledge services for the full life cycle of heritage conservation; better support the updating of heritage knowledge and the digging of its value; and lay the groundwork for the transition towards smart survey in the field of architectural heritage.

2.1.1 Information Indexing Framework

Architectural heritage metric survey and documentation is intelligent information management and service-oriented towards the full life cycle of architectural heritage conservation. As the core technology, HBIM should be oriented towards the full life cycle of architectural heritage conservation, establish an information indexing framework, and continuously provide information management and knowledge services. The term 'full life cycle' refers to research, conservation, management, utilization, and monitoring conducted throughout the life span of the heritage, forming a 'Conservation Cycle' as shown in Figure 2.

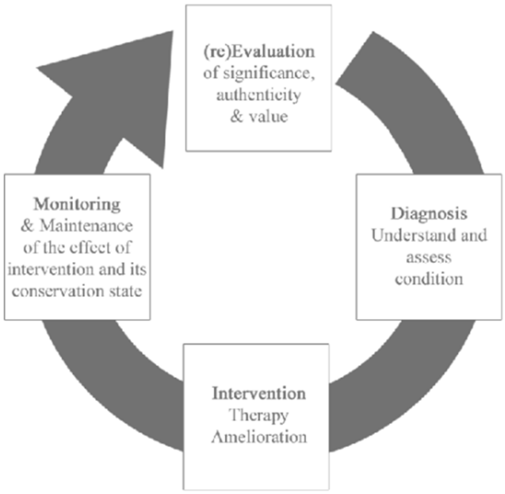

Figure 2. The conservation cycle (Quintero et al., 2007).

The ICOMOS lists 14 professional activities in its official guidelines, including value assessment, information acquisition, diagnosis, documentation, and interdisciplinary collaboration (ICOMOS, 1993). HBIM technology should provide information services for all activities and the full life cycle of heritage conservation, necessitating the establishment of a knowledge-guided, semantics-driven information indexing framework. This framework should express the architectural characteristics and construction logic of the building, without being confined to minor differences or defects, and establish an 'idealized model' based on 'typical metric survey' and 'sample dimensions.'

In HBIM-related research, target models have always had different focuses, such as the as-found model (Banfi et al., 2019), the as-built model (Brilakis et al., 2010; Kalyan et al., 2016; Kim et al., 2013; Maiezza, 2019; Pătrăucean et al., 2015; Xiong et al., 2013; Zhang et al., 2016), and the as-designed model (Shao et al., 2024). Among these: the as-found model describes the current preservation status of the surveyed object, serving as an objective record of the present period; the as-built model describes the completed state of the surveyed object, representing an idealized reconstruction to a certain extent; the as-designed model describes the original design state of the surveyed object, representing an idealized state unrelated to the current condition. If an information indexing framework is to be established for the entire conservation process, the above three models each have their limitations. This paper proposes the establishment of an 'as-recognized model': making semantics the protagonist of heritage recording activities, identifying semantics, reproducing semantics, and assigning knowledge to the image, thereby forming a knowledge-guided, semantics-driven information indexing framework. It includes both the expression of the current state and the identification and restoration of knowledge. On this basis, establishing an information indexing framework model can maintain the coordination of the three elements: image, quantities, and semantics, which enables more flexible information attachment and better information management functions.

2.1.2 The Knowledge Enrichment and the Value Exploration

To better provide information management and services throughout the processes of recording, managing, and serving, HBIM work needs to be guided by knowledge in the field of architectural heritage. This is because knowledge in the architectural heritage domain belongs to an open-domain type, lacking a unified design paradigm, and requires continuous bottom-up accumulation and refinement. It is based on existing cases to enrich knowledge, which in turn guides metric survey activities in practice, updating and supplementing the existing knowledge system. Meanwhile, this workflow can be standardized and systematized to form a recording paradigm, better reconstructing the design and construction logic of buildings in practice, and summarizing design paradigms of architectural heritage within a certain scope. As knowledge of heritage continues to evolve, it may form elements that support value, facilitating further value digging and the implementation of the new era's policies for cultural relics work.

2.2 The Technical Route

2.2.1 The Four Essential Elements of Model

Image, Quantities, and Semantics are three interdependent elements that are mutually reinforcing and integral to the full life cycle of the metric survey, including data collection, processing, and representation. Knowledge guides the modelling process to achieve these three elements.

