ICCEPM 2022
The 9th International Conference on Construction Engineering and Project Management
Jun. 20-23, 2022, Las Vegas, NV, USA

Ontology based Integrated Construction Information Management for Modernized Traditional Housing (Hanok)

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Abstract: In an attempt to disseminate modernized Korean traditional housing (Hanok), a ten-year research project was initiated in 2010 by the Korean Government to reduce the construction cost, improve the facility performance, and automate the Hanok construction industry. To meet these objectives, various research areas, including public policies, planning methods, design standards, new building materials, construction standards, maintenance procedures, advanced project management tools, and integrated IT applications have been developed. In addition, comprehensive technologies developed were applied to the ten pilot Hanok buildings to validate the real-world performance as part of the research project. To further facilitate the digital transformation of the Hanok industry by using the research results, it is required to disseminate the developed technologies in an automated and standardized manner. In particular, it is crucial to systematize and manage the interoperability of various technical data and accumulated historical data for different business functions, especially within the highly fragmented industry. In this context, this paper proposes an ontology-based Hanok information dissemination platform to enable industry-wide automated knowledge and information sharing. The system architecture, standardized historical database, and advanced analytics based on ontology web language (OWL) for the Hanok industrialization platform are introduced.

Keywords: construction management, automation, ontology, modernized Korean housing

1. INTRODUCTION

Hanok stands for the architectural style of a unique wooden building that has been with Korea's long history.[1] The basic structure of a Hanok is a heavy wooden structure of column and beam system and has a tiled roof. In terms of environmental friendliness and the succession of traditional architectural styles, Hanok is receiving a lot of attention in Korea. Nevertheless, there are few construction cases outside of special areas due to the perception of high construction costs.[2]

Various efforts have been made to solve this problem and modernize Hanok. Representatively, there is a research project for Hanok technology development, a research project conducted by the Ministry of Land, Infrastructure, and Transport for about 10 years from 2010.[3] The research project has been conducted from various perspectives as follows, within the scope of maintaining the architectural characteristics and beauty of Hanok to disseminate Hanok as a residential and public building. (1) Reduction of construction cost, (2) Improvement of performance for each part, and (3) Reinforcement of structural safety. The technologies developed in this way were practically verified through 10 demonstration sites. However, it is difficult to apply the developed methods and technologies to new construction sites.[4] Furthermore, there is a need to develop more construction technologies due to legal finances such as zero energy.[5] Therefore, it is necessary to propose a technology dissemination plan to activate the application of new construction methods and new technologies in the field.

In general, the construction technologies applied to buildings can be divided into construction materials, construction equipment, and construction methods, and are determined by the designer at the design stage.[6] However, in the design stage, it is difficult to adequately review the construction method due to the lack of information, time and cost limitations, and the project delivery method.[7] In addition, as 3D-based BIM technology has recently been developed, related technologies are rapidly demanding the need for field application.[8]

This study aimed to propose the 'Reference Construction Data Library' that can integrate and manage information on the new construction methods and building construction of Hanok in the planning and design stages using BIM. It has four objectives: (1) proposal of a classification system for accumulating construction information of Hanok, (2) analysis of the characteristics of each part of the case where new technology is applied, (3) classification of data and definition of metadata to help designers, and (4) information expression using ontology. The construction technology used in this study is based on the construction method and the building construction developed through the results of 10 years of research. These were organized through 10 modernized Hanok.

2. HANOK CONSTRUCTION TECHNOLOGY RESEARCH PROJECT

In Korea, Hanok villages to protect Hanok are established as cultural protection districts, and there are not many other cases of Hanok construction. Therefore, to disseminate Hanok architecture, policies are being operated in which the state and local governments support part of the construction cost of Hanok. The legal definition of a Hanok to be selected for support is as follows. Hanok is defined as "a building whose main structure is a wooden structure composed of columns, beams, and a Korean-style roof frame and reflects the traditional Korean style and its annexes". Therefore, in this study, Hanok is defined as a Korean-style wooden structure, which is a structure with a roof using tile as a heavy timber structure of the column-beam method.

2.1. PURPOSE OF HANOK RESEARCH PROJECT

To disseminate the Hanok architectural style, it is necessary to improve it to a building that meets the needs of the modern lifestyle so that a lot of new Hanok can be built. First of all, it was necessary to reduce the construction cost per m^2, which is three times higher than that of general concrete buildings. In addition, plans for improvement of the performance of facilities and dissemination as public buildings as well as housing were required. Hanok research was largely conducted in design, construction, construction management, and maintenance technology. In this study, the results of the development of Hanok construction management technology are explained from the main point of view.

