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BIM Information Standard Framework for Model Integration and Utilization Based on openBIM

Chanwon Jo [1] and Jungsik Choi [2,*]

[1] buildingSMART Korea, Seoul 06600, Korea; cwjo@buildingsmart.or.kr
[2] Major in Architecture IT Convergence Engineering, School of Smart Convergence Engineering, Hanyang University, Ansan-si 15588, Korea
* Correspondence: jungsikchoi@hanyang.ac.kr; Tel.: +82-31-400-5962

Abstract: The use of Building Information Modeling (BIM) is becoming more common in the construction process, and the demand for the integrated use of BIM data is expected to continue increasing. BIM is a technology that can maximize various efficiencies by sharing facility information in an integrated manner; however, the information generated in the life cycle of the construction industry is broad, diverse, and complex. Accordingly, because BIM information is difficult to share and is often duplicated, it is not easy to obtain the effects of various BIMs. The solution to this is to create a systematic standard so that one item of information can be used in various ways, and everyone shares and uses it together. To this end, various standards (guides, classification systems, information standards, etc.) are being created; however, the interrelationships between standard elements are complex, so there is confusion and overlap between standards. This paper proposes an information standard framework for BIM to identify a systematic standard and method to effectively develop various guidelines for the standard.

Keywords: building information modeling (BIM); information standard; framework; guide; classification system; information standard; integrated model

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1. Introduction

1.1. Background and Necessity

Design technology changed in the 1980s from the paper drawing era to the CAD application era, and, through this, a change was made to a digitalized design environment. In the 2000s, the international spread of BIM technology began in earnest, and it began to be used in Korea around the 2010s. In Korea, the introduction of BIM was promoted by public initiatives, such as the Public Procurement Service, and the Korean government is actively promoting policies to accelerate its introduction. BIM is a technology that intends to use integrated information in a variety of ways depending on the purpose. However, it is not easy to use a single, integrated information model for various purposes because the demand for information is diverse and complex for each purpose. For use of the original purpose of BIM in an integrated manner, a standard shared by all is necessary. This is an indispensable condition for the establishment of BIM in the construction industry and for information sharing and reuse in the future fourth industrial revolution. To this end, ISO, the United States, and the United Kingdom have developed and used various standards for a long time; however, the use of standards in Korea is relatively weak. Accordingly, in Korea, various efforts are being made to use standards, and it is very important to develop effective methods and use the complex standard elements where standard use is weak.

1.2. Research Method

In this paper, the necessity of the information framework in BIM is reviewed, and the direction of the information framework is derived based on the status of information standards in Korea. The paper then compares the standard with international standards

or foreign cases to check the validity, suggest application plans, and draw conclusions according to the test application. The research method of this paper is shown in Table 1.

Table 1. Research method of this paper.

Analysis of problems in BIM information sharing
▼
Verification of the BIM information standard framework direction
▼
Derivation of the BIM information standard framework
▼
Utilization of the BIM information standard framework
▼
BIM information standards framework examination
▼
Conclusions

1.3. Related Research Status

Bilal Succar explored the BIM framework and suggested three interlocking BIM fields of activity: Technology, Process, and Policy [1]. Tomo Cerovsek introduced a framework for the validation and verification of the technological development of BIM tools and standards that would be relevant for standardization organizations, researchers, software vendors, and AEC/O software end users [2]. Atul Porwal and Kasun N. Hewage proposed a structured public project procurement, and a collaborative BIM-Partnering project procurement framework is proposed for public sector BIM users [3]. Lieyun Ding et al. presented a framework of BIM applications generated from past project implementations of BIM that would enhance communications, share understanding and knowledge growth among all the academic researchers and industry practitioners, and integrate relevant concepts into a descriptive or predictive model [4]. Youngsoo Jung and Mihee Joo proposed a BIM framework focusing on the issues of practicability for real-world projects, and a comprehensive BIM framework consisting of three dimensions and six categories was developed to address the variables for theory and implementation [5]. Dat Tien Doan et al. proposed a BIM framework for practical assessment and suggested eight main categories of the BIM assessment framework along with 39 elements [6]. Cho defined the standard framework as a framework of holistic and interrelated standards for sharing and exchanging information in a BIM implementation environment as a common assumption for the introduction of BIM at the construction industry level [7].

2. Analysis of BIM Information Sharing Problems

2.1. Basic Concepts of BIM

BIM involves accumulating data generated during the life cycle of a building in a 3D model, and the data can cover a variety of aspects of the building, such as design, construction, structure, facilities, and maintenance [8]. Building-related information acquired through BIM is computerized, managed, and utilized, and, therefore, many advantages of computers, such as high accuracy and secure storage of information, can be utilized. However, because the construction industry is vast and complex, there are various construction subjects, and various software is used to process computerized information by field. In the process of exchanging information between software, information is omitted and errors occur. To overcome these problems, buildingSMART proposed the openBIM concept. This concept is not limited to BIM platforms based on an open format and facilitates information interoperability and compatibility between platforms [9]. The utilization of standards is a

very important part in openBIM, and the BIM concept applied in this paper is treated the same as the openBIM concept.

BIM was originally a concept that used an integrated model for various purposes, which means that there must be an information standard, i.e., a common promise on how to express information. If there is no information standard, only partial implementation can be achieved. In fact, today many BIM application cases remain in partial implementation. For example, individual BIM application cases for legal interpretation or construction cost calculations have been announced; however, it is difficult to find a case that implements both simultaneously. Atul Porwal and Kasun N. Hewage present the concept of overall utilization by BIM data as an example of the concept. In the paper, it is explained that the Full Design Model is the result of the integrated model for each field. For the model for each field to be integrated, it is necessary for the individual models to have consistency [3]. In other words, it suggests that a common promise, that is, a standard, is needed so that information representing the model, such as the shape and properties of individual models, can be integrated.

The Uses of BIM, published by Penn State University, is well known. In Korea, BIM uses are classified according to the contents of KBIMS (Korea BIM standard) announced by buildingSMART Korea [10], www.kbims.or.kr (accessed on 17 June 2021), 2019, which is presented as follows (Table 2).

Table 2. BIM uses of KBIMS.

Purposes	Uses
Planning	Status analysis, design plan, construction plan, maintenance plan
Analysis	Design review, interference check, quality verification, quantity calculation, cost calculation, process plan, constructability review, engineering analysis, environmental simulation
Realization	Business operation management, procurement, production, transport, processing, assembly, measurement, control
Operation	Maintenance, operation management
Communication	Drawing calculation, document calculation, visualization, collaboration, submission, licensing
Convergence	Measurement technology, observation technology, control technology, experience technology, analysis technology, production technology, operation technology, other technology

2.2. Problems from the User's Point of View

BIM is a technology concept of integrated information for various purposes. However, it is not easy to create an integrated model because the information required for each BIM use is diverse, and the subject of creating the information is different. For example, the information required for each purpose, such as construction cost calculation, energy analysis, and legal review, is not the same. Therefore, to use it for multiple purposes at the same time, it is necessary to create a single model by integrating various pieces of information. It is not easy to create a model by considering numerous factors. However, creating a separate model for each application is not consistent with the original concept of BIM.