Quantities can generate images, serving as the foundation for creating visual representations, while an image is the visual expression of metric values. Semantics can be identified through images and quantities, and it endows images and quantities with additional meaning. For example, scan point cloud data can generate basic images and include quantities. By classifying the functions, forms, and specifications of components, we can assign identity and relational characteristics to images and quantities, which are systematic and theoretical understandings of the three elements: image, quantities, and semantics: that constitute knowledge.

Between image and semantics, image is the external form (i.e., 'shell'), while semantics is the substantive content (i.e., 'meaning' or 'core'). A model without semantics can only create an image that is 'hollow,' while a model with semantics can achieve both 'form and substance.' An HBIM model should be a model that possesses both form and substance. Under the guidance of professional knowledge in the field of architectural heritage, it can generate rich and varied images, thereby better conveying semantics and meeting the diverse needs of heritage conservation across different application scenarios.

2.2.2 The Comparison of Two Routes

'Scan-to-BIM' introduces three-dimensional laser scanning technology into the field of heritage conservation, using point clouds as the prerequisite and primary source of spatial data. It involves segmenting the point clouds, referencing point cloud modelling, mapping the model back to the point cloud, and finally attaching semantic information to the model. The key technical aspect lies in the processing and utilization of point clouds, following a workflow of first modelling, then organizing and attaching semantic information, where semantic information does not interfere with the modelling process.

'Rule-based reconstruction' focuses on uncovering the regularity of semantics and quantities, achieving knowledge integration by establishing regularized models. This approach is based on measured data while balancing the expression of semantic regularity and quantitative variability. It involves obtaining data through field investigations and applying reverse knowledge mining to recreate semantics through models (Figure 3, Table 1).

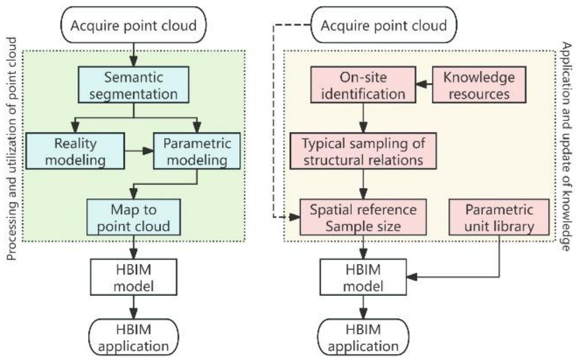

Figure 3. The comparison between two technical routes (Left: Scan-to-BIM; Right: Rule-based reconstruction).

Table 1. The comparison between two technical routes.

	Scan-to-BIM	Rule-based reconstruction
Discipline Background	Metric survey and mapping	Architecture
Modelling Purpose	Current conditions	Information indexing framework
Key Issue	Processing and utilization of point clouds	Application and updating of knowledge
Application of Semantics	Semantic segmentation	Semantic representation
Method of Knowledge Integration	Processing point clouds Reference to pattern books	On-site recognition With related knowledge and experience
Driven by	Point clouds	Semantics

2.2.3 Tooling Solution of Pattern Books

The ‘point cloud’ driven modelling references ‘pattern books’ until the modelling phase starts: first, scanning the architecture; second, semantic segmentation of point clouds; last, wrapping them into segmented mesh models.

The ‘semantics’ driven modelling presets knowledge and experience to interactive tools for on-site recognition, where the ‘pattern books’ are already integrated (Figure 4): first, develop interactive check forms to identify the characteristics at the very beginning of the on-site investigation; second, develop visual-programming modelling tools to automatically generate models with clear patterns or update the algorithms for the new patterns.

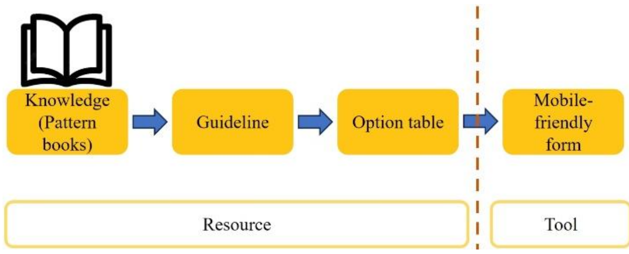

Figure 4. Tooling solution of pattern book.

