Development of Open BIM-based Code Checking Modules for the Regulations of the Fire and Evacuation

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Abstract

The Industry Foundation Classes (IFC)-based open BIM has been internationally developed as a solution to interoperability problems among different software applications. Despite much interest and effort, the open BIM technologies are rarely introduced to the construction industry and hence need more technical development for practical application. This research aims to develop automated code-checking modules for the quality assurance of BIM data. The research has analyzed domestic regulations focusing on super-tall buildings and developed open BIM-based code-checking modules for the regulations of fire and evacuation. The modules are able to validate refuge regulations such as the installation of emergency elevators and fire safety places, as well as egress route. The authors expect to improve the process of BIM quality assurance and enhance the quality of BIM data by this research on automated checking system.

Keywords

Open BIM, fire and evacuation, BIM quality control, super-tall buildings, automated checking module, IFC.

INTRODUCTION

Recently in the construction industry, the increasing uncertainty of business promotion and the degradation of reliability have arisen from the complexity and size of the buildings. Furthermore, the specialization and departmentalization of the construction business continue to deepen. The collaboration demand with various sectors is also increasing. The open BIM is a solution to this situation. Moreover, the main countries in the AEC industry are leading in the introduction and application of BIM. The delivery of BIM data, based on BIM standards is mandatory in these countries, and they are verifying BIM quality, included the suitability of the regulations, automatically. This automatic model suitability review of regulation can reduce errors, time and inefficient use of human resources through objective verification (Eastman *et al.,* 2009; Choi, 2011). The automatic regulation review is one of the most important systems for accurate and objective quality control, at BIM order level (Cho, 2012). The research is planned for development of an automatic module to check the legality of BIM data in the process of quality verification. The application architecture defines super-tall buildings (with at least 50 floors, or greater than 200meters in height in domestic regulation). The application regulation set limits to the regulation of fire and evacuation, issues prevention systems due to the nature of the super-tall building (consideration of evacuation movements).

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The research method, through case analysis of quality assurance automatic systems, deducts domestic evacuation regulation check and the possibility of application. The verification lists of existing quality assurance software are developed as a module. The research draws a conclusion from the adopted super-tall building BIM data. The rule set of Solibri Model Checker (SMC), an IFC model review software based Rule, is selected as a development object. This program (SMC) provides a standard rule set and environment, and the user can develop requirements through the API directly.

CASE STUDY

QUALITY ASSURANCE AUTOMATION SYSTEM APPLICATION STATUS

The research examines the application of automatic check system with domestic and foreign regulations for connectivity of the automatic review module.

SEUMTER, Korea

SEUMTER is an electronic system which enables the automation of all of processes and various documents related to architectural and housing administration services. Thus, SEUMTER can quickly provide the collected information pertaining to architectural and housing information to both public institutions and civilians. Through fire prevention review of the legality of check lists by SEUMTER, the installation standard of fire partition, standard of fireproof and regulation of firewall, site, building scale, use, and structure, and construction facilities can be checked in advance (Kim and Choi, 2009).

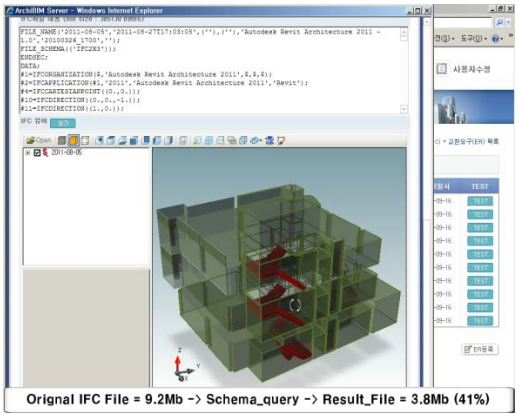


Figure 1. SEUMTER Legality check system

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 the submission of electronic building plans, checking and approval processes. 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 building information modelling (BIM) technologies. E-PlanCheck system, which is part of the e-Submission system, can review automation regulation check, formatted IFC. This

system, based on Singapore regulation can interpret and analysis result can be checked through FORNAX viewer (Cheng, 2009; Eastman *et al*., 2009).