For this reason, it is relatively easy to use BIM for one purpose; however, it is very difficult to simultaneously use it well for multiple purposes. Therefore, a method is required for creating a unified information model for information and sharing among several people to write each piece of information separately.

2.3. Problems of Standard Use in Korea

Korea is very weak in shared construction industry standards, leading to obstacles in the introduction of BIM, which requires standards. Therefore, Korea, which began to

introduce BIM around 2010, began to create and use individual standards or guides for each client. The problems caused by this are:

- Similar and redundant efforts are required for guidelines developed for each client.
- From the user's point of view, there is a burden to understand the separate standards.
- For this reason, similar trials and errors are being repeated for each organization.
- It is difficult to share and recycle information from a lifecycle perspective because the information in the model is different for each client.

2.4. Improvements

The way to address the above problems is to systematically secure standards and use them as a common promise. Multiple standards are required to use one integrated model. First, it is a creation standard to express the model shape at a necessary level. Second, an information standard is to define the properties included in model information. Third, a classification system is needed to ensure consistency of attribute values. Creation standards and information standards can prevent the model from being too large or too small to be utilized. The classification system helps the machine to identify attribute values consistently. For example, the same material can be better understood by a machine using a single code.

Standards can be developed and distributed by international organizations, countries, organizations, and companies; however, because various information is used for each field, it is not possible to develop and disseminate all standard elements in one place. However, it is still necessary to use standards. Specifically, it is efficient to divide the standard into common standard elements and individual standard elements, divide and develop roles, and use them as a set of completed standards by selectively combining them. In this paper, we present the BIM standard framework as a comprehensive and interrelated set of standards for sharing and exchanging information in the BIM implementation environment. Individual standard systems can be created by combining elements of various standards based on the information standard framework. The concept applied in this paper is shown in Figure 1.

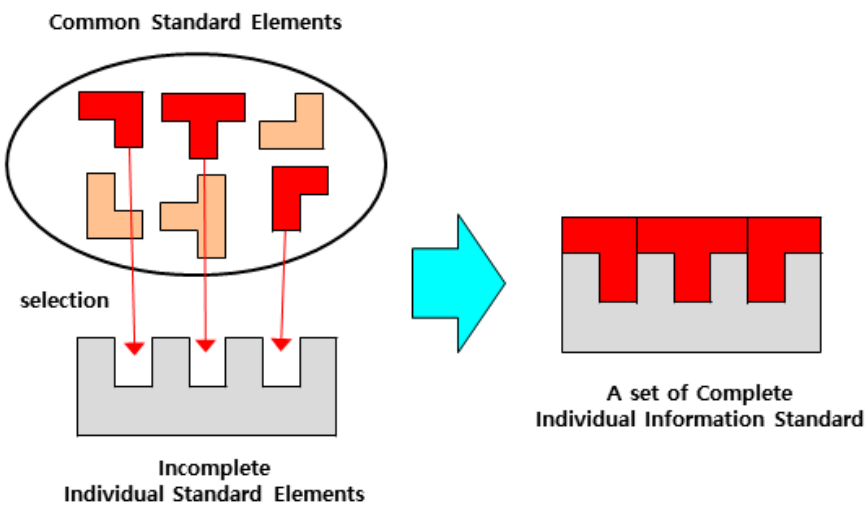

Figure 1. Compositional relationship between individual standards and common standards.

3. The Direction of the BIM Information Standard Framework

3.1. Information Standards Status of the Korean Government

In the construction field in Korea, information standards use the concept of architecture or standard structure instead of a framework. First, in 1998, the Ministry of Construction and Transportation of Korea announced, "Construction CALS (Continuous Acquisition and Life-cycle Support) Basic Plan (Proposed) [11]". Construction CALS was promoted by the government for public projects as a national construction informatization strategy to

share and exchange information generated over the whole process of construction projects (Table 3). In this plan, the term architecture is used as a concept, like framework, and three elements were presented.

Table 3. Construction CALS basic structure (Architecture of CALS).

Architecture	Content	Keywords
Process Re-engineering	Redesign of execution procedure	Process modeling, EDI, electronic manual
Information Infrastructure	Information and communication network and application system construction	Information infrastructure, CALS standard
Policy Improvement	Policy, system, organizational reorganization	Institution, organization, education

Later, with the introduction of BIM in Korea, the Ministry of Land, Transport and Maritime Affairs, the successor of the Ministry of Construction and Transportation, announced the "Guide to Apply BIM in Architecture" in 2010 with the roadmap [12] and three standard structures (Table 4). This is an example of applying the three basic structures of construction CALS to BIM that also contains the concept of a framework.

Table 4. Standard structure of a BIM roadmap.

Standard Structure	Content	Keywords
Process	Standards required for business performance	Business procedure, business information, and output
Information Technology	Standards required to implement information technology	Information standard, digital format, object classification
Management	Standards required for business management	Ordering guidelines, quality standards

The common keywords of the above two data sets are business procedures, information technology, and common management. The Ministry of Land, Transport and Maritime Affairs then announced the "Guide to Applying BIM in the Construction Field" in the "Basic Guide for BIM Application for Facility Business" by the Public Procurement Service, Guidebook v1.0 [13], 2010.12 Etc. This guide influences the BIM guidelines of many Korean orderers.

3.2. Review of the Information Standard Framework Direction in Korea

By combining the contents of the construction CALS basic structure and the standard structure, the standard required for the introduction of BIM was basically established with process, information, and common standard elements (Table 5).

Table 5. Suggested standard framework for BIM.

BIM Information Standard Framework	Content
Common Layer	The set of principles and standards required to introduce BIM and manage your business.
Process Layer	The set of standards you need to build a model, control quality, and use it for your purpose.
Information Layer	A set of standards and classification systems required to express information and standards for outcomes

The relationship between the existing construction CALS architecture and standard structure according to the BIM roadmap is as follows (Figure 2).

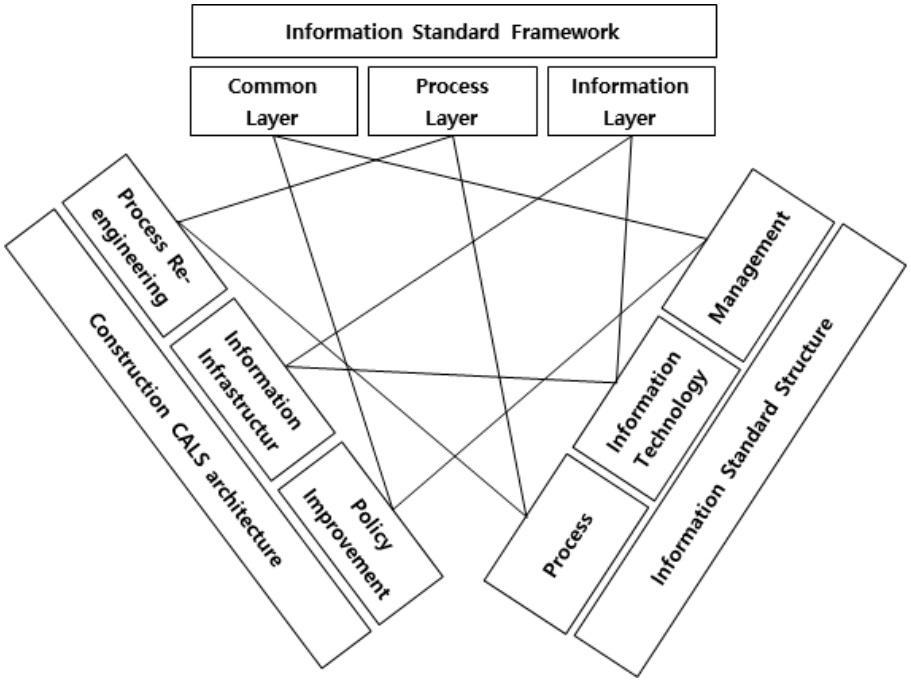

Figure 2. Composition of the information standard framework layer.