2.2.4 The KSQI Route

To better integrate and express the above three elements through the HBIM model, this paper focuses on the whole protection process, aiming to establish an index framework model for information. A fused technical route for modelling, referred to as the KSQI route, is proposed (Figure 5): guided by Knowledge, driven by Semantics, and based on Quantities as fundamental data, it expresses the Image that semantically enriched while updating and enriching existing knowledge. The KSQI route coordinates, prioritizes, supplements, and refines ‘Scan-to-BIM’ and ‘Rule-based reconstruction’ to better integrate knowledge with models and optimize HBIM modelling techniques.

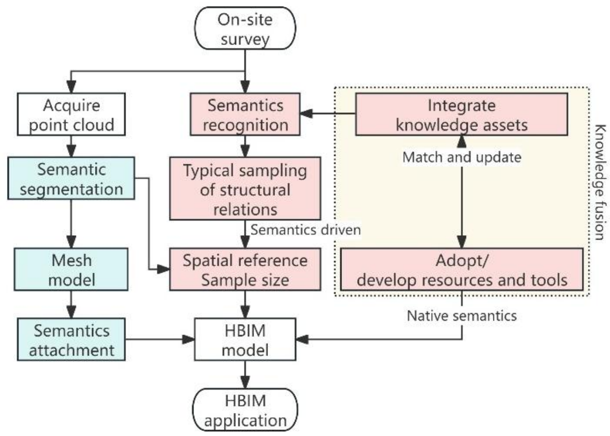

Figure 5. The KSQI technical route.

This fusion route requires the model to both ‘represent’ by recording quantitative values to express spatial positions, coordinate relationships, etc., and ‘convey meaning’ by recording semantics to express design and construction logic, applying and updating knowledge, thereby better serving informatized metric survey and mapping and laying the foundation for the future development of smart metric survey and mapping. The key issues to be addressed are as follows:

(1) Transforming knowledge and integrating resources. It is proposed to enhance the operability of knowledge during its application and updating by transforming knowledge and integrating resources.

(2) Optimize the selection of tools to address challenging issues. It is proposed to reduce the difficulty and technical barriers in learning knowledge and improve efficiency by selecting optimal general tools and developing specialized tools. Using tools infused with knowledge to accomplish various tasks inherently meets standards and technical requirements.

In practice, resources and tools are often closely related. Transforming knowledge and integrating resources are also part of selecting optimal general tools and developing specialized tools.

2.3 Workflow and Phase Requirements

As mentioned earlier, apart from the preliminary preparation, the substantial workflow of HBIM can be divided into three phases: on-site survey and data collection; modelling and validation; delivery and archiving (Figure 6).

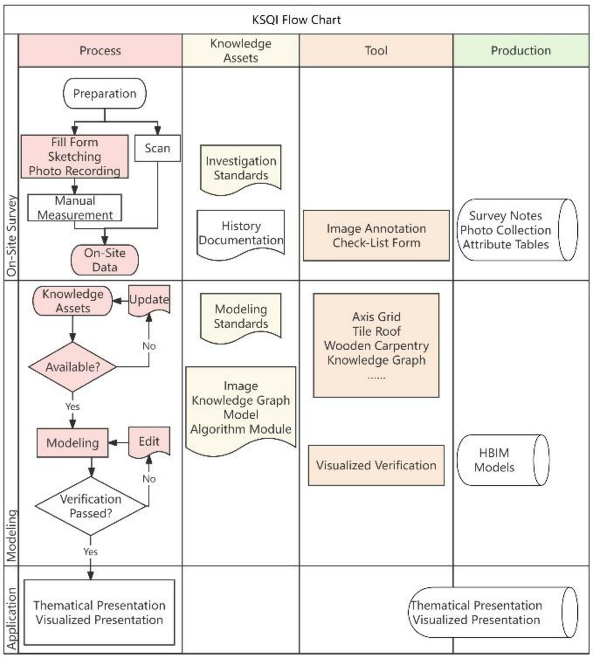

Figure 6. The KSQI route flow chart.

2.3.1 Phase 1: On-Site Survey and Data Collection

Objective:
(1) Semantic Recognition: On-site identification of formal characteristics, and preliminary confirmation of semantic information of formal characteristics at different levels.

(2) 3D Data Acquisition: Collect 3D data of the survey target as comprehensively as possible.

Main Tasks:
(1) The Three-pronged Approach (Figure 7): Conduct close observation of the survey target, and simultaneously carry out three tasks - filling out formal characteristic attribute tables, drafting measurement sketches, and photographic documentation - following the principle of ‘filling, drawing, and photographing in sync.’ This is done at different levels including parts, units/components, structural components, and sub-components, and involves confirming ‘typical’ components, etc.