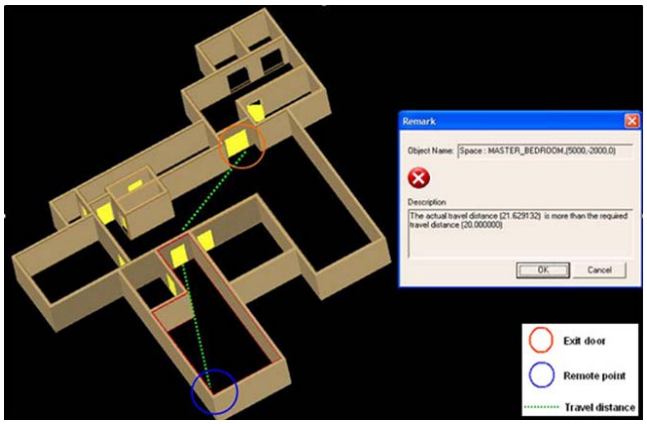


Figure 2. CORENET regulation check

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

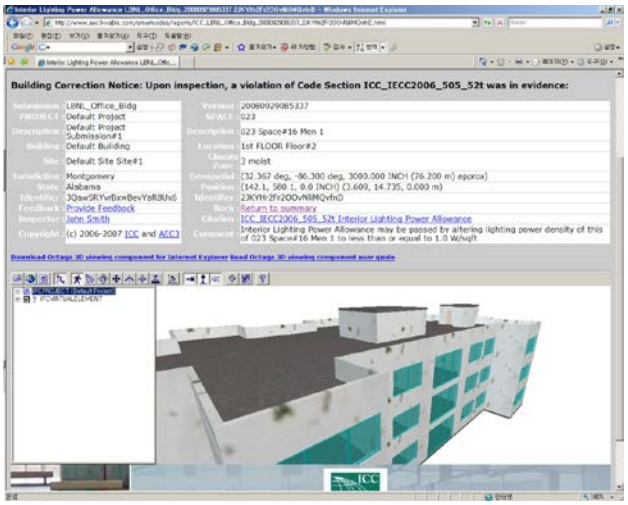


Figure 3. SMARTcodes automatic code compliance checking (AEC3 XABIO)

EVACUATION QUALITY ASSURANCE SOFTWARE BASED ON BIM

The automatic verification software analysis of fire evacuation of is preceded for the development of fire evacuation regulation verification. There are two ways to verify the evacuation of a building through some commercial software. One is simulation. The other way is to use BIM quality management software. The application simulation is software, which uses building information model data for building owner.

buildingEXODUS

One of the management software, buildingEXODUS, developed by FSEG Group at Greenwich University in the UK, is utilized for fire evacuation analysis at Düsseldorf airport, San Francisco subway, London millennium dome and so on. The buildingEXODUS place many people at unspecified locations in software to measure the time for people to evacuate through the exit. And then, it calculates the required evacuation time by comparison with allowed evacuation time.

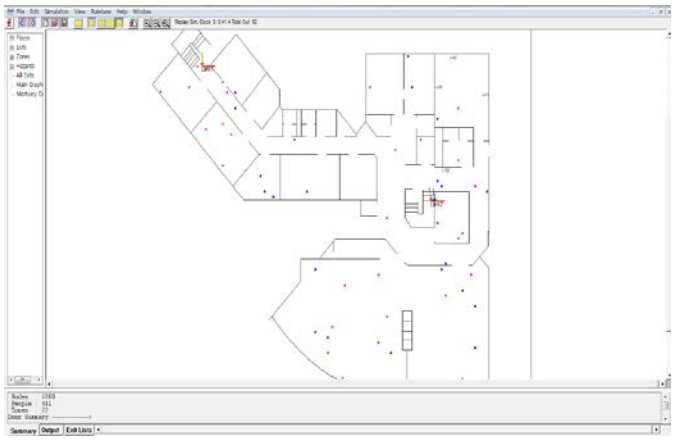
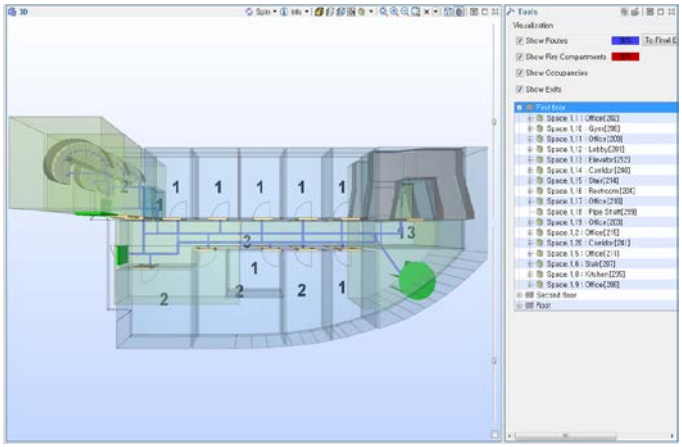