The three layers above are the layers presented in the process of introducing construction CALS by the Korean government before the introduction of BIM, and in this paper, they are applied to fit BIM. The reason is that developing the already presented layers can have the consistency of informatization development in the construction industry.

The framework is divided into three standard layers. However, there is one issue: Various standard documents are not clearly classified into one of the three, and there are many cases where three standard layers are mixed, except for standard documents with clear characteristics. This paper acknowledges this and assumes that many standard documents can be decomposed into three standard layers.

The information standard framework layer can be applied to BIM as it is a classification for the basic standards required for informatization regardless of the type of technology. Accordingly, in this paper, the standard will be reviewed from the perspective of three layers.

3.3. Current Status of Overseas' Standards from the Perspective of the Framework Layer

(1) Common layer

In the case of overseas' standards, it is difficult to find a case where the standards for education curriculum or environment are used as standards at the industry level. ISO 19650 requires EIR, AIR, OIR, BEP, etc., which are necessary for ordering, contracting, or project progress management, and the same case occurs for the British CIC's BIM protocol.

(2) Process layer

Various guides have been published in each country, and, among them, the contents pertaining to the performance of the business are applicable. The US GSA's BIM Guide series [14] is "There are Common BIM Requirements 2012 by Finland Senate Properties [15]", etc., and there are various guides for each client.

(3) Information layer

IFC according to ISO 16739 refers to the data format. In addition, international standards, such as BCF and cityGML, are typically established and continuously developed. The information attribute is COBie or there is an example of "VA FM Data Spreadsheet v1.0"

included in the "VA BIM Standard BIM Manual v2.2" of the US Department of Veterans Affairs. The classification system is Omniclass in the US and Uniclass in the UK.

3.4. Status of Existing Korean Standards

(1) Common layer

In Korea, there is similarly no standard for education curriculum or environment at the industry level. However, it is expected that national standards will be required as the core strategy, including fostering BIM professionals in accordance with the government-led BIM introduction policy [16]. The concepts of EIR, AIR, OIR, and PIR according to ISO 19650 are not sufficiently reflected in the Korean public order standards.

(2) Process layer

The first data published by the government were the 2010 BIM application guide in the field of construction by the Ministry of Land, Infrastructure and Transport. The Public Procurement Service then further published the basic guidelines for applying BIM to the facility business in 2010, and then announced v2.0 in 2020 via continuous revision. Since 2010, public orderers have provided different guides. Accordingly, the government is preparing the "Basic Guidelines for Construction Business BIM" as of November 2020 to ensure consistency of public orderer guides.

(3) Information layer

In the case of data format, public ordering organizations in Korea require IFC and a commercial original format according to ISO 16739 for the data format. In the case of information standards, some of them are included in the instructions of each orderer (e.g., the code value according to the classification system should be entered in the guidelines of the Public Procurement Service). Information standards are being studied in various R&D departments at the government level; however, a standard that has a status as a working guide to be shared by all subjects has not been published. The construction information classification system [17] announced by the Ministry of Land, Infrastructure, and Transport consists of five facets: facilities, space (type), part, type of work, and resources. The Public Procurement Service provides a separate type of work type.

4. Derivation of BIM Information Standard Framework

4.1. Composition of the BIM Information Standard Framework

As a result of dividing the BIM information standard framework into common, task, and information, and reviewing the status of overseas and Korea standards for each layer, it is necessary to develop the framework in the following directions.

(1) Common layer

In Korea, government-led BIM is being introduced, so a standard is needed for the state to provide a basic environment. Accordingly, the common layer targets a set of standards for managing or indirectly supporting business process or information technology, project management, performance capability, education, and collaboration.

(2) Process layer

Because there are many cases of developing and using BIM guidelines for each client, and organizations considering the development of new guidelines will continue to emerge, it is necessary to present the basic structure and common content necessary for the BIM guidelines. Accordingly, the business process layer targets a set of standard elements that target the process of directly performing the task of deriving and reviewing design proposals using BIM.

(3) Information layer

Data formats, information standards, and classification systems need to make the most of international standards and existing Korean standards, and it is necessary to

present insufficient content for the use of BIM. Accordingly, the information technology layer targets a set of standard elements that target elements, such as software, information, content, and books, that are directly used in the process of performing business procedures.

The components of the BIM information standard framework layer reflecting this are assumed as follows (Table 6).

Table 6. Components of the BIM information standard framework layer.

Framework Layer	Content	Keywords
Common Layer	0 Environment	Concept, terminology, introduction, education, knowledge, competency
	1 Management	Contract, request, performance plan, collaboration, CDE, responsibility, rights
Process Layer	2 Business Process	Business definition, business procedure
	3 Authoring Model	Library, data writing standard/design document writing standard
	4 Quality Control	Quality verification standards, quality activity standards
	5 Application	Classification of use, standard of use
Information Layer	6 Model	Object list, attribute specification, attribute dictionary... BIL/design book information
	7 Technical Contents	Material information, unit price information, detailed information...
	8 Classifications	KCCS, Public Procurement Service Code . . .
	9 Outputs	Data format, product composition

This proposal was reviewed for conformance with ISO 12911 [18] and NBIMS. However, because the existing standards each deal with many detailed elements, it is not exactly mapped 1:1 with the layer elements presented in this paper. The proposal roughly compares with the overall context of the standard.

4.2. Review of Conformity of BIM Information Standards Framework with ISO 12911

ISO 12911 presents a total of 165 items across up to five levels in three sections. For convenience, in this paper, the relationship of 14 items at two levels is mapped. Accordingly, the conformity of the BIM information standard framework with ISO 12911 is roughly as follows (Figure 3).

