The 6th International Conference on Construction Engineering and Project Management (ICCEPM 2015)
Oct. 11 (Sun) ~ 14 (Wed) 2015 • Paradise Hotel Busan • Busan, Korea
www.iccepm2015.org

A study on the Development of BIM-based Quality Pre-checking System in Architecture Design Phase

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Abstract: Recently, the mandate on utilizing BIM implemented by public institutions of many countries has great impact on the significantly increasing practices of BIM. The improvement of work efficiency and productivity, which is occurred by BIM adoption, depends on the consistency and accuracy of data. To maximize the benefit of BIM, the interests in BIM data quality have been enlarging all over the world. The BIM data quality pre-check, which is conducted by designer in the design phase, offers opportunities for quality improvement by continuously assessing BIM data. However, BIM quality pre-check is being conducted under arbitrary interpretation of users because of the absence of specific review factors and assessment methods for checking BIM quality. The purpose of this study is to establish an automated BIM quality pre-checking system to improve BIM design quality effectively and efficiently. It could be expected to meet the owner's requirements and to minimize the cost and time occurred additionally from revising and reproducing data by constructing consistency and accuracy of it.

Keywords: Building Code Checking, Building Information Modeling (BIM), Data Quality, Pre-Checking

I. INTRODUCTION

A. Overview

The Building industry is a collaboration environment that requires repetitive data exchanges and communication among different domains and applications in a high frequency [1]. Building Information Modeling (BIM) is a technology that supports a process of information exchange and communication by integrating, interchanging and reusing data during the building lifecycle. Recently, BIM has actively been adopted in order to improve the productivity of the building industry. Furthermore, the public institutions of advanced countries, such as the US, the UK, Singapore and South Korea, have applied mandates to implement BIM in design delivery. It has great impact on significantly increasing practices of using BIM [2]. The improvement of work efficiency and productivity occurred by BIM adoption, depends on the consistency and accuracy of data. To maximize the benefits of BIM, interests in BIM data quality have been enlarging all over the world.

BIM data, as a final result of design delivery contract, could lead to additional time and cost when quality degradation of BIM data occurs due to error or omission of information. In addition, it is the key element to be secured in the design phase because it could raise legal issues. However, a lot of problems have been faced while reviewing information of various fields comprehensively to meet the quality requirements in BIM application guides. BIM quality pre-check is a frequent review of BIM model performed by designer in the design phase. It is suggested in BIM guides (BIM guide series of U.S, COBIM of Finland, BIM guides of Korea, etc.) to ensure the quality of BIM data at the time of delivery. BIM quality pre-check is also a process of reviewing essential items before implementing various analyses. It improves work efficiency and satisfaction about design quality through producing consistent and accurate information and increasing the reliability of analysis result. Currently BIM quality pre-check is being conducted under arbitrary interpretation of users. There is no specific factors to be reviewed and no specific assessment methods for reviewing the BIM quality [3]. Therefore, BIM data quality pre-checking system is required for constructing BIM data systematically and securing data quality efficiently.

The purpose of this study is to establish an automated BIM quality pre-checking system to improve BIM design quality effectively and efficiently. Domestic and foreign BIM guides have been analyzed to construct a process and to derive items for BIM quality pre-check. The derived checking items have been systematized and structured to enable for the development of an automated checking system. We would propose the direction of continuous quality management of BIM data by analyzing the possibilities of implementation of an automation of BIM data quality pre-check.

B. Methodology

BIM data quality check is conducted over various fields such as code checking and energy analysis. This paper focuses on code checking which is a costly bottleneck in the building delivery process [4]. The methods and procedures in the following were performed to develop the BIM data pre-checking system.

1) Review the definition of BIM quality and BIM quality pre-check and then suggest the standard for

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BIM Data Quality Pre-check(BDQPC)

2) Analyse domestic and foreign BIM guides and evacuation and fire protection laws to construct a process and items for BDQPC
3) Systematize items of BDQPC in accordance with criteria of BIM data quality management system
4) Structuring the items of BDQPC according to IFC format and define checking algorithms
5) Verify the appropriateness of BDQPC system and the possibilities of implementation of an automated quality checking, using Solibri Model Checker (SMC)[1]

II. Literature Review

A. Preceding Research Analysis

The review of previous studies was conducted, focusing on BIM data quality management and related subjects.