Hanok construction management technology development was conducted with the roadmap shown in Figure 1. The roadmap is composed of "H.A.N.O.K", which means "Hanok project

management by Abstract Technology & New Project supporting technologies, Which based on the Optimized historical data by Korean wooden housing standards". A brief description of each step is as follows.

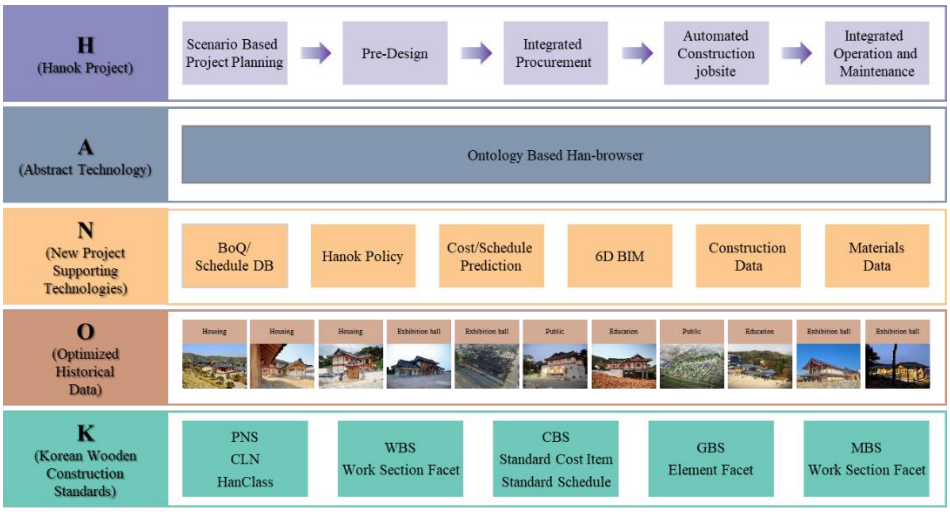

Figure 1. Hanok construction technology development research project roadmap

"H" (Hanok Project Management): The final goal of the Hanok construction project is to systematically manage construction information through Hanok information standards. Therefore, Hanok research project was conducted with the aim of "development of scenario-based business plan and planning and design support technology", "integrated material management plan", "site automation plan", and "integrated maintenance technology development". In particular, for the successful completion of a project, the most important step is to reflect the requirements from the initial planning and design stage of the project to the final maintenance stage in advance.

" A" (Abstraction Technology): Hanok used its architectural term and became a communication barrier for architects who did not know it. Therefore, there was a need for a standard to systematize the traditional terms used in the field. In addition, it was necessary to manage a large amount of accumulated information and to specify and conceptualize information for retrieval and sharing of information. Therefore, the information of the construction project is organized in the stage of linking and abstracting information through the application of ontology technology.

" N"(New Project Supporting Technology): At the planning stage, the development of technology to support decision-making is required. Supporting technologies such as Hanok policy strategy, project requirements, cost estimation, process estimation, and construction technology data were developed. In addition, for the management of visualized information, an integrated information management method was proposed through 6D BIM.

" O"(Optimized Historical Data): A total of 11 Hanok built through research from 2010 to 2021 was applied with a new construction method to improve their performance, and there was a change in construction cost through changes in construction methods for each part. Therefore, this construction information shows the characteristics of modernized Hanok and can be used as useful data for new Hanok construction in the future. All information was organized in RDB (Relational Database) based on the Hanok standard classification system.

" K" (Korean Wooden Construction Standards): The standard classification system can be divided into classifications for managing processes, items, and elements. In the development of the standard, the characteristics of traditional Hanok and the new construction method of modernized

Hanok had to be considered together. In addition, traditional Hanok engineers and designers had to be able to understand Hanok terms together, and the standards had to have a systematic structure for computerization.