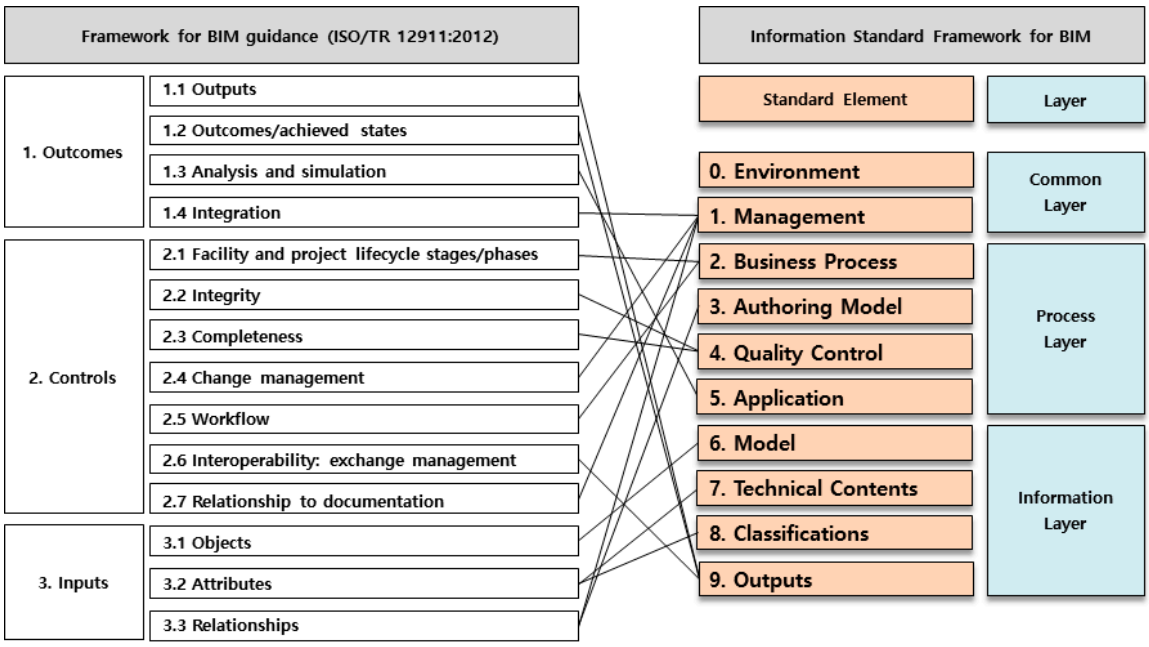

Figure 3. Conformance with ISO 12911.

In ISO 12911, the seven elements of the Outcomes and Inputs group mostly deal with the information system and, thus, correspond to the Information Layer. The seven elements of the Controls Layer group deal with the execution process and, thus, correspond to the Process Layer. Accordingly, ISO 12911 confirms that mapping is generally possible, except for the environment building element. It is understood that the Execution Environment Element does not fall within the scope of the specifications for the commissioning of BIM that ISO 12911 intends to present.

4.3. Review of Conformity of BIM Information Standard Framework with NBIMS

The US NBIMS v3.0 [19] is divided into four parts and consists of 43 physical files. Among these, it is composed of approximately 24 unit modules, excluding introduction or explanation elements. The relationship with the standard elements of the framework presented in this paper is as follows (Figure 4).

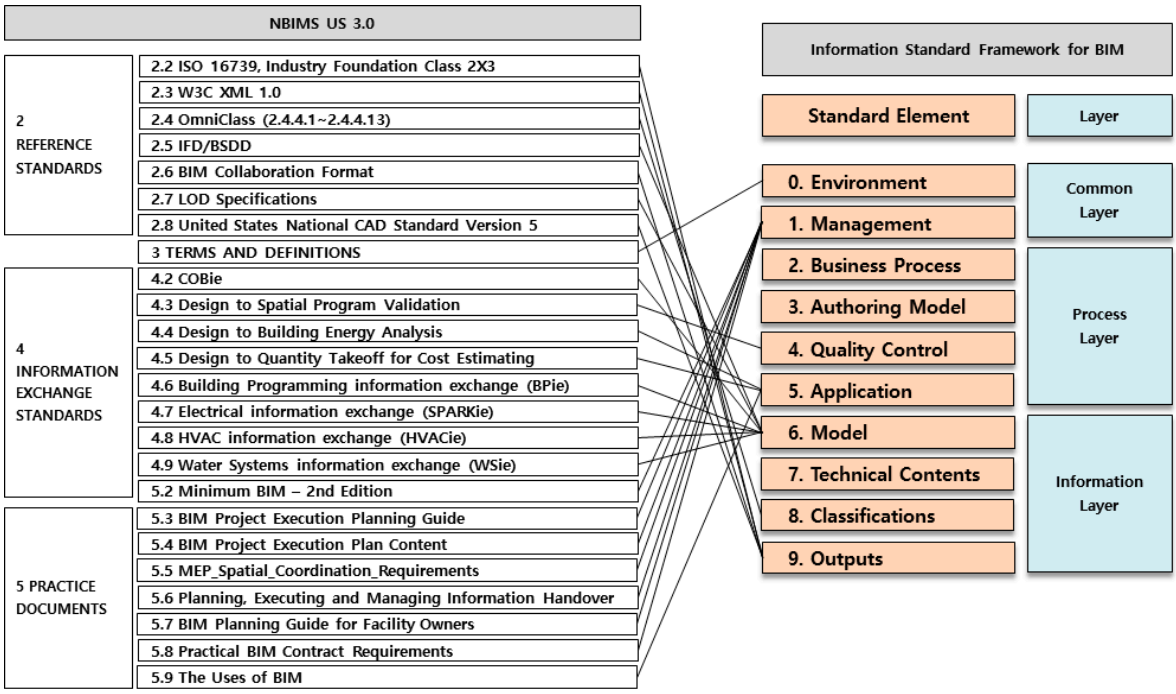

Figure 4. Conformance with NBIMS US 3.0.

In NBIMS, the seven elements of the Reference Standards group mostly deal with data specifications and, thus, correspond to the Information Layer. The nine elements of the Information Exchange standards group cover the modeling method and span the Process Layer and the Information Layer. The seven elements of the Practice Layer group belong to the Common Layer, as they deal with the management aspect. Therefore, NBIMS v3.0 confirmed that the overall mapping is possible, except for the three elements of Business process, Authoring Model, and Technical Contents. In the United States, the content of business procedures and model preparation are provided with individual guidelines for each client, and, accordingly, it does not appear to be included in the scope of NBIMS. Additionally, in the case of technical information, various contents, such as material information, are not covered by NBIMS.

4.4. Summary

Comparing the assumed BIM information standard framework layer with ISO 12911 and NBIMS US 3.0 confirmed that mapping is approximately possible and the range that could sufficiently include them is covered. Accordingly, it is necessary to develop the

framework so that the BIM information standard framework layer presented in this paper can be specified and used.

5. Application of the BIM Information Standard Framework

5.1. Common Master Standards for Utilizing Information Standards Framework

The type and content of standards required in practice are very broad. In addition, individual BIM guidelines require different standards. Therefore, it would be very effective if the common standards for each country or sector are rearranged according to the information standard framework and shared by everyone to create individual guidelines. In this paper, a set of common standard elements that can be shared is referred to as a common master standard. This can reduce the time, effort, and trial and error required for individual guideline development, and can be very helpful for collaboration and information sharing with unspecified people.

However, it is difficult for a common master standard to provide all requirements of the various individual guidelines. Therefore, it is necessary to complete the guidelines by selecting possible standards from a common master standard and individually adding insufficient standards. The schematic concept of this is as follows (Figure 5).