(2) 3D Data Acquisition: Includes but is not limited to control metric survey, 3D laser scanning, photogrammetry, and manual measurement.

Figure 7. The three-pronged approach.

Special Requirements: mainly pertain to semantic recognition. Mature 3D data acquisition technologies are not elaborated upon here.

(1) Resources: Field surveys and semantic recognition require work guidelines. These guidelines integrate knowledge of various aspects of ancient architecture, propose specific survey content and depth requirements for different parts, and aim to be as comprehensive and detailed as possible, achieving component-level detail. This ensures no survey items are overlooked and maintains consistency in the form of results.

(2) Tools: To better complete semantic survey work, the knowledge content of the guidelines needs to be further transformed into interactive software tools that support mobile devices, which are the forms (Figure 8). This facilitates on-site operations, better connects with subsequent modelling stages, and establishes associations.

Figure 8. The forms.

2.3.2 Phase 2: Modeling and Validation

Objectives: based on the data obtained in the field survey phase, transform the spatial reference, create models using sample dimensions, ensure that model units are hierarchically endowed with basic and enhanced semantics, and maintain traceability throughout the process.

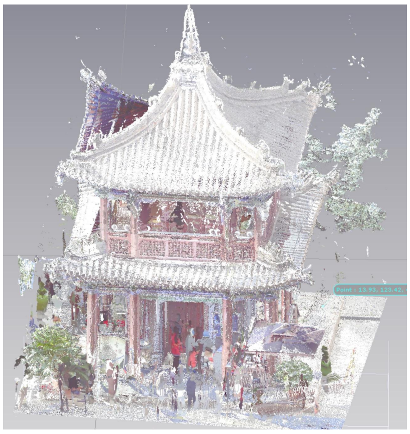

Figure 9 Point cloud acquisition

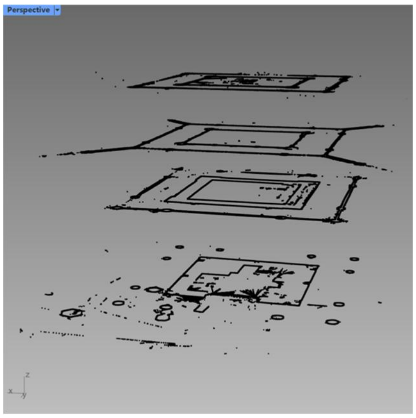

Figure 10. Point cloud sections.

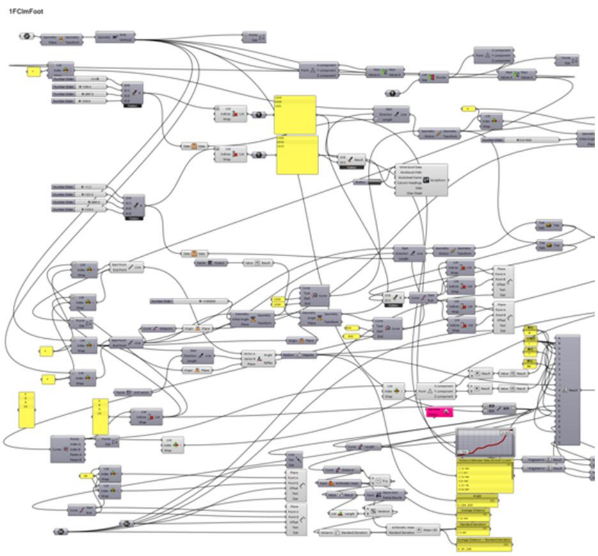

Figure 11. Automatically generate the axis data.