2.2. CHANGES IN CONSTRUCTION METHOD FOR EACH ELEMENT

To analyze the characteristics of the construction methods developed through the research project, Hanok standards classification system was used.[9] In a previous study, the effect of construction cost according to the change of construction method for each element was analyzed.[10]

Table 2. The number of construction methods developed

Classification Work Section	No.	Classification Element	No.
C03_Concrete	3	A1030.30_Foundation	3
C04_Masonry	9	A2010l40_Cornerstone	2
		A3010.40_Cornerstone	7
C06_Wood	17	B1010.61_Vertical wood member	10
		B2010.66_Roof assembly	7
C07_Thermal and Moisture Protection	65	C1010.71_Insulation	65
C08_Openings	22	C2010.81_Window	22
C09_Finishes	30	C4010.71_Floor finishing	4
		C6010.71_Wall finishing	26
C10_Roof	8	C7010.01_Roof finishing	8
C12_Site and Infrastructure	5	B1030.45_Fence	5
Total	159	Total	159

Table 1 shows the new construction methods developed through the Hanok research project. A total of 159 new construction methods were proposed. Breaking down by work section, the number of developed construction methods is 3, 9, 17, 65, 22, 30, 8, and 5 from ‘concrete’ work section to ‘site and infrastructure’ work section. In the number of construction methods for each part, insulation, wall finishing, and window accounted for the highest proportion in the order of 65, 26, and 22. This shows that due to the low airtightness of wooden structures and wall components, there have been many technological developments to improve insulation and maintenance.

As an example, there is a construction method called ‘Precast ocher wall framework and its manufacturing method’. In this construction method, a frame is made by assembling a lattice wooden frame produced in advance at the factory between wooden pillars at the construction site and then fixing it at a certain distance between the frame and the frame. Then, after attaching an iron plate to the outside of the wooden frame, the space between the wooden frames is filled with an insulating material and finished with ocher or quicklime on the outer iron plate. At this time, natural materials are used as finishing materials for the walls to preserve the eco-friendliness of traditional Hanok and to secure improved thermal performance by tightly replenishing fillers inside the wall frame.

In addition, 25 construction methods for the wooden structure and roof were proposed to reduce the construction cost, which accounts for a high proportion of the total cost. Also, a construction

method to secure structural stability due to the weight reduction of the roof was proposed at the foundation element.

3. ONTOLOGY CONCEPT FOR INTEGRATED MANAGEMENT

The amount of construction information produced in various formats over the entire life cycle is enormous. Therefore, there is a limit to accurately retrieving or reusing the necessary information by the index word at an appropriate time. To improve this, research on various construction information integrated management methods is in progress. Nevertheless, information management methods are proposed from different perspectives according to the business characteristics of each construction company, and as a result, information systems are being built for each project or life cycle. The most appropriate way to solve this is to develop a system that can understand the relationship of information like a human and provide appropriate information. From this perspective, there is the semantic web concept presented by Tim Berners-Lee.

3.1. ONTOLOGY CONCEPT FOR HANOK CONSTRUCTION MANAGEMENT

The management perspective of construction information using the ontology concept is being discussed in various ways. A representative activity is an establishment of a reference data library (RDL) that is commonly used in process plants including oil and gas facilities, based on the ISO 15926 international standard.[11]

In the ontology of Figure 2, ‘facility type’, ‘business function’, and ‘project outline' are linked as major points of view. The core classes were defined centering on the Hanclass proposed through the Hanok technology development research project, and the construction method and material class are also connected to the Hanclass in the core class. In addition, the upper class that connects the relationship with the upper ontology and user class that shows the actual construction information of the user were defined. This ontology needs to be verified for information indexing through SPARQL, finding ways to link and manage more information in the future.

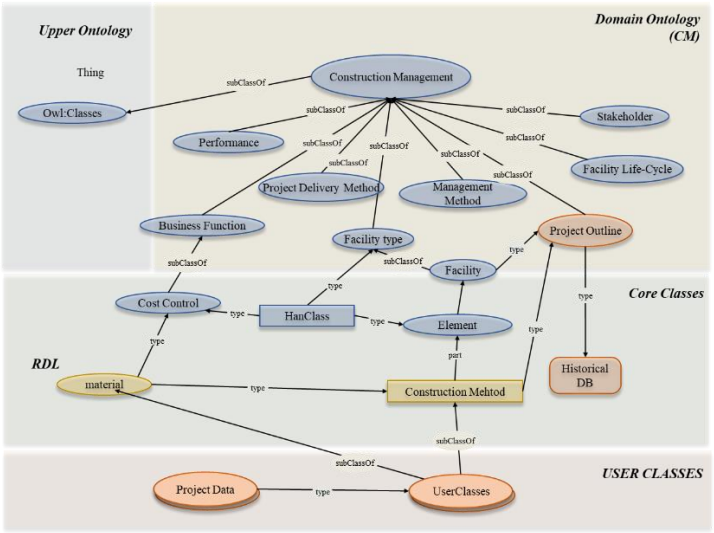

Figure 2. Hanok construction management ontology

3.2. CORE CLASSES FOR MODERNIZED HANOK

From the perspective of the Hanok construction management ontology described above, in this study, a total of 16 entities including construction work sections reflecting the characteristics of Hanok and 1727 classes were defined as core classes for Hanok construction management. The information is construction information to be considered together from the designer's perspective in the initial design stage and can be used for design automation and planning.