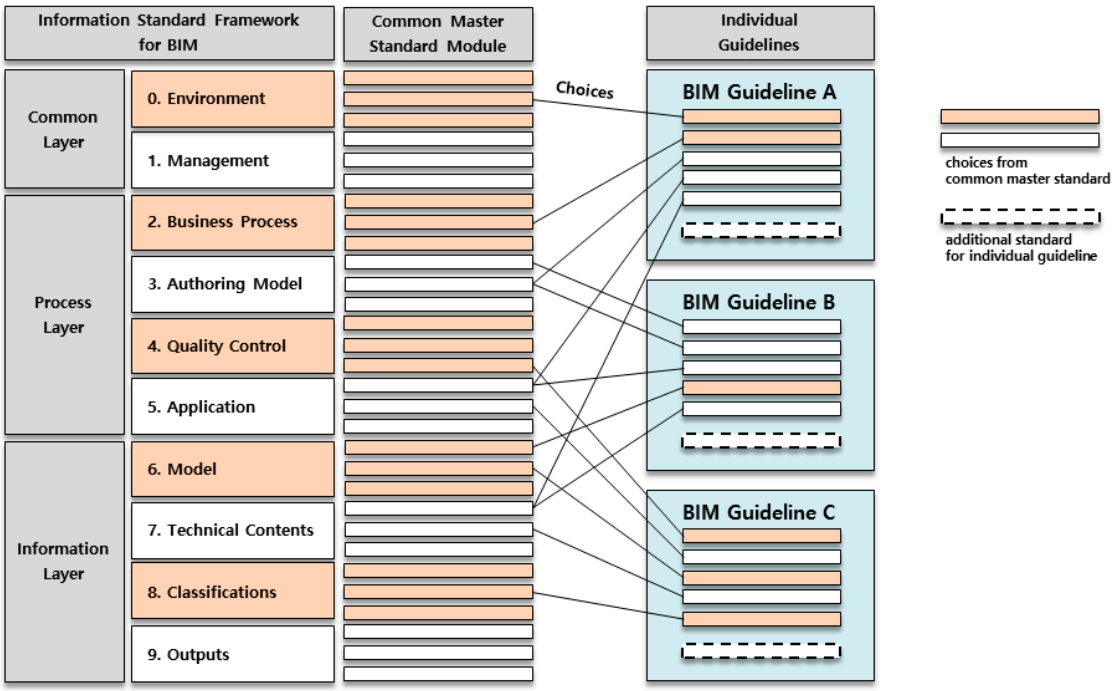

Figure 5. Relationship between Common Master Standards and Individual Guidelines.

5.2. How to Apply a Common Master Standard for Application Testing

The application is reviewed for multiple uses to confirm the feasibility of the information standard framework presented in this paper. The purpose is for estimation and legal checking (Korean Code checking). For the purpose of the test estimate, a common promise on six items, data preparation standards, quality verification standards, attribute specifications, unit price information, work type classification, and data format, is required. In the case of a test law check, schematically shown in Figure 6, a common promise is needed for four items: data creation standards, quality verification standards, attribute standards, and data format.

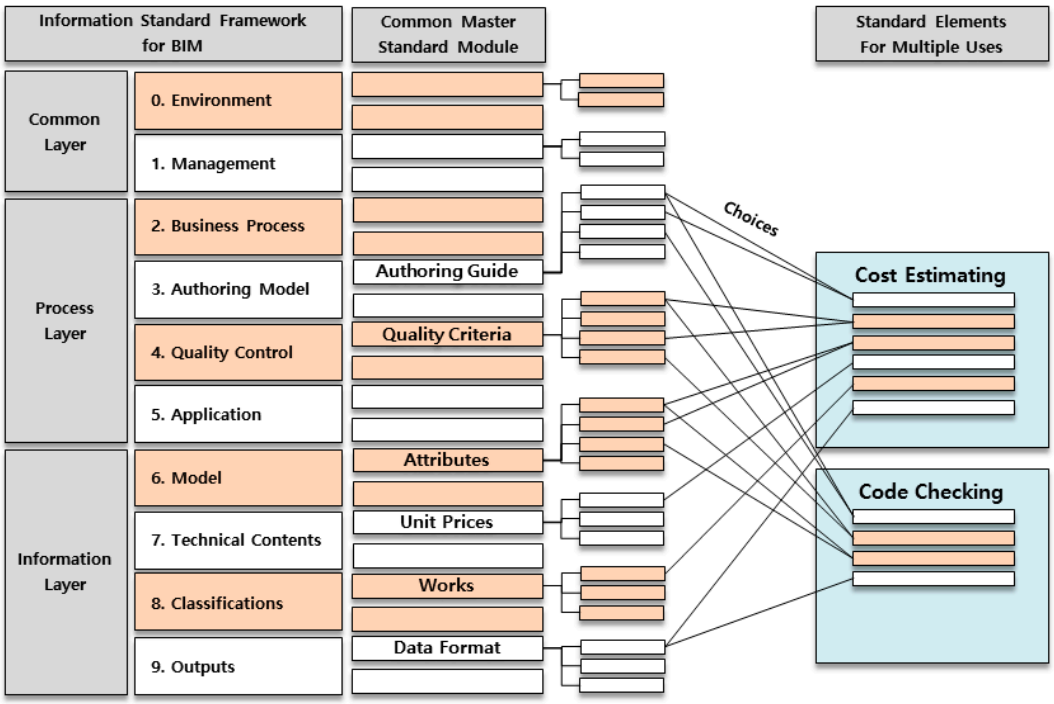

Figure 6. Concept of using the common master standard for cost estimating and code checking.

5.3. Presenting a Common Master Standard for Application Testing

A common master standard based on a standard framework that practitioners can know is required to simultaneously perform an estimation and legal check using a single model. A common master standard was developed because six standards were needed for cost estimating and four standards were required for code checking. Some of the content of the four standard modules simultaneously required for two purposes are as follows.

(1) ISF-L3 data creation criteria

Part of the Authoring Guide belonging to the Authoring Model Layer is as follows (Table 7).

Table 7. Authoring Model Layer—Part of the Authoring Guide.

Level 1	Level 2	Text Content	Cost Estimating	Code Checking
General Information	Principle of sub-object classification	All sub-objects are written separately. (Example: Do not create one object by combining columns and beams, but create them separately)	○	○
	No interference between object	In principle, object of BIM data should be prepared so that interference collisions with other objects do not occur. The allowable error range of interference is as follows.	○	○
Object name	Object Named Object	In the case of an object given an object name such as structure, window, etc., the corresponding contents are reflected in the library name and properties.	X	○
Criteria for each object	Windows	The smoke window is expressed by the name of the object.	X	○
	Lift	The elevator consists of the elevator door and the elevator car as separate libraries.	X	○
		Express emergency and evacuation in the elevator car library properties.	X	○
Level of detail and units	Level of detail	The level of detail of BIM data should be around BIL 30 of the BIM information expression level. (Example: In the case of a window, it refers to the level indicating the existence of a frame; in the case of a staircase, it refers to the level indicating the existence of a handrail; etc.	○	○