O. Kwon & et al. (2009) suggested the IFC-based BIM data quality management system for quantity take-off and verified by using SMC. J. Song & K. Ju (2013) have developed the Rules of SMC to automatically check the quality of BIM model against clauses in the BIM guide of Korea. They also defined the quality standard specification to support quality check system. C. Zhang & et al. (2014) have developed a model view checker for model instance validation of IFC models based on mvdXML and BIM Collaboration Format (BCF). According to the results of the review, the studies on BIM data quality pre-check are very limited and are in the early stage of research. Depending on increasing of BIM adoption, the construction of BIM data quality pre-checking system is expected to become more important. In addition, it could be assessed as a well-timed and important research subject.

B. BIM Quality

Project Management Institute (PMI) of the US defined quality and quality control as shown below [5].

1) Quality: The degree to which the project fulfills requirements.
2) Quality Management: It includes creating and following policies and procedure in order to ensure that a project meets the defined needs intended.

BIM-based design work can be interpreted as an activity to meet the requirements established in advance by a client. In this study, BIM Quality is defined as the degree of meeting the requirements of client on BIM project. In addition, BIM Quality Management is defined as a whole system, which includes the policies and the processes on quality standard, assurance and monitoring to create satisfiable BIM data.

C. Quality Pre-checking

BIM quality pre-check is defined by Basic BIM Guidelines for Facilities Project (Public Procurement Service), BIM Guideline for Design (Ministry of Land, Transport and Maritime Affairs). BIM quality pre-check is conducted by designer before delivery. It checks the items, which is essential for securing BIM data quality itself and the quality of results of its application. BIM quality check is conducted by client after delivery and it is based on the quality pre-checking report (a checking on the additional items is performed as needed). The development of objective and clear items of BDQPC is essential especially in Korea, where the BIM quality is assessed largely based on BDQPC items.

D. The Three Criteria for BIM Data Quality Management

The quantitative and objective management system is needed to continuously manage the BIM data quality. To develop the standard for BIM data quality management, BIM data quality management criteria are defined according to the 3 Management Criteria of Data Quality [7] by Korea Database Agency.

1) Quality Standard (QS): It is a criterion to assess the degree of BIM data quality. In other word, it is a type of measurement standard which is managed to secure the accuracy of data. The 5 types of quality standards is shown in Table 1.
2) Critical Quality Criteria (CQC): It is an important criterion as a substantive management object in BIM data. It directly affects to data quality.
3) Business Rule (BR): It is the consistent and formalized rules that is applied to management or assessment activities. It is a detailed content that each CQC should comply.

TABLE I
5 Types of Quality Standards for BIM quality

Quality Standard		Definition
Name	Sign	
Uniqueness	U	Data item must be unique and must not be overlap.
Integrity	I	The critical data item must exist in data model (no omission).
Correlation	C	The predefined relationship between data items should be formed.
Validity	V	Data item must be represented in prescribed form.
Accuracy	A	Data item must have the accurate information which is required.

[1] SMC is a Ruleset-based BIM quality check program developed by Solibri. It has been utilized in the a lot of project at the state level related in BIM quality, such as US Court Design Guide of GSA, Sanate Properties of Finland, the Ramboll Headquater of Danish[6].

III. BIM Quality Pre-checking System

A. BIM Quality Pre-checking Process

BIM quality pre-checking process is developed based on BIM guides including Basic BIM Guidelines for Facilities Project and BIM Guideline for Design of Korea and COBIM Series 06 of Finland. It reflects the domestic circumstances of design delivery which is shown in Figure I. In this process, designer could continuously conduct BIM quality check and revise occurred error. By maintaining target throughout design project, maximizing the effects of BIM utilization could be induced. After delivery, this process could provide objective and rapid quality check to client by automatic review of quantitative items on quality pre-checking report.