Table 3. Core classes for modernized Hanok

Classes represented in the Reference Data Library		
Instance of entity type	**Content sample**	**Number of Classes**
ClassOfFacility	Educational Facility	168
ClassOfWork	carpentry	52
ClassOfElement	Wood Structure	159
ClassOfLifeCycle	Design	6
ClassOfLocater	1st Floor	6
ClassOfCrew	carpenter	39
ClassOfMethodSteel	Steebar	9
ClassOfConstructionMethod	Strip footing	159
ClassOfTraditionalTerm	Changbang	105
ClassOfStandardSpecification	KCS 41 33 02	2
ClassOfManagement	Project outline	66
ClassOfBusinessFunction	Design & Engineering	14
…	…	…
ClassOfWBS	L101C0320	62

In addition, the relationship between classes is expressed in RDF (Resource Description Framework). RDF is a framework for representing resources on the web. An integrated approach is needed to standardize a target that has a wide range of applications and involves multiple stakeholders. Based on this concept, it is required to define a standardized reference model that reflects the common requirements of various stakeholders participating in the modernized Hanok construction project.

In this study, the first step was to establish reference data for the construction method. Hanok element class was taken as the core class of the construction method, and the standard specifications related to the developed construction method were connected. In addition, a thesaurus relationship between traditional and modern terms was established to define the relationship between the names of elements used in traditional Hanok. Also, materials used in each construction method, types of steel joint, design drawings accumulated through Hanok construction, field photos, and detailed drawing information were linked. This is shown in Figure 3. In other words, the relationships defined by the reference data of the construction method are built with (1) element classification of Hanclass, (2) thesaurus relationship between traditional terms and modern terms, (3) relationship with the upper class such as the standard specification, (4) materials and steel joint, (5) drawings and photos. In addition, the semantic structure of the construction method was organized with metadata to enable automatic cost estimation through linking with 3D graphic information.

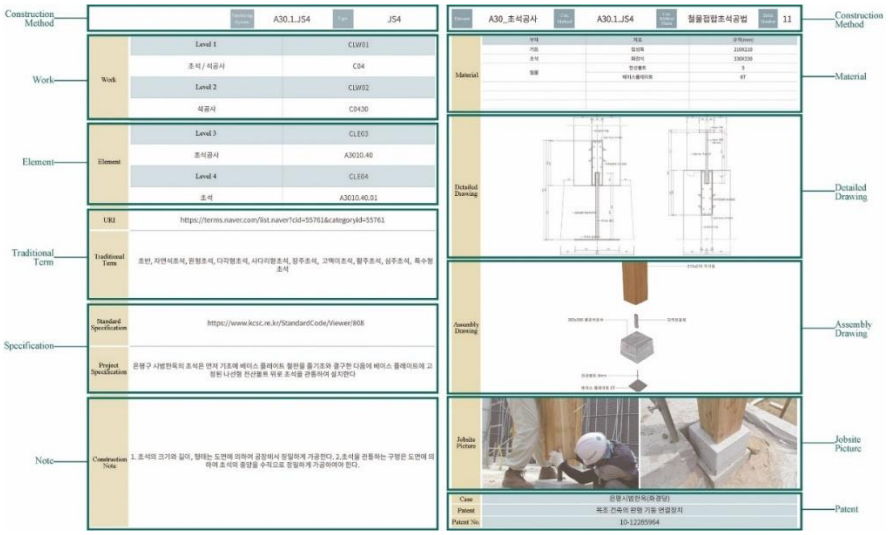

Figure 3. Construction guide metadata

3.3. CONSTRUCTION DATA WEBSITE FOR HANOK

Based on the Core Class defined in Chapter 3.2, the modernized Hanok construction data website was published. This site is a website that integrates and manages all the construction information listed above (construction items, schedule, construction cases, construction methods, standard classification system, etc). The integrated site seeks to overcome the limitations of information reusing according to the construction management perspective and to make all information organically connected. Nevertheless, since there are still technical difficulties in semanticizing all data, the currently proposed website also provides general document downloadable and photo-oriented data in the form of reference.

