Development of an Open BIM-based Legality System for Building Administration Permission Services

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Abstract
In Korea, the government has developed SEUMTER, an administration system for building-related public services, to facilitate and promote electronic submission and permission activities. SEUMTER is a progressive legality system based on 2D drawings for building administration permission services. However, there are a lot of problems related to the development of a legality system due to the complexity of Korean regulations, relationships and structures, the inefficiency of designing a legality system based on 2D drawings, the duplication examinations of documents (soliciting forms for civil affairs), and the drawings themselves. Therefore, the purpose of this study is to develop a legality system for building administration permission services based on open Building Information Modeling (BIM) in Korea. To achieve this purpose, the authors investigate the permission procedures and regulation structures used in current building administration permissions, then formulate an ideal permission procedure and regulation structure for the legality system in Korea. In addition, the authors investigate element technologies (for example, methods of structuring regulation, BIM model checker, BIM model viewer) for a legality system based on BIM and develop a prototypical legality checking software. Finally, the authors suggest strategies and future applications for a legality system based on BIM.

Keywords: building administration permission service; Building Information Modeling (BIM); legality checking; legality system

1. Introduction
The architectural industry involves compiling a multitude of data from various sources working within different disciplines in a process that includes a variety of design stages. Specifically, building administration permission information has been utilized in the establishment of national policy, individual property protection, and facility management.

SEUMTER was developed for use in building administration permission services in Korea. The legality system in SEUMTER was developed based on 2D drawings and documents related to soliciting forms for civil affairs (Choi & Kim, 2009). However, there remain many issues related to current legality systems, owing to limitations of building legality checking based on 2D drawings, the inaccuracy of legality checking, and the inefficiency of duplication examination documents and the drawings themselves. In addition, the architectural industry paradigm has evolved from 2D to 3D through the use of Building Information Modeling (BIM) technology (Seo & Kim, 2009). 3D information-based BIM using Industry Foundation Classes (IFC) can solve many of the problems inherent in conventional 2D drawings, because 3D models can include a range of information for the legality system (Choi & Kim, 2013). Furthermore, environmental factors (government policies, information environments, international environments, etc.) can also be included in BIM (Cho et al., 2011; Choi et al., 2015).

The delivery of BIM data is mandatory in advanced countries, and these countries promote automated legality checking. For example, Singapore has developed a BIM-based automated legality checking process through the software FORNAX and has built a construction administration system, CORENET (Liebich et al., 2004). The SMARTcodes project in the USA has structuralized the regulations of the International Code Council (ICC) and developed an automatic legality checking system (Conover & Lee, 2008). In particular, legality checking through an automated legality checking system can reduce errors, time, and inefficient use of human resources (Choi et al., 2014). Therefore, it is necessary to develop a legality system for building administration
permission services based on open BIM in Korea, as an improvement over the conventional 2D drawings and documents.

The purpose of this study is to develop a legality system for building administration permission services based on open BIM in Korea. To archive this purpose, the authors investigate permission procedures and structuring regulations used in current building administration permission systems, analyze current case works for a legality system based on BIM and suggest application plans for a legality system in Korea. In addition, the authors investigate element technologies for a legality system based on open BIM and develop a prototypical legality checking system. Finally, the authors suggest a strategy and future direction for applications related to the regulation and element technology of a legality system based on BIM.

2. Related Case Works

2.1 CORENET

Singapore Construction and Real Estate NETwork (CORENET) has focused on the development of a set of infrastructure and industry projects in order to provide government to business infrastructure, so as to facilitate electronic building plans submission, checking and approval processes (Fig.1.). CORENET consists of an e-submission system and integrated plan checking. An e-submission system is an internet-based system for the submission of electronic plans and documents for approval within a secure environment. Integrated plan checking is an automated checking process for IFC-based files and leading-edge systems that can integrate expert knowledge of regulations, artificial intelligence (AI) and BIM technologies (Teo, 2014; Khemlani, 2005).

2.2 SMARTcodes

The SMARTcodes project of the International Code Council (ICC) has developed automatic code compliance checking for the I-Codes at the international, federal, and state levels. The automated code compliance checking takes the building plan, which is represented by BIM, and automatically checks for code compliance using Model Checking Software (MCS) (See & Conover, 2008). As shown in Fig.2., architects and designers can use BIM software to document and present their designs, and then load the BIM (IFC) into MCS, where the ICC compares the SMARTcodes with BIM. Architects and designers can then submit the BIM to the checking agency as part of their permit applications.