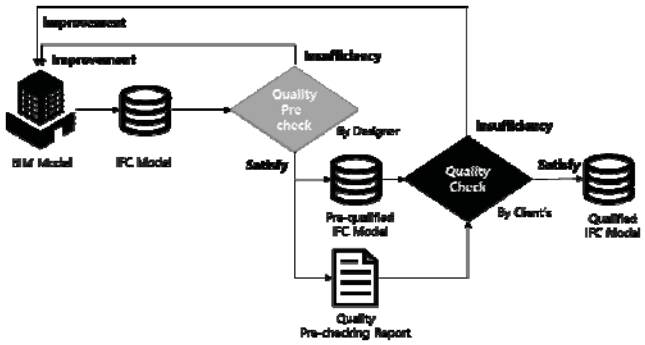

FIGURE I
BIM QUALITY PRE-CHECKING PROCESS

B. BIM Data Quality Pre-checking Items (BDQPC Items)

The required quality of BIM data of each project are different, depending on the purpose and the field of BIM adoption. The needs of client is also an important factor on this. In this study, the common and critical items of BDQPC that could be universally applied in various projects have been derived. The BDQPC items are categorized into two parts; 1) General item: minimum standard that must be met to all BIM model; 2) Item in field: minimum standard that must be met to support effective utilization of BIM in specific field. In this study, the BDQPC items for code checking are developed and the items for other fields such as energy analysis, are planned to be developed later on.

Basic BIM Guidelines for Facilities Project (Korea), BIM Guideline for Design (Korea), BIM Guide Series 02 (US), STATSBYGG BIM Manual (Norway) and COBIM Series 06 (Finland) were analyzed. A total of 35 items were extracted as the General BDQPC items.
Evacuation and fire protection laws, which are the most frequently reviewed regulations among the law check list of 4 project (2 commercial buildings, 2 apartment houses) in design firms, had been analyzed. The analyzed articles of building act enforcement decree are as follows:

- Article 34(Direct stairs)
- Article 46(Fire protection district)
- Article 56(Fireproof structure)
- Article 90(Emergency elevator)

13 BDQPC items for code checking were extracted.

TABLE II
BIM DATA QUALITY PRE-CHECKING SYSTEM (EXAMPLE OF WHOLE SYSTEM)

	Critical Quality Criteria	QS	Business Rule				
			Code	Contents	Structuring according to IFC format		
					Entity	Required Attribute	Value
GENERAL	General	U	U_GE_01	All of BIM objects must have a GUID.	IfcElement	GlobalId	IfcGloballyUniqueId
		C	C_GE_01	Building elements must be connected to the space where they belong to.	IfcRelSpace Boundary	RelatingSpace Related BuildingElement	IfcSpace IfcBuilding Element
	Wall	I	I_WL_01	External wall must have an attribute value of outside exposure.	IfcWall	Pset_WallCommon - IsExternal	IfcBoolean
	Window	I	I_WD_01	Window must have an attribute value of fitting information.	IfcWindow Style	ConstructionType	IfcWindowStyleConstruct ionEnum
	Space	V	V_SP_01	Each space, of which area is more than 0.5 square meters in building, is necessarily represented as a single space object.	IfcQuantity Area	AreaValue	IfcAreaMeasure >0.5m2
		I	I_SP_01	Type of space must be defined.	IfcSpace	ObjectType	IfcLabel
CODE CHECKING	Fire compart - ment	A	A_FC_01	Main structure and wall, which are surrounding fire compartments, must have an attribute value of fire proof.	IfcBuilding Element	Pset Common - FireRating	IfcBoolean =True
		A	A_FC_02	Space included in fire compartment must have an attribute value about this.	IfcSpace	Pset SpaceFireSafety Requirements-FireExist	IfcBoolean =True
		A	A_FC_03	Fire door must have an attribute value of fire compartment.	IfcDoor	Pset_DoorCommon - FireRating	IfcBoolean =True
	Direct Stair	A	A_DS_01	Direct stair must have an attribute value about fire compartment.	IfcStair	Pset SpaceFireSafety Requirements -FireExist	IfcBoolean =True
		A	A_DS_02	The main structural part must be composed of non-combustible material.	IfcBuilding Element	Pset Common-Combustible	IfcBoolean =True
	Emergency Elevator	A	A_EE_01	Emergency elevator must have an attribute value about fire compartment.	IfcTranspor tation	Pset SpaceFireSafety Requirements -FireExist	IfcBoolean =True
	Ramp	I	I_RP_01	A slope value of ramp must be defined.	IfcRamp	Pset RampCommon - RequiredSlope	IfcPlaneAngleMeasure

The 36 BDQPC items (23 General items, 13 Code checking items), which could be expressed with object, attribute and relation of BIM model, have been extracted from 48 items. These items are subjects of this study and are utilized as items for automated BIM quality check later.