4. CONCLUSION

This study proposes Hanok construction management ontology to disseminate construction technology developed through Hanok technology development research project. The ultimate goal of defining Hanok construction management ontology is to integrate Hanok construction management data by linking Hanok graphics and information. Therefore, it was necessary to analyze the characteristics of Hanok for the systematization of Hanok construction management data, and the information needed by stakeholders was structured.

To define the thesaurus, the work was carried out to connect the synonyms of the traditional terminology of Hanok and the terminology of modern architecture. A total of 159 construction methods were developed for each element of Hanok, and 40% of them are insulation construction methods for the wall element of Hanok. In addition, window and wall finishes accounted for 30%, and structural and roof elements accounted for 18%. Through this, it can be seen that the technological development of the Hanok has been intensively developed on the method of constructing the wall to improve the insulation and waterproofing performance. Also, to reduce the construction cost of the structural elements, construction methods were developed. Therefore, to structure the Hanok construction data, the classification system for elements, materials, and steel joints had to be reflected in the classification of construction methods.

The Hanok construction data website proposed in this study is currently under additional work. This site was published with open data of the construction method guide developed through the research project, definition of Hanok elements, and 3D graphics for each element. Through future research works, it is planned to consider the use of ontology, which includes defining domain

ontology for construction project management, and automatic cost estimation and maintenance through BIM.

ACKNOWLEGEMENTS

This study was financially supported by the National Research Foundation of Korea (NRF) grant founded by the Korea government Ministry of Science and ICT (MSIP) [No. NRF-2021R1A2C1006997]

The support of Ministry of Land, Infrastructure and Transport of Korean Government under Grant No. NRF-2021R1I1A1A01055223 is gratefully acknowledged.

REFERENCES

[1] B. Jeon, K. Lee, The definition and scope of Hanok, Hanok Policy Brief, No2, Architecture & Urban Research Institute, 2011.11.

[2] M. Kim, Y. Kim, Y. Lee, Y. Jung, “Comparative Analysis of Construction Productivity for Modernized Korean Housing (Hanok),” Korean Journal of Construction Engineering and Management, vol. 14, no. 3, pp. 107–114, 2013.

[3] C. Kim, H. Lee, M. Jang, Y. Lee, Y. Jung, “Hanok Construction Guide to Promote the Dissemination of Modernized Hanok,” Proceedings of KICEM Annual Conference, pp. 43-44, 2021

[4] J. Lee, J. Han, P. Han, “A Study on Defining the Hanok Design Process and Required Design Information,” Journal of architectural history, vol. 22, no. 2, pp. 31–42, 2013.

[5] Ministry of Land, Infrastructure and Transport, “Building Energy Conservation Design Standards,” 2017

[6] O. Choi, H. Cho, G. Kim, “The Selection of Roof Waterproofing Methods using the Analytic Hierarchy Process (AHP) Technique”, Journal of the Korea Institute of Building Construction, vol. 10, no. 4, pp. 95–103, 2010.

[7] H. Seo, N. Shin, D. Yeom, Y. Kim, “A Decision Support Model for the Selection of Exterior Wall Formwork in Residential-Commercial Building Construction”, Journal of the Architectural Institute of Korea Structure & Construction, vol. 29, no. 9, pp. 97–104, 2013.

[8] J. Song, J. Yu, K. Kim, “On-site Quality Control Support Tools Based on Mobile BIM - Focusing on Quality Management Work”, Korean Journal of Construction Engineering and Management, vol. 21, no. 6, pp. 27–37, 2020.

[9] Y. Jung, M. Joo, “Building information modelling (BIM) framework for practical implementation”, Automation in construction, vol. 20, no. 2, pp. 126-133, 2011.

[10] N. Seo, S. Kang, Y. Lee, Z. Jin, Y. Jeong, and Y. Jung, “Variations of Building Methods and Costs of Modernized Hanok Test-bed Projects”, Korean Journal of Construction Engineering and Management, vol. 20, no. 3, pp. 86–96, 2019.

[11] Y. Jeon, S. Byon, D. Mun, "Development of an Editor for Reference Data Library Based on ISO 15926", Transactions of the Society of CAD/CAM Engineers, vol. 19, no. 4, pp. 390-401, 2014.