2.3 ByggSøk

ByggSøk is a public system for electronic services in zoning and building matters in Norway. ByggSøk consists of three modules: an information system, a system for submission of building applications and a system for zoning proposals. ByggSøk has implemented an electronic e-submission system similar to Singapore’s CORENET, and the two countries have collaborated to allow Norway to benefit from Singapore automated legality checking system experience (Choi & Kim, 2008). On the HITOS pilot, the legality checking efforts have focused predominately on accessible design. The building model data are stored and accessed through the EDM Model Server in IFC format (Greenwood et al., 2010).

2.4 Analysis of Case Works

As shown in the analysis, it is possible to use current cases of Korean legality systems based on open BIM. The development contents and application of the legality system based on open BIM are shown in Table 1.

3. Element Technologies for a Legality System Based on Open BIM

3.1 Method of Structuring Regulation

The purpose of the structuring regulation is to link the BIM data to the regulation in the legality system based on open BIM. The legality checking progresses through the identification of the targets and contents of building objects in BIM data compared with the regulations (Choi et al., 2014). The regulation can be divided into standardized and atypical regulations. For example, inaccurate terminology such as convenience
or stability is hard structured. In this study, atypical regulations are exceptions in the scope of applied regulation. Regulations can also be classified as atypical if they require substitution plans at the structural regulation stage.

For example, Korean regulations related to U-values can be structured according to the SMARTcodes method, as shown in Table 2. The regulation is a hierarchy, which 'selects' and 'applies' filtering down before arriving at a particular requirement. SMARTcodes handles this by using the original table, as published. This allows the individual requirements in the main cells of the table to be associated with header and sideways cells.

3.1.1 Development of K-code XML Schema and Support Tools

SMARTcodes is a structuring regulation in XML format using the SMARTcode Builder (SCB) that was specifically developed for SMARTcodes. SCB is a custom built XML editor developed by the US Pacific North West Laboratories for the ICC. It implements the SMARTcodes schema and software specifications developed by AEC3 Ltd. The editor was specially developed to handle only commands and operations specific to SMARTcodes (Wix, 2008). It was necessary for Koreans to secure or develop software that supported Korean grammar and sentence structure, so as to better structure Korea's regulations (K-codes). In the short term, the tool developed for this case can be implemented in a legality system based on open BIM. However, for the long term, it is necessary to develop a tool that is able to accurately reflect the unique character of Korean regulations.

3.1.2 Development of a Dictionary

All of the main terms that may be defined as attributes are defined in a 'dictionary' (technically, an ontology), which describes the terminology hierarchies. The values and units for the specific attributes can also be set, which then provides the basis for comparisons with the properties of the submitted BIM data (Wix, 2008). The dictionary can be used to control the compliance checking process. It can document which terms have been mapped to IFC, and can direct the application to a relevant executable function. The SMARTcodes dictionary is comprised of terms, objects, and properties that are critical for communication between the MCS, BIM and SMARTcode.

Table 1. Analysis Results of Case Works

| Commonness | Development contents | Application plan of legality system in Korea |
|------------|----------------------|---------------------------------------------|
|            | - Application and development of legality systems based on open BIM | - Reflection of process when applying legality systems based on open BIM |
|            | - Development of software that supports a legality system based on open BIM | - Development and purchase of software decision |

**CORENET & ByggSøk**
- Development of submission and approval procedures for permission based on BIM/IFC
- Reflection of permission procedures based on open BIM

**SMARTcodes**
- Development and application of element technologies and methods of structured regulation
- Introduction and development of software that can structure regulation