Table 7. *Cont.*

Level 1	Level 2	Text Content	Cost Estimating	Code Checking
	Unit	In principle, BIM data uses millimeter (mm) units.	○	○
	Factual conformity of dimensions	The dimensions of the BIM model are made to match the actual dimensions. The dimensions of the BIM object are not arbitrarily adjusted differently from reality. However, if an error is allowed, the tolerance is presented.	○	○
Layer composition	Principle of belonging to the floor	All spatial objects and sub-objects must belong to a specific floor.	○	○
Attribute processing criteria	Input criteria	Whether or not the main structural parts (e.g., load-bearing walls, floors, stairs, etc.) have a fire-resistance structure is expressed as an attribute.	X	○
		Ventilation windows are expressed as "window opening/closing ratio" attribute value.	X	○
		The main entrance is expressed as the attribute value of "whether or not there is a main entrance or not".	X	○
		The reference ground floor refers to the first floor connecting the inside and outside of the building, and is expressed as a property of the floor.	X	○
		Enter the property value of 'Public Procurement Service Standard Construction Code' in the part object.	○	X
		For a part object with a member name, input the object name in the library.	○	X
Spatial object creation requirements	Preparation of spare spatial object	If necessary, in the design process, if you want to secure space in advance for facility piping or maintenance, you can create a spare space object and assign its purpose to the "real name" attribute value.	X	X
	Meeting deployment requirements	If there are any requirements regarding the layout of the space, they must be met (e.g., floor allocation for a specific room, minimum height, adjacency between two rooms, etc.)	X	X
Building envelope	Modeling of building envelopes	It should be modeled so that there is no open space through which air can pass through the inside and outside of the building. If the inner wall and the outer wall are connected, the inner wall and the outer wall must be created separately.	X	X

(2) ISF-L4 quality verification standards

Some of the Quality Criteria belonging to the Quality Control Layer and quality verification standards are as follows (Table 8).

Table 8. Quality Control Layer—Part of the Quality Criteria.

Level 1	Level 2	Text Content	Cost Estimating	Code Checking
Common	Principles of creating floor units	Do all part objects contain layer information?	○	○
		Are all walls divided by floor?	○	○
	Input of properties	Is the "real number" attribute value assigned to all spatial objects?	X	X
		Are "real name" attribute values assigned to all spatial objects?	X	X
		Is the "Spatial Classification Code" property value assigned to all spatial objects?	○	○
		Is the "Public Procurement Service Standard Construction Code" attribute value assigned to the building structure object input target for the estimate?	○	X
		Is the "Object Name" property value assigned to all structure objects?	X	X
	Window condition	Are all windows entered to belong to the wall?	○	X

Table 8. *Cont.*

Level 1	Level 2	Text Content	Cost Estimating	Code Checking
		Are "window opening/closing ratio" attribute values assigned to all windows?	X	○
	Wall condition	Are all walls assigned the attribute value of "Boundary wall or not"?	X	○
	Condition of the door	Are all doors assigned a "main entrance" attribute value?	X	○
	stair condition	Are all stairways assigned a "fire-resisting structure" attribute value?	X	○
Planning quality				
	Satisfaction of area conditions	Does the area of each space meet the area standard by the space program?		
	Satisfying space requirements	Does the data of the spatial model meet the requirements? (if conditions apply)		
	Satisfying the design conditions for the disabled	Does it meet the design requirements for the disabled?	X	○
	Satisfying evacuation and disaster prevention design conditions	Does it meet the design requirements for evacuation and disaster prevention?	X	○
	Creation of vertical movement space	Are all spatial objects created based on the wall centerline?	X	○
		Is the vertical movement space a single space on all floors?	X	○
	Satisfying parking lot design conditions	Does it meet the parking lot design conditions?	X	○
	Satisfaction of elevator design conditions	Does it meet the elevator design requirements?	X	○
	Fulfillment of design conditions for smoke exhaust facilities	Does it meet the design requirements of the smoke exhaust system?	X	○

(3) ISF-L6 attribute specification

Some of the attributes belonging to the Model Layer are as follows (Table 9).

Table 9. Model Layer—Part of Attributes.

Division	Attribute Name	Type	Unit	Attribute Dictionary ID	Cost Estimating	Code Checking
Discrimination						
	Production information	text	-	01001	X	X
	KBIMS-Part Code	text	-	01008	X	X
	Public Procurement Service Standard Construction Code	text	-	01002	○	X
	Object name	text	-	02002	X	X
	Instance ID	text	-	02002	X	X
Basic						
	Layer	text	-	01018	○	○
	Width	real	mm	07003	X	X
	Length	real	mm	07003	X	X
	Area	real	m^2	07005	○	X
	Frame thickness	real	mm	07003	X	X
	Frame width	real	mm	07003	X	X
	Panel thickness	real	mm	07003	X	X
	Panel width	real	mm	07003	X	X
	Fire rating	text	-	02002	X	X
By use						

Table 9. *Cont.*

Division	Attribute Name	Type	Unit	Attribute Dictionary ID	Cost Estimating	Code Checking
Energy	Thermal conductivity	real	W/mk	07002	X	X
	Thermal transmittance	real	W/m^2 K	07002	X	X
Legal review	External exposure	BOOL	T/F	02005	X	○
	Whether main entrance	BOOL	T/F		X	○
	Spatial classification code	text	-		X	○
	Fire-resistance structure	BOOL	T/F		X	○
	Boundary Wall	BOOL	T/F		X	○
	For the disabled	BOOL	T/F		X	○
	Window opening and closing costs	BOOL	T/F		X	○
	Reserved power supply	BOOL	T/F		X	○
	Emergency Elevator	BOOL	T/F		X	○
	Elevator for evacuation	BOOL	T/F		X	○
	Base ground level	BOOL	T/F		X	○
	Evacuation floor	BOOL	T/F		X	○

(4) ISF-L9 data format

Some of the outputs belonging to the Information Layer are as follows (Table 10).

Table 10. Information Layer—Part of Outputs.

Level 1	Level 2	Text Content	Cost Estimating	Code Checking
Data format	BIM data submission format	Submission of BIM data is subject to both standard format and original format of IFC 2 × 3 or higher standard according to ISO 16739.	○	○
	Choice of BIM software	BIM data creation software supports IFC 2 × 3 or higher according to ISO1 6739 and is software capable of performing BIM tasks according to this guideline	○	○

6. BIM Information Standards Framework Test

6.1. Test Model Creation

The integrated test of the information standard framework was conducted so that the estimate and the code checking were simultaneously performed in one model using the common master standard module for a 10-story virtual office building. A model was prepared by preparing data creation criteria so that the classification system was reflected in the model information, and technical content was developed for the estimation estimate. The conceptual diagram is shown in Figure 7.