Figure 4. Evacuation simulation software (buildingEXODUS)

SMC

The verification of fire evacuation safety based on BIM data is checked by Solibri Model Checker (SMC), quality management software. The checklist can be confirmed through default rule set which provides. SMC is used by GSA in the USA, Senate Properties in Finland and BIPS in Denmark as BIM project quality management software. Basically SMC supports IFC model and standard specific rules (Architecture, MEP, and Structure). Especially the architecture rule set includes interference check of objects and space, space program review, accessibility review, egress analysis review, and so on. This is a list of egress analysis rule set.

- Fire compartment area must be within limits
- Fire walls must have correct wall, door, and window types
- Space must be included in fire compartments
- Door minimum dimensions



- Doors and windows must be connected to space

Figure 5. Egress routes analysis through SMC

SMC is helpful as a rule check system on quality management side, but there are limits to use of the basic rule set, which limited scope in national regulation, domestically. However, the development of rule set, adopted domestic regulation is possible through API development environment. Through this effort, SMC could be useful in quality management process

APPLICATION METHOD OF EVACUATION REGULATION VERIFICATION MODULE IN SUPER-TALL BUILDINGS

APPLICATION OF EVACUATION REGULATION

The research deals with domestic (Korea) evacuation regulations and super-tall buildings as an application object for the development of quality check automation. In domestic evacuation regulation, the “Evacuation of building, structure of fire protection rules” has been enacted. In addition, some evacuation regulation contents are included in “Building code” and “Architects enforcement”. This research selects items for automation of quality checking module and regulations only for super-tall building, not general architects. The selected items are given priority matter in super-tall buildings than general architects. The item of article 2 in “Architects enforcement” is also selected. This is the table of derived regulation for the realization below.

ENVIRONMENT ANALYSIS OF RULE BASED QUALITY ASSURANCE SYSTEM

The research uses SMC, quality check software based rules for automation of quality check module. SMC was used by Court Design Guild Research of GSA in Georgia Tech, USA. In that project, space program check of the court facility and flow of movement check were utilized with a suitable for the purpose rule set by SMC. And also the SMC rule set was developed for adopting SMARTcodes of ICC and utilized for regulation checking. In Rambøll Headquarter project, Denmark, the delivered BIM model was performed to check the interference between the objects. The Senate Properties in Finland, the project team created a checklist in each sector for improving of business decisions in design and construction process. In addition, they developed SMC new rule set for automation of reviewing the checklist.

Table 1. Check list of super-tall buildings on evacuation regulation (Korea)

Check List	Regulation	Basis	Content
Super-tall building	Architects enforcement	Article 2.	Definition of super-tall building
Installation criteria of evacuation safety zone	Regulation of the evacuation and fire proof construction criteria	Article 34.	Installation of direct stair
	Special law on disaster management of high-rise building and complex building linked underground	Article 18.	Installation of evacuation safety zone
Criteria for emergency elevator installation	Architects enforcement	Article 90.	Installation of emergency elevator
Evacuation distance	Architects enforcement	Article 34.	Installation of direct stair
	Regulation of the evacuation and fire proof construction criteria	Article 11.	Installation standard of outside the exit of the building

CONCEPT OF EVACUATION REGULATION VERIFICATION MODULE

The Table 2 below represents the derived evacuation regulation checklist for adopting of automation check module. These are classified the required standards under the regulation checklist. And the concept of algorithm that can reflect is derived.