Table 2. Example of Structured Korean Regulations

| Original Regulation | Structuring Regulation |
|---------------------|------------------------|
| Article 21 (prevention of a loss of heating) 1 | In the building built, permitted actions concerning energy utilization rationalization can be found in the following subparagraphs. |
| 1. The application of a U-value in an external wall of the living room, the ceiling of the living room on top of a ceiling or roof, above a living room in the lowest level of a building, on the side wall of an apartment house, the ground floor of an apartment house (see Table IV). | |
| 2. ... | |
| 3. This does not apply in any cases that fall under the examples detailed in the following subparagraphs. | |

| Check | Apply | Exception | Select | Applies | Select | Applies | Requirement |
|-------|-------|-----------|--------|---------|--------|---------|-------------|
| U Value | Garages, machine rooms, buildings without established heating or cooling equipment | Building in which there is no energy saving effect such as factory, warehouse equipment, exc acts treatment plant | External wall | Living room | When directly facing outdoor air | Lower than 0.47 | |
| | Ceiling or roof | | Living room (top story) | When directly facing outdoor air | Lower than 0.46 | |
| | Fabric | | Living room (overground story) | When directly facing outdoor air | Lower than 0.43 | |
| | Floor | | Living room (overground story) | When directly facing outdoor air | Floor heating | Lower than 0.41 | |
| | | | | | Except floor heating | Lower than 0.40 | |
| | | | | | Floor heating | Lower than 0.55 | |
| | | | | | Except floor heating | Lower than 0.54 | |
| | | | | | Floor heating | Lower than 0.50 | |
| | | | | | Except floor heating | Lower than 0.49 | |
| | | | | | Floor heating | Lower than 0.55 | |
| | | | | | Except floor heating | Lower than 0.54 | |
3.2 Development of a BIM Guideline for a Legality System

The BIM guideline is a reference guide that outlines the roles and responsibilities of project members when using BIM at different stages of a project. In addition, the BIM guideline includes BIM user modeling guidelines in terms of BIM software and BIM requirements (e.g., property and geometry for legality checking). Most countries that have applied a legality system based on BIM have already developed BIM guidelines. For example, Singapore has developed a common BIM guide and BIM e-Submission guide (e.g., architectural guidelines, structural guidelines, MEP guidelines) (Teo, 2014). However, Korea has not yet specifically developed BIM guidelines for legality checking. Therefore, there are a multitude of problems related to BIM data for a legality system, including properties for legality checking. It is necessary for Koreans to develop BIM guidelines for the legality system. In the short term, BIM guidelines should be developed in order to create BIM data. However, in the long term, BIM guidelines should reflect the general environment for BIM applications.

Fig. 3. shows the spatial information definition method that is defined in the GSA guidelines. Through this method, it is possible to compare the properties of IFC and determine legality based on the regulations.

3.3 Development of Software for the Legality System

3.3.1 Model Server

A few software vendors have implemented a complete IFC data model as a database, which is then able to accept and store all data objects that are in compliance with the IFC. A computer system with such a database is termed an IFC model server. A model server is a database, a set of server applications that enable multi-user database management and allow for the use of the IFC data model (Jørgensen et al. 2008).

1) EDM Model Server

The EDM Model Server was developed based on the data modeling language Express (ISO 10303-11). The Express Data Manager EPM Technology is a database product for which the database structure is defined by Express (Jørgensen et al. 2008).

2) Eurostep Model Server (EMS)

EMS, from Eurostep in Finland, is based solely on the Java programming language. It is, therefore, available for use on any server platform that supports Java. EMS can also be installed on multiple databases: MySQL, SQL Server and ORACLE (Jørgensen et al. 2008).

3) IFC Model Server

The IFC Model Server was developed by VTT Building and Transport and SECOM Co., Ltd, in 2002. It is offered in a technologically independent way, using XML and Simple Object Access Protocol (SOAP) for communication between the model server and client software. Therefore, the model server functionality can be utilized independently of the programming language used to create the model server clients (Jørgensen et al. 2008).

3.3.2 Model Viewer

The Model Viewer allows for the viewing of BIM data. In addition, it offers link functions between the legality system results and BIM data. There currently exists free software that supports IFC (http://www.ifcwiki.org - Freeware). SMARTcodes uses the Solibri Model Viewer (SMV) and Octaga Viewer.

3.3.3 Model Checker (Code Compliance)

The Model Checker uses a constraint schema for legality checking. In addition, the Model Checker tests and verifies the rules of the IFC model. The Model Checker analyzes the results after comparing and checking the structured regulation (K-code) with BIM data (e.g., Pass or Fail). SMARTcodes uses Solibri Model Checker (SMC) and XABIO for its legality checking. The CORENET e-PlanCheck system is provided by an independent platform called FORNAX. FORNAX takes the basic building model information from IFC and adds to it higher level semantics that are relevant to legality checking requirements. The commercial quality check software SMC is widely used. Fig. 4. shows the e-PlanCheck web interface that displays the legality checking results of a specified clause for a project. The non-compliance results are detected by e-PlanCheck, and the problem area is highlighted in red in the checker (Khemlani, 2005; Teo, 2006).