Model production was carried out in the following environment:

- Target building: 10-story virtual office building (gross floor area 14,520 m^2)
- OS: Windows 10
- H/W: CPU i7-8565U, RAM 16.0 GB, HD 2 TB
- BIM authoring tool: Revit 2019 Korean version
- File size: Revit 273 MB/IFC 142 MB

Utilization of the created IFC file was carried out in the following environment:

- OS and H/W: same as model production specification
- IFC Viewer: KBIM D-Generator v1.0
- Cost Estimating system: KBIM EST-P v1.0
- Code checking system: KBIM Assess-Lite v1.0

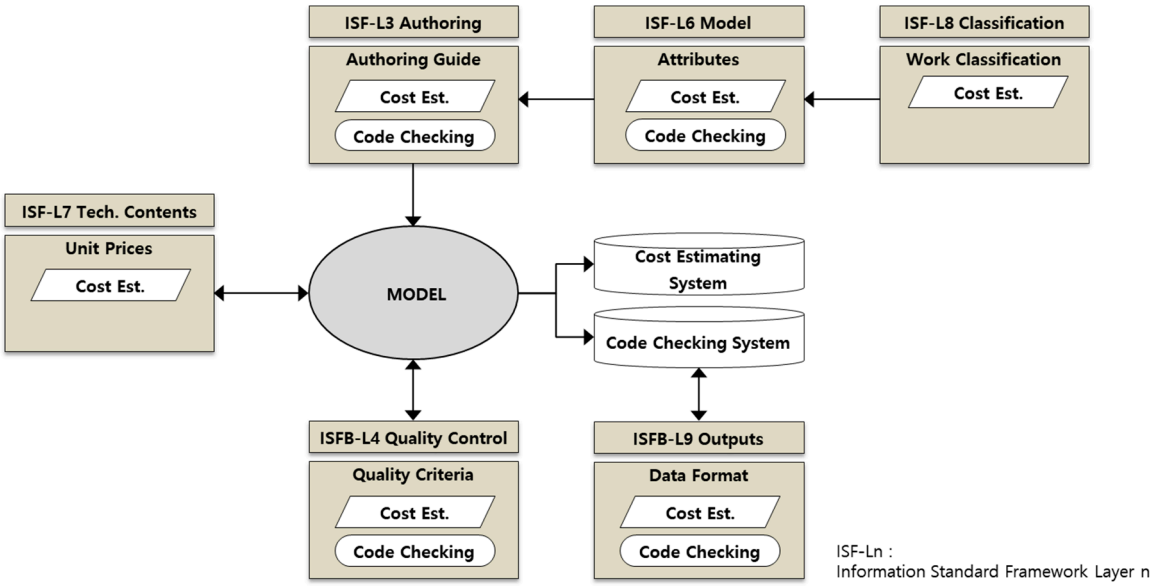

Figure 7. Test concept diagram of the common master standard module.

The shape of the model created in Revit is shown in Figure 8.

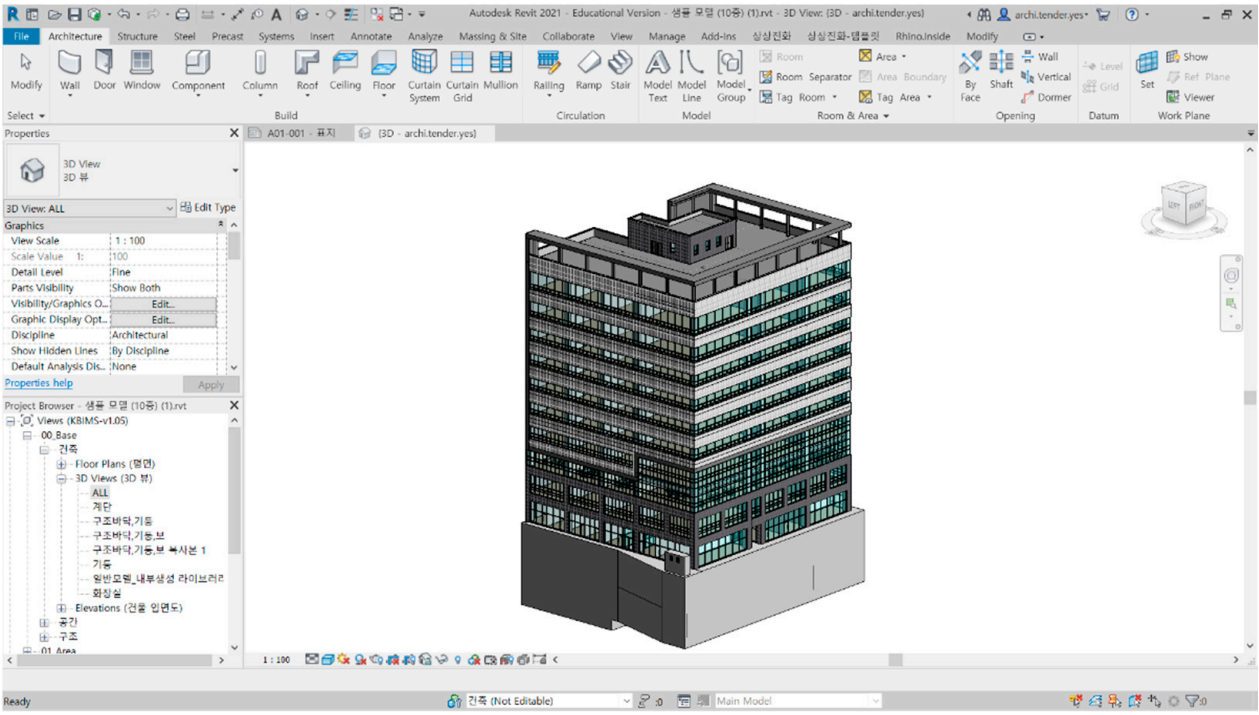

Figure 8. Test model created by Revit.

The shape of the model converted to IFC is shown in Figure 9.

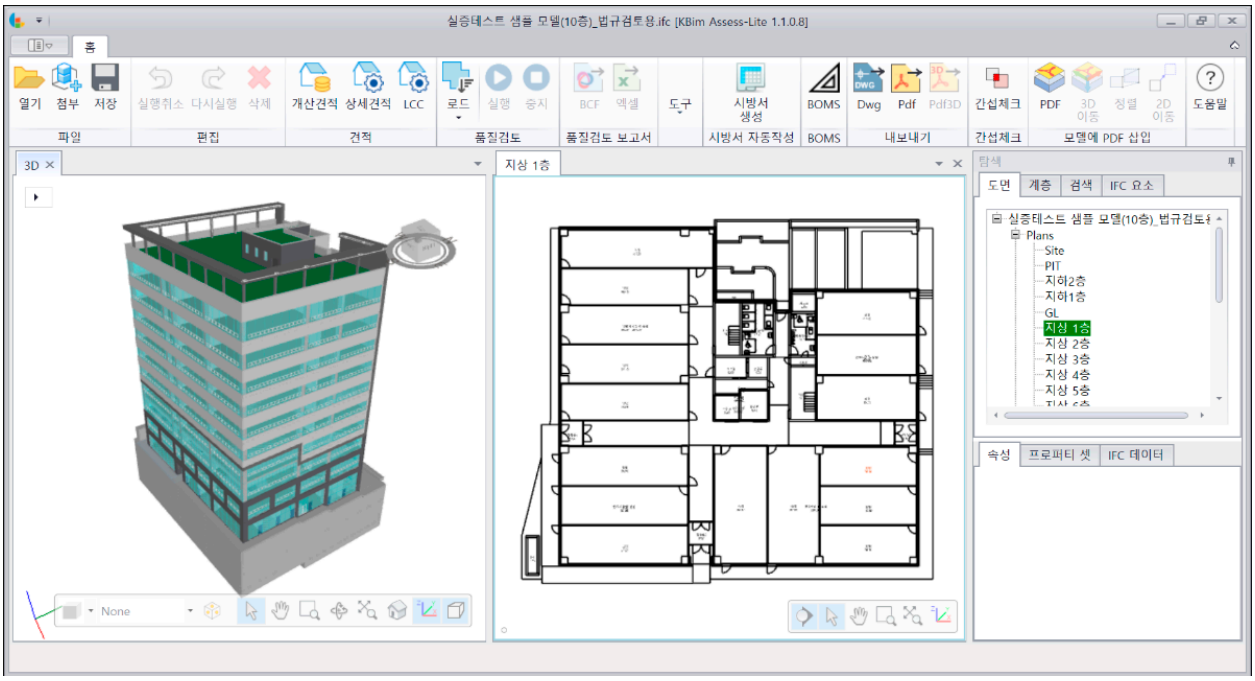

Figure 9. Result converted to IFC.