C. Systematization of the BDQPC Items

A total of 36 BDQPC items derived in the previous section were classified according to the BIM data quality management criteria. First, the BDQPC items were categorized by Critical Quality Criteria and given the Quality Standard type depending on the characteristic of its check rule as shown in Figure II.

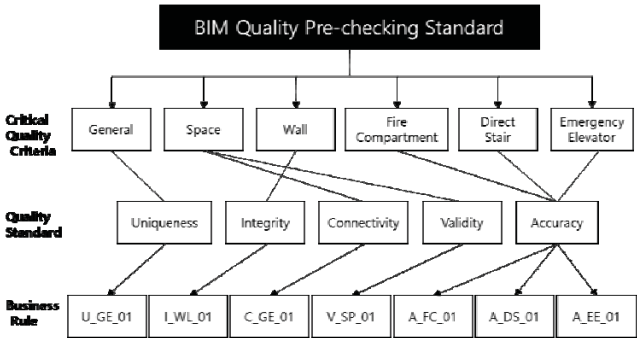

FIGURE II
SYSTEMATIZATION OF THE BDQPC ITEMS

To systematically manage the BDQPC items, the Business Rule of Critical Quality Criteria has given a five-digit code shown in Table II. Code assigning was conducted, considering an additional expansion later on.

(Sign of QS)_(Abbreviation of CQC)_Order (1)

This Code is comprised of the sign of Quality Standard type, abbreviation of Critical Quality Criteria and its order as shown above. Through this code, users could easily understand the characteristics and the kinds of information related to Business Rule.

D. Structuring of the BDQPC Items

In order to enable an automatic quality pre-check, the BDQPC items which consist of natural languages, should be translated into computer readable language. Structuring of BDQPC items into IFC structure was conducted for this reason. 36 Business Rules were quantitatively represented as object, attribute and relation of IFC format (the standard data format of design delivery). It is also shown in Table II. In addition, the algorithms for performing the quality pre-check were defined as flow chart and Pseudo Code. Figure Ⅲ is the flow chart of "Each space, of which area is more than 0.5 square meters in building, is necessarily represented in a single space object (V_SP_01)" item. To review this item, required information of IFC entities and evaluation method by each step is defined. The structured BDQPC items would be used as a rule of BIM quality pre-checking program.

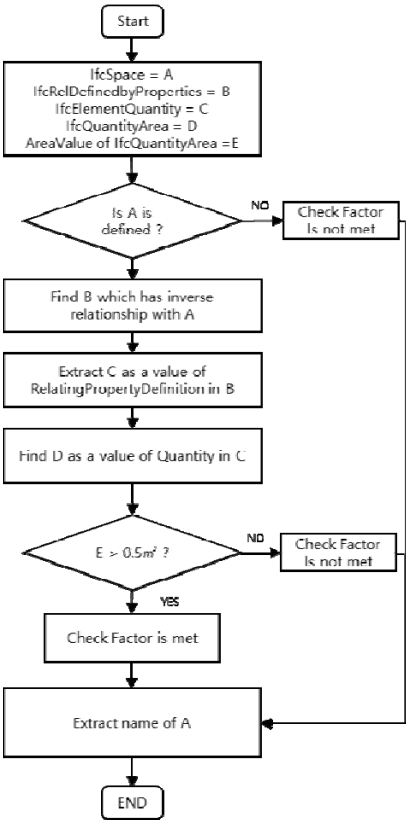

FIGURE Ⅲ
THE FLOW CHART OF ITEM OF BDQPC (V_SP_01) (EXAMPLE)

IV. VERIFICATION OF BIM PRE-CHECKING SYSTEM

A. Case Application for Verification

To verify an adequacy of the developed BIM Quality pre-checking system and the possibilities of implementation of an automatic quality check, SMC was utilized. The rules of SMC, a similar concept to Business Rule of BDQPC items, are made by ruleset manager in SMC. The Code was entered as the name of each rule like shown in Figure Ⅳ.