Fig. 4. Example of the Non-Compliance Result by e-PlanCheck
4. Implementation of Korean Regulation Examples as SMARTcodes Method

Subsequently, it is necessary to develop a prototypical software for the development of a legality system based on open BIM. The prototypical software should apply key regulations and element technology for legality checking based on open BIM. The method for applying Korean regulations concerning case work (such as XABIO) has been proven to be an effective method.

4.1 Preparation and Processing of Demonstration Regulations

The development of an advanced regulatory solution involves three distinct elements, as follows:
1) The capture and mark-up of the Regulation, and its use within a checking engine to generate results.
2) The capture and development of the Dictionary, and its use during mark-up and during checking.
3) The development and capture of the Building, and its use during the checking.

The priority task is to capture the English equivalent of the regulation and show the Korean regulation operation using the SMARTcodes method.

4.2 Regulation

This study deals with the Korean regulation (rules about a building's facilities criteria) related to U-values. The purpose of the following process is to capture the text and tables of the regulations in a format that preserves the original appearance, but allows for the insertion of extra mark-up that captures the meaning of the regulations in a way that is verifiable, developable and efficient. Fig.5. shows an example in which an excel-based regulation is changed by structuring regulation through mark-up using the SMARTcodes Builder.

The table contains 45 distinct requirements, marked in blue. Each requirement is associated with the applicability (green) and exceptions (orange) found at the head and side of the table. The table has been modified to eliminate spanning ('merged') cells, as these are not handled. For clarity, the left side of the table has been split into four columns. The phrases 'external', 'in top floor and roof' and 'in lowermost story' can be ignored, as the actual applicability is determined by whether the building element is in direct or indirect contact with the outside air.

4.3 Dictionary Processes

The dictionary is relevant at several stages of the process.
1) The dictionary can be used to summarize the vocabulary and to clarify if two terms (e.g., 'domestic' and 'private') are synonymous, are alternatives or are taken from distinct properties. The dictionary can be derived from an existing mark-up.
2) The dictionary can be used to document the relevant IFC lookup alongside any natural language terms.
3) The dictionary can be used to control the compliance checking process. It can document which terms have been mapped to IFC and can direct the application to a relevant executable function.

Fig.5. Mark-up of a Table (Reference Table 2.)
4.4 Building Processes

The purpose here is to prepare a building model, with the spaces and types associated to their specifications. The building model is prepared using a BIM design application such as Revit, ArchiCAD or Bentley, and then exported to IFC format (Kim et al. 2012).

The BIM data are based on the real building design for examination of the legality checking system, although the final design is significantly different from the design represented in this BIM data (nam’ed 'J_model.ifc'). The property definition in BIM data is shown in Fig.6. Supplementary information, such as U-values for named types and constructions, is added from a spreadsheet or from some other application and merged into the IFC model, either prior to or after loading into the checking application. A building model is supplemented by 'specification' information, which can be accepted separately or can be added to the standard BIM. This spreadsheet allows the addition of extra information about the construction types, door types, window types, etc. When making a building model, care must be taken to know the name of the construction types, door types and window types. The spreadsheet U-values are not calculated from the model. The list of object types in the spreadsheet must match what occurs in the model, by 'name' or by the 'reference' property. This solution should be temporary, until Revit, ArchiCAD, Bentley, etc. support the addition of this information from within their applications.

4.5 Compliance Checking

In this study, AEC3 XABIO is used for compliance checking. AEC3 XABIO uses the EXPRESS Data Manager as its engine. These results can be rapidly transformed into a presentable report. Alternatively issues can be uploaded to a design issue management system. The viewer automatically highlights, isolates and zooms to the element at issue. The detailed report repeats the information from the summary, but adds information about the location in the building of the failed element, a 3D interactive viewer with the object highlighted and a detailed trace of the reason for the failure (Fig.7.).

5. Application Strategy and Plan for Legality System

5.1 Regulation

In this study, the application strategy and plans for the regulations pertaining to the legality system are divided into three phases (Table 3.).

5.2 Element Technologies

In this study, the application strategy and plan of element technologies for the legality system are divided into two phases (Table 4.).