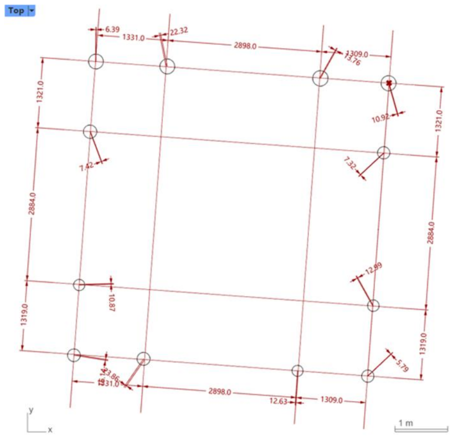

Figure 12 Preview of the axis data

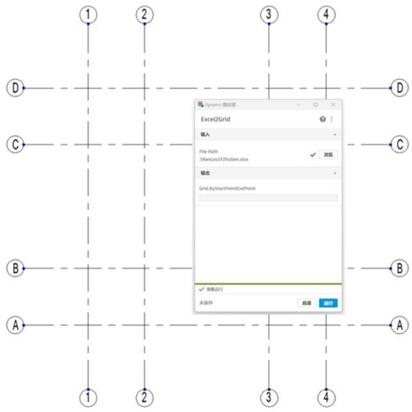

Figure 13. Automatically draw the axis grid in Dynamo in Revit.

Main Tasks:
(1) Convert the survey control network into architectural spatial references, i.e., identify and restore layout axes and elevations (Figure 9, Figure 10, Figure 11, Figure 12, Figure 13).

(2) Hierarchically create sub-models, assign basic semantics, and then merge them into the general assembly model. Record information transfer paths to facilitate problem tracing (Figure 14).

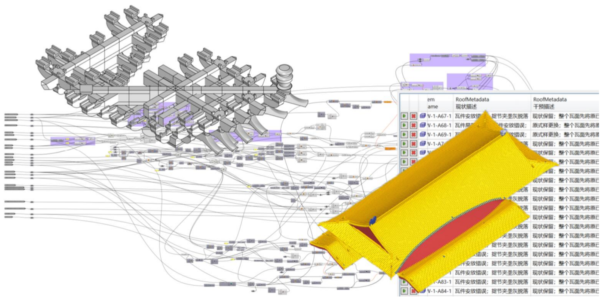

Figure 14. Semantics-driven modelling.

(3) Extract attribute tables from the model and merge them with information from survey forms. Attribute tables include basic semantic information such as project details, model geometric dimensions, and functional-form characteristics.

(4) Finally, verify the correctness and completeness of semantic information through tabular checks, and verify geometric dimensions to complete semantic and accuracy index validation.

Special Requirements:
(1) Resources. Resources required for modelling and validation include guidelines and a shared unit library. Guidelines should cover modelling methods for various components, applicable modelling techniques for different object types, model detail requirements, data exchange principles, etc.; the shared unit library enables the model to be lightweight through reuse.

(2) Tools. Dedicated tools need to be developed to meet special modelling requirements:

a) Spatial reference conversion tool. Develop a layout axis generation tool that automatically determines optimized regular layout axes based on irregular site conditions, minimizing the sum of the mean and standard deviation of distances from reconstructed axis intersections to existing axis intersection columns.

b) Three types of modelling tools are required:

Tools for spatial structural model units, targeting linear components with clear tectonic logic, including large-timber frame components and dougong (corbel bracket) groups;

Tools for planar composite model units, targeting flat components with clear 2D contours, including foundation components and finishing components;

Tools for curved surface paving model units, targeting components(massively) covering complex hyperbolic surfaces, including rafter-and-sheathing and roof-tile components. For model units with low quantity and low repeatability, more suitable general tools (e.g., Rhino or Revit's built-in parametric tools) can be used for modelling.

2.3.3 Phase 3: Delivery and Archiving

Objectives: deliver a visual, thematic, and integrated interactive result system following GB/T 51301 - 2018, combined with project requirements (Figure 15).

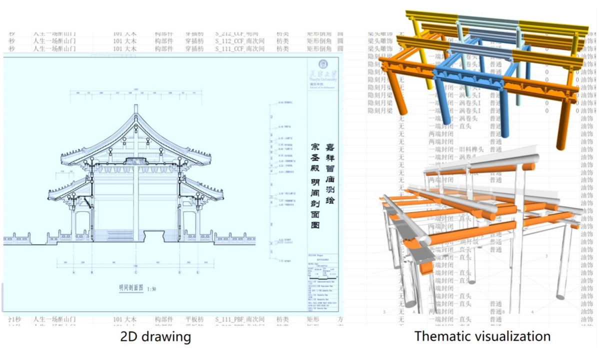

Figure 15. Delivery of 2D drawing and thematic visualization.