Table 2. Summarization of evacuation regulation for super-tall buildings application

Check List	Condition		Criterion
Super-tall building	-		Over 50th floor or Over 200m height
Installation Criteria of evacuation safety zone	For super-tall building		Installation within each maximum 30th floor from ground level
Criteria for emergency elevator installation	For height of building over 31m	The maximum floor area less than 1,500㎡	Installation more than one
		The maximum floor area more than 1,500㎡	Installation plus one elevator for each (more than 1500㎡ and less than 3000㎡)

Basically, the quality management software loads model and rule set. And then it checks model by the loaded rule set. Each object consists of property. The rule set check requires regulation standards, and suitability with calculated location and quantity of objects. From derived regulation standards, as shown in Figure 6, the review concept about the emergency elevator installation criteria which is research target and installation criteria of evacuation safety zone can be expressed.

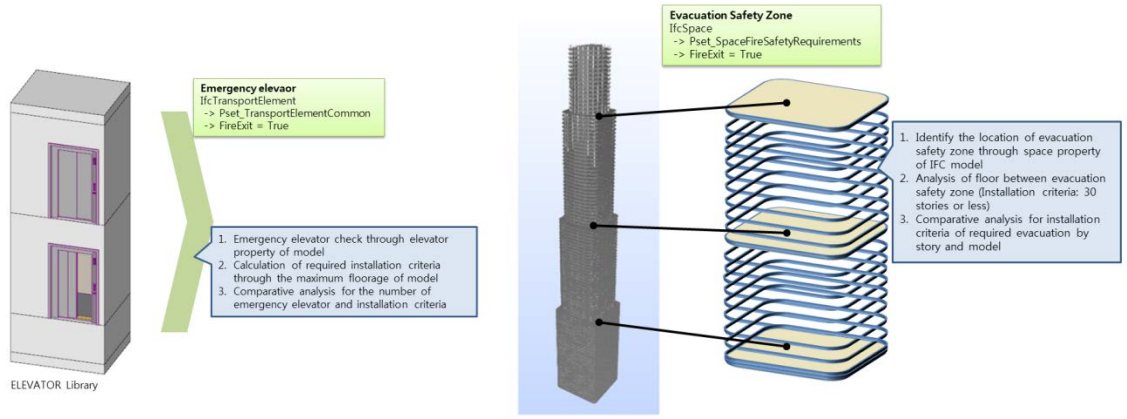


Figure 6. Check modules concept for installation standard of emergency elevator and evacuation safety zone

DEVELOPMENT OF EVACUATION REGULATION VERIFICATION MODULE FOR SUPER-TALL BUILDINGS APPLICATION

DEFINITION OF IFC PROPERTYSET

In order to adopt the derived evacuation regulation on automation module, the property must be defined to reflect object definition and required information of building model through the structuration of relevant regulation. IFC has the structure of building information which is consisted of a set of PSET and sub-property. In this study, PSET information of IFC, international standard, is utilized for objective and consistent review. Figure 7 shows object in accordance with the requested information which is specified “Architects enforcement article 34” and example of defined IFC property.