1) Short term plan
- Testing for application possibility deduction
- Development of prototype system
2) Long term plan
- Continuous research for domestic application
- Continuous participation for international standard reflection

5.3 Process Changes for Legality System Based on Open BIM

The change of process for the legality system based on open BIM can be expected as follows (Fig.8.).

1) Architects use BIM software and BIM guidelines to create BIM data.
2) Architects upload BIM data into SEUMTER.
3) Legality system in SEUMTER applies regulation checking according to K-code.
4) Architects revise the design, re-checking until compliance is achieved.
5) Architects then submit the BIM data to the checking agency for approval.
6) Finally, the person in charge of the checking agency confirms the building permission.

6. Conclusions
In the architectural industry, building administration permission information requires innovative change through the limitations of current operations, changes in the environmental factors and a design environment paradigm. Therefore, this paper suggests the development of an open BIM-based legality system for building administration permission services. To archive this purpose, the authors investigate the permission procedures and regulation structures used in current building administration permission systems and analyze current case works of legality systems that are based on open BIM, subsequently advocating for the application of such a legality system in Korea. In addition, the authors investigate element technologies for a legality system based on open BIM and develop a prototypical legality system using the SMARTcodes method for the implementation of a legality system in Korea. Finally, the authors suggest a strategy and future

| Table 3. Application Strategy and Plans for the Regulation of Legality Checks |
|-----------------------------|-----------------------------|-----------------------------|
| Shape Checking              | Function Checking           | Analysis Checking           |
| Contents                    | - Grasp of external/interior shape of the 3D building - Extraction of the 2D drawing from BIM data - Subjective judgment | - Grasp of space, building element, mutual relations - 3D model or extraction of the 2D drawing - Objective judgment | - Analysis of composition and attribution value of building elements through BIM data |
| Examples                    | - Appearance, Surrounding environment … | - Movement distance, equipment establishment, lighting | - Energy, U-value, analysis of sunshine and area |
| Access method               | - Practical use of simplest level - Short-term approach | - Standard and data practical use preparation system - Short-term, medium term approach | - Practical use after security of standard, tool, data attribute - Medium term, long-term approach |
| Regulation (related building permission) | - Height limit (by road) | - Stair installation (direct, escape) - Exit establishment - Fire prevention block - Building coverage ratio/floor area ratio - Elevator installation - Prevention of heating loss | - Stair installation (direct, escape) - Exit establishment - Fire prevention block - Stair installation criterion and structure - Height limit (for sunshine security) - Elevator installation - Prevention of heating loss |

| Table 4. Application Strategy and Plans of Element Technologies for Legality Check for the Regulation of Legality Checks |
|---------------------------------------------------------------|---------------------------------------------------------------|
| Short term plan                                              | Long term plan                                               |
| Development of K-code XML schema                              | - Application and test of Korean regulations in an XML schema, developed in case work - Reflection of prototype system - Progress of structured Korean regulations - Software introduction and verification that is developed in case works | - Development of XML schema that can reflect the specific characteristics of Korean regulations |
| Development of dictionary                                    | - Application and testing in the prototype system - Development of dictionary parallel with structured regulation | - Extension of dictionary contents - Development of dictionary that can be integrated with ISO12006-3 - Interoperability between dictionaries |
| Development of BIM guide                                      | - Development of guide related to created BIM data for legality check | - Development of related guide that reflects the general environment for BIM applications - Reflection of related standard |
| Development of Software                                        | - Development of software, including check rules for legality check - Development of basic software for application in prototype system | - Partial introduction of software that was developed based on the standard - Continuous participation for standard reflection |
direction for applications related to the regulation and element technology of an open BIM-based legality system.

BIM-based legality checking software can reduce the inefficient use of time and human resources and minimize errors. The errors in the checking results can be minimized by improving the quality of the legality checking software to allow it to check the regulation automatically.

This study discusses a strategy and plan for the development of an open BIM-based legality system as the initial phase in the development of a system. Therefore, future works should confirm any problems, allowing for the possibility of progress for the prototype system and its gradual application to a business system.

Various research and work utilizing BIM and element technologies has been continuously developing; therefore, an open BIM-based legality system can be gradually applied in the context of systematic and long-term plans for its successful and effective application.

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Note

Open BIM is a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows. Open BIM is an initiative of buildingSMART and several leading software vendors use the open buildingSMART data model.

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