Main Tasks: guided by knowledge and driven by semantics (manifested as intents or themes), generate rich and varied visual expressions for related topics to form HBIM models, survey drawings, attribute information tables, and other results that are 'semantics-driven in form,' 'integrating form and essence,' and 'diverse and colorful.' Model expressions should be produced in multiple forms as needed, such as thematic views, tables, documents, images, multimedia, and web pages. As part of the survey task, external materials such as survey drafts, rubbings, point clouds, and photographic records should be standardized and archived as results. Associative access relationships should be established among various model expressions and between models and external materials.

2.4 Model-data decoupling and re-coupling

Following the completion of the initial modeling workflow, the baseline model can represent fundamental semantics and image characteristics. However, the BIM team still requires interdisciplinary collaboration to integrate heritage conservation expertise—such as historical information, material specifications, structural stability assessments, and physical environmental data—into the model. Therefore, it is essential to establish a "model-data decoupling" mechanism at the preliminary stage. This approach enables specialized domains to develop discipline-specific datasets independently before the BIM team consolidates all information to finalize the HBIM model through a systematic decoupling and re-coupling workflow.

3. Conclusion

HBIM is foundational for digital documentation in architectural heritage conservation, but current approaches face critical flaws: poor integration of knowledge resources (hampering access/updates), inefficient, hard-to-learn tools, and a lack of standardized modeling paradigms (undermining workflow reusability). These issues persist even as intelligent surveying advances, causing low modeling efficiency and high knowledge barriers.

To address these, this study proposes a fusion route by comparing "scan-to-BIM" and "rule-based reconstruction" methods, developing the KSQI integrated framework. This framework systematically integrates knowledge resources, combines general-purpose and specialized tools to boost efficiency, and embeds iterative knowledge-updating mechanisms—ultimately enabling reusable workflows. Core dimensions of KSQI are as follows.

Knowledge-driven guidance (K): Leverages heritage conservation knowledge to direct modeling. Semantic empowerment (S): Enriches models with contextual meaning (e.g., historical significance, protection rules) beyond geometry. Quantitative foundation (Q): Ensures accuracy via precise measurement data (e.g., scans, dimensions). Semantically enriched imagery (I): Merges semantic data with visuals for intuitive, information-rich documentation.

Future work will expand the semantic knowledge base and explore AI-driven automation within KSQI to advance heritage conservation.

Acknowledgments

This paper is partially supported by the following institutions: the Palace Museum, China; Jiayuguan Academy of Silk Road (the Great Wall) Culture, Gansu; Cultural Heritage Administration of Jizhou District, Tianjin.

References

Aftab, I., Kristof, K., Lovas, T., 2023. Automating Scan to BIM Operations Using Grasshopper. *Periodica Polytechnica Civil*

Engineering.

Banfi, F., 2019. THE INTEGRATION OF A SCAN-TO-HBIM PROCESS IN BIM APPLICATION: THE DEVELOPMENT OF AN ADD-IN TO GUIDE USERS IN AUTODESK REVIT. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-2/W11.

Banfi, F., Brumana, R., Aljishi, A., Sayeh, N.A., Quintero, M.S., Cuca, B., Oreni, D., Midali, C., 2019. GENERATIVE MODELING, VIRTUAL REALITY AND HBIM INTERACTION: IMMERSIVE ENVIRONMENT FOR BUILT HERITAGE: CASE STUDY OF SHAIKH ISA BIN ALI HOUSE, BAHRAIN. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-2/W11.

Bosché, F., Ahmed, M., Turkan, Y., Haas, C.T., Haas, R., 2015. The value of integrating Scan-to-BIM and Scan-vs-BIM techniques for construction monitoring using laser scanning and BIM: The case of cylindrical MEP components. *Automation in Construction* 49, 201-213.

Bosche, F., Haas, C.T., 2008. Automated retrieval of 3D CAD model objects in construction range images. *Automation in Construction* 17, 499-512.

Brilakis, I., Lourakis, M., Sacks, R., Savarese, S., Christodoulou, S., Teizer, J., Makhmalbaf, A., 2010. Toward automated generation of parametric BIMs based on hybrid video and laser scanning data. *Advanced Engineering Informatics* 24, 456-465.

Capone, M., Lanzara, E., 2019. SCAN-TO-BIM vs 3D IDEAL MODEL HBIM: PARAMETRIC TOOLS TO STUDY DOMES GEOMETRY. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-2/W9.

Croce, V., Caroti, G., Piemonte, A., Luca, L., Véron, P., 2023. H-BIM and Artificial Intelligence: Classification of Architectural Heritage for Semi-Automatic Scan-to-BIM Reconstruction. *Sensors* 23.