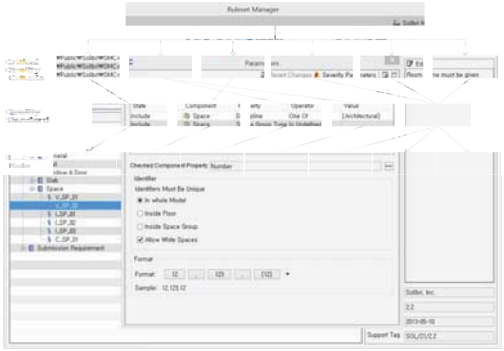

FIGURE Ⅳ
THE SCREEN OF SMC RULE PARAMETER ON A BDQPC ITEM(V_SP_02)

The verification of the developed BIM quality pre-checking system was conducted using the BIM model of the fifteen-storey design firm's headquarter building

located in Seoul, Korea. Verification was carried out in two aspects; 1) Conformity of algorithms of BDQPC items; 2) Contribution to increase BIM data quality.

1) Conformity of algorithms of BDQPC item

: The six error have created intentionally in BIM model to confirm whether these could be founded or not by the developed algorithms. The results of BIM quality pre-checking showed that all six error were recognized. It was also confirmed that the results of passing rules was obtained correctly.

2) Contribution to increase BIM data quality

: The code checking on fire compartment standard of the detailed article of facilities evacuation is performed, targeting an original BIM model and revised BIM model according to the result of quality pre-checking. In the revised BIM model, there was one error by comparison with original BIM models, where eight error was occurred(shown in Figure Ⅴ).

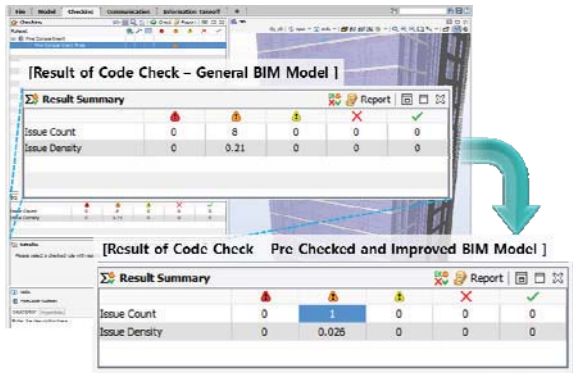

FIGURE V
THE RESULTS OF CODE CHECK ON FIRE COMPARTMENT STANDARDS
(UP: RESULT OF ORIGINAL MODEL, DOWN: RESULT OF REVISED MODEL)

B. The Result Analysis

Through verification, the developed BIM data quality pre-checking system and checking algorithm can correctly review design error and provide high confidence level of results to users. In addition, detecting error in advance by performing pre-quality review, it was confirmed that design quality could be considerably improved by modifying them. We made conclusion that this system is suitable for systematic management on BIM data quality by providing environment of advanced prevention of data error and omission.

V. CONCLUSION

This study suggested the BIM data quality pre-checking system by verifying possibilities of improving the quality and reliability of BIM data. As a fundamental research for developing automatic BIM quality pre-checking program, quality pre-checking process, item and checking algorithm have been developed based on the definition of BIM quality, BIM quality pre-check and BIM data quality management criteria. The Code system has been adopted to efficiently manage the BDQPC items which are planned to be extendedly develop for various BIM adoption fields.

The results of this study have a significance for providing quantitative and objective BIM-based environment to secure the design quality. In addition, the developed system which enables to continuous pre-check quality in the design phase, could minimize the cost and time occurred additionally from revising and reproducing data by constructing consistency and accuracy of it. This study is been expected to contribute to improving the efficiency of BIM-based design work and to meet required quality from client.

ACKNOWLEDGEMENTS

This research was supported by a grant (15AUDP-C067809-03) from Architecture & Urban Development Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.
This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. 2013R1A1A2065654).

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