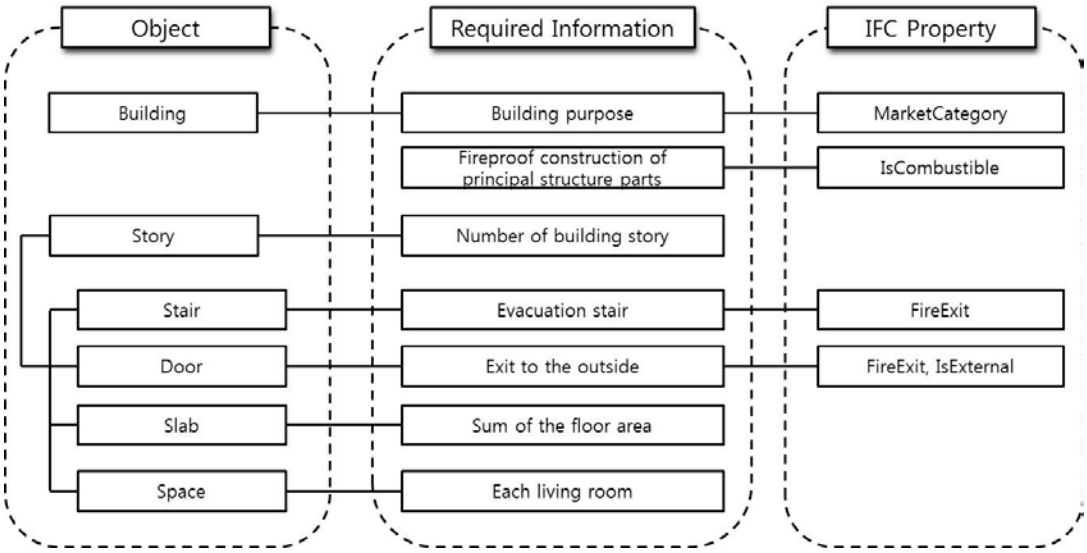


Figure 7. Structuration of evacuation regulation

ANALYSIS AND APPLICATION OF RELATED FUNCTION

The research demonstrates the examples of algorithm and related function with Java Code on installation standard for emergency elevator. The algorithm that implemented according to the criteria for emergency elevator installation process is defined as follows (see Table 3).

Table 3. Process for emergency elevator installation check

Check List	Algorithm and process
The height of building model (Judgment of super-tall building)	
The number of emergency elevator in building model	1. It extracts the total element entities of model through SElement class. 2. It extracts the true FireExit (Boolean) elements, subordinate property (Pset_TransportElementCommon) for the distinction of the emergency elevators. 3. It defines the number of emergency elevator by the number of extracted element.
The maximum of floorage	4. It extracts all slab entities of model through SSlab class. 5. The maximum of floorage is defined through the result of the largest calculated slab of extracted slabs.
The number of emergency elevator required by the maximum floorage	6. It calculates the largest extracted floorage depending on criteria of regulation. 7. The number of emergency elevator is calculated by applying the rounding function as an integer.

APPLICATION OF EVACUATION REGULATION VERIFIED MODULE AND ANALYSIS OF RESULTS

The result of this research can be verified based on the fire evacuation checklist, developed as the automation of quality check module. The verification of the following procedures is performed as shown in Figure 8.

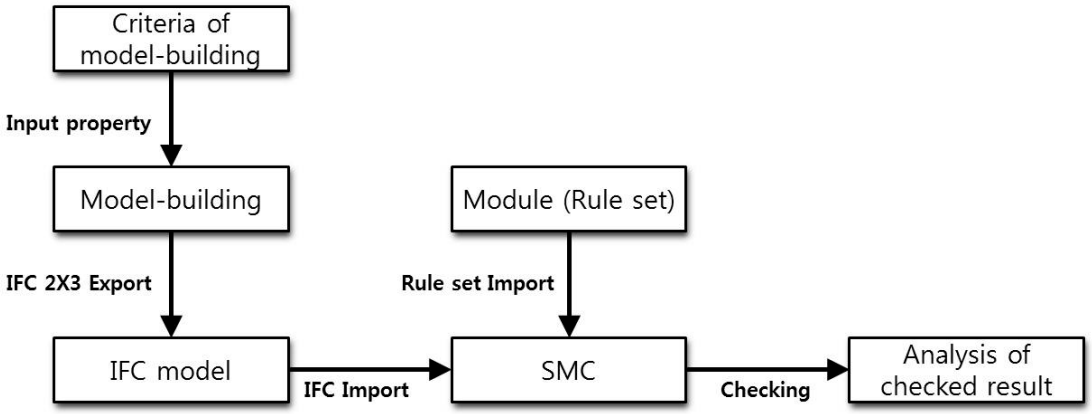
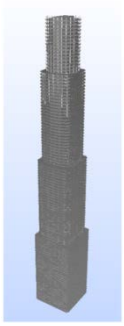


Figure 8. Verification procedures of research results

The BIM model is made by 3 types with Revit Architecture2011, ArchiCAD V.14, and typical commercial BIM software. The BIM model exported as IFC 2X3 version. The checked list through the module is judgment review of super-tall building, installation criteria review of emergency elevator and installation criteria review of evacuation safety zone. Each type of models includes evacuation safety zone with the emergency elevator library and the required properties. The information of each type of BIM models is shown in the table below.