Gustavo, R., Luís, M., Jorge, F., Victor, F., 2020. A Scan-to-BIM Methodology Applied to Heritage Buildings. *Heritage* 3.

HAN, S., WU, C., LI, D., 2022. Information Presentation of Condition Inspection for Architectural Heritage Based on HBIM: Taking Three Duty Rooms in Forbidden City as an Example. *Traditional Chinese Architecture and Gardens*, 52-57.

ICOMOS, 1993. Guidelines on education and training in the conservation of monuments, ensembles and sites. ICOMOS, London.

Kalyan, T.S., Zadeh, P.A., Staub-French, S., Froese, T.M., 2016. Construction Quality Assessment Using 3D as-built Models Generated with Project Tango. *Procedia Engineering* 145, 1416-1423.

Kang, T., 2023. Scan to BIM Mapping Process Description for Building Representation in 3D GIS. *Applied Sciences* 13, 9986.

Khalid, A.H., Hani Ismaeel, E., 2020. State-of-the-art of Historic Building Information Modelling - HBIM Trends in the Built Heritage - Review Paper. *Diyala Journal of Engineering Sciences* 13, 77-90.

Kim, C., Son, H., Kim, C., 2013. Automated construction progress measurement using a 4D building information model and 3D data. *Automation in Construction* 31, 75-82.

Laing, R., Leon, M., Isaacs, J., Georgiev, D., 2015. Scan to BIM: the development of a clear workflow for the incorporation of point clouds within a BIM environment.

Liu, Y., Xie, L., Li, A., Hou, M., Liu, H., 2019. Multi-LoD Expression and Automatic Information Integration of Cracks in Ancient Wooden Buildings. *JOURNAL OF GRAPHICS* 40, 1123-1129.

Maiezza, P., 2019. AS-BUILT RELIABILITY IN ARCHITECTURAL HBIM MODELING. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* XLII-2/W9, 461-466.

Pătrăucean, V., Armeni, I., Nahangi, M., Yeung, J., Brilakis, I., Haas, C., 2015. State of research in automatic as-built modelling. *Advanced Engineering Informatics* 29, 162-171.

Quintero, M.S., Blake, B., Eppich, R., 2007. Conservation of Architectural Heritage: The Role of Digital Documentation Tools: The Need for Appropriate Teaching Material. *International Journal of Architectural Computing vol. 5 - no. 2, pp. 240-253* 5.

Rebolj, D., Pučko, Z., Babič, N.Č., Bizjak, M., Mongus, D., 2017. Point cloud quality requirements for Scan-vs-BIM based automated construction progress monitoring. *Automation in Construction* 84, 323-334.

Shao, J., Yao, W., Wang, P., He, Z., Luo, L., 2024. Urban GeoBIM construction by integrating semantic LiDAR point clouds with as-designed BIM models. *IEEE Transactions on Geoscience and Remote Sensing* PP, 1-1.

Stanga, C., Hasníková, H., Previtali, M., Brumana, R., Grimoldi, A., Banfi, F., 2019. THE ASSESSMENT OF THE BAROQUE VAULT CONSTRUCTION TECHNIQUE BYSCAN-TO-BIM PROCESS: ST. BERNARD'S CHAPEL IN THE PLASY MONASTERY. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-2/W15.

Tang, P., Huber, D., Akinci, B., Lipman, R., Lytle, A., 2010. Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques. *Automation in Construction* 19, 829-843.

WANG, C., GUO, Z., ZHU, X., 2019. Application of HBIM in architectural heritage protection -- a case study of Erxian temple in Xiaohuiling, Lingchuan, Shanxi. *China Cultural Heritage*, 84-89.

WU, C., LI, K., LI, S., ZHANG, L., BAI, C., 2016. From Digitization to Informationization: Preliminary Exploration on the Application of Information Technology in Architectural Heritage. *China Cultural Heritage*, 18-24.

Xiong, X., Adan, A., Akinci, B., Huber, D., 2013. Automatic creation of semantically rich 3D building models from laser scanner data. *Automation in Construction* 31, 325-337.

Zhang, C., Kalasapudi, V.S., Tang, P., 2016. Rapid data quality oriented laser scan planning for dynamic construction environments. *Advanced Engineering Informatics* 30, 218-232.