Table 4. BIM models for the test cases

	Type A	Type B	Type C
IFC Building model (SMC screen)			
Story	105-story	63-story	58-story
Height	509.4m	262.5m	173.2m
Emergency Elevator	2	1	2
Evacuation Safety zone	1st floor, 30th floor, 65th floor, 90th floor, 105th floor	1st floor, 30th floor, 59th floor	1st floor, 30th floor, 57th floor
IFC version	IFC2X3	IFC2X3	IFC2X3
BIM Software	Revit Architecture 2011	ArchiCAD14	ArchiCAD14

The summarized the results that applied automatic check module of evacuation regulation by 3 types of BIM models are shown in Table 5 below.

Table 5. Verification results of evacuation regulation check-list

	Type A	Type B	Type C
Result of judgment of super-tall building	Super-tall building	Super-tall building	Super-tall building
Result of Criteria for emergency elevator installation	Legal standard: Minimum 2 Model reference: 2	Legal standard: Minimum 2 Model reference: 1	Legal standard: Minimum 2 Model reference: 2
Result of Installation Criteria of evacuation safety zone	Error	No error	No error
Error contents	The number of evacuation safety zone is 35 (between 35F and 65F)	1 lack of emergency elevator	No error

In case of type A, the BIM model is violated the evacuation regulation criteria that evacuation safety zone should be installed within each 30th floor. In case of type B, the evacuation regulation needs 2 emergency elevators, but BIM model has only one emergency elevator as an error.

CONCLUSION

The suitable criteria of the quality control must be present in advance for checking through BIM quality control process. In order to develop new criteria, the function of system, which is suitable for the purpose should be developed together. This is because the scope of using BIM data tends to limit the software function. Especially, the regulations of logical information quality of quality control target need to self-develop for the applying domestic regulation.

In this paper, the research presents a development plan of the automation module, which can be used in quality control process based on open BIM. For condition of automation module, checklist of environmental matters, support of the open BIM, and possibility of applying the domestic regulation are considered. The results of this study can be summarized as follows.

- The object and rage of study are selected by regulations of super-tall building evacuation. The automation module is made with domestic evacuation regulation that can adopt in super-tall buildings.
- The structure of laws and property of IFC is derived for implementing the derived list of regulation as a module.
- The new rule set is developed with SMC, quality control software. The rule set is about judgment of super-tall building, criteria for emergency elevator installation and installation Criteria of evacuation safety zone.
- 3 type of BIM models are made, which are checked with developed rule set of SMC. The result is verified with analysis.

The quality control process has the effect of the following **expectations** when automation checking which is developed in this study.

- It can reduce the human resources and loss of cost in the process of checking the existing regulations. And also the super-tall building BIM model that has lots of information can check easily with automation regulation check module.
- The submitted models are able to be reviewed objectively with IFC standard format in design competition. In terms of designers, they design the model that appropriated the requirements and criteria through pre-check.
- It suggests the possibility of extension of automation check system in BIM quality control process. In addition, it is able to review of checking various sectors and propose the specific criteria for quality control. For this way, the BIM model's quality improvement can be expected.

The current analysed item of regulation is limited to actual work-site. Because, the research set limits in scope and target in many items of fire evacuation regulation on purpose. In order to compensate, the target and scope should be extended with possible to add the rule set. Also the open BIM technology element, IDM and MVD should be utilized for standard definition which is about property of evacuation regulation to develop the software. Finally, the authors will have to improve this developed module as a reliable system with exploitation of linked analysis system.

ACKNOWLEDGEMENT

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