6.2. Cost Estimating Result

The BIM model is composed of a library in which the classification of the Public Procurement Service of Korea is entered as an attribute. In addition, the unit cost according to the classification system of the Public Procurement Service was established as a DB. The unit cost is the sum of material cost, labor cost, and overhead expenses. Accordingly, the quantity according to the PPS classification system was calculated from the BIM model, and the construction cost was calculated by linking it with the unit cost. The developed application program was developed targeting the IFC standard.

The approximate results of the test model were derived as follows (Figure 10).

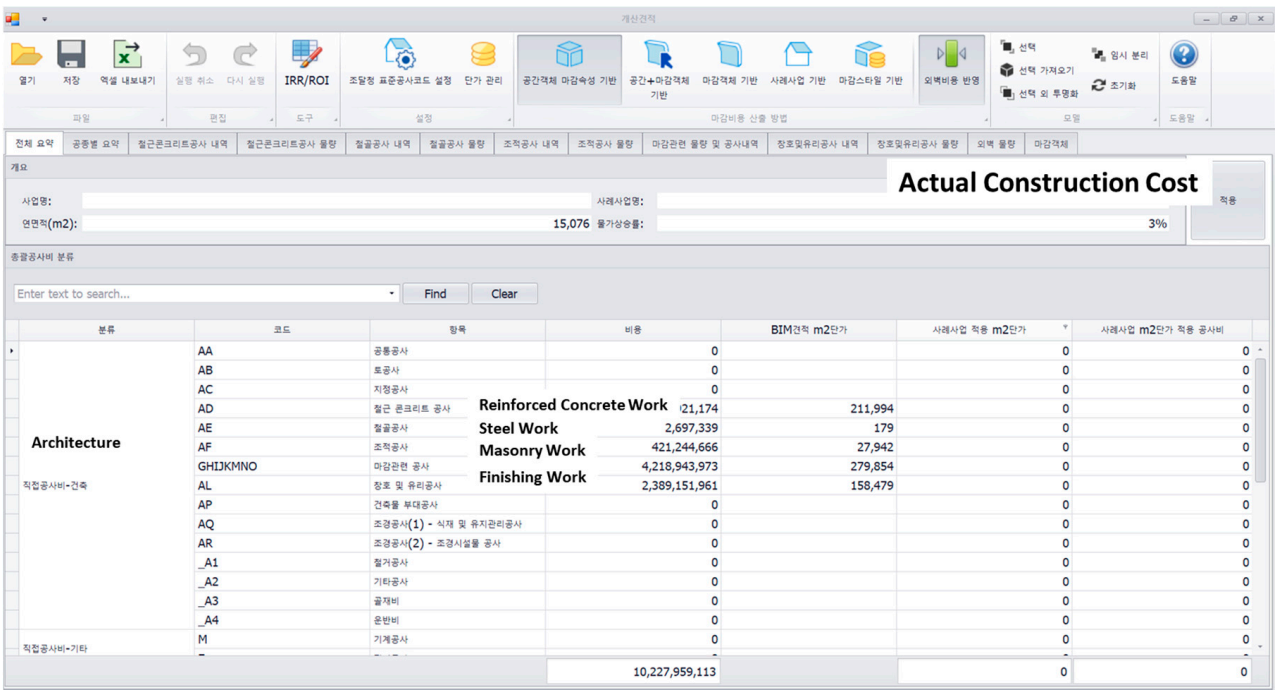

Figure 10. Approximate construction cost result screen: total construction cost.

The quantity of objects was derived from the model, and the property was aggregated by work classification. The standard unit price data were then applied to calculate the construction cost for each work type (Figure 11). In addition to the total construction cost, the detailed basis for calculating the construction cost can be checked by floor and part.

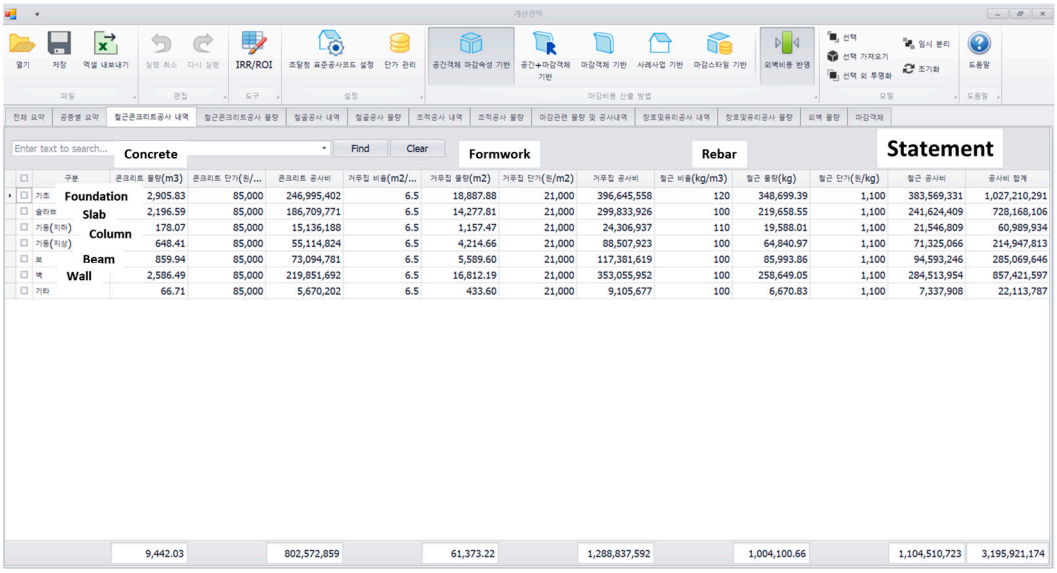

Figure 11. Estimated construction cost result screen: part of the construction cost.

6.3. Code Checking Results

The BIM model contains various information that can be utilized in the construction phase. To utilize this information more accurately and in various ways, the BIM model can be checked through various criteria. Among them, in this paper, the BIM information standard framework was tested by checking the information in the BIM model (the design concept was applied) and the code checking criteria. When authoring the BIM model, an authoring guide was applied and various attributes were included to enable more accurate checking.

The results of the code checking for the test model were derived as shown in Figures 12 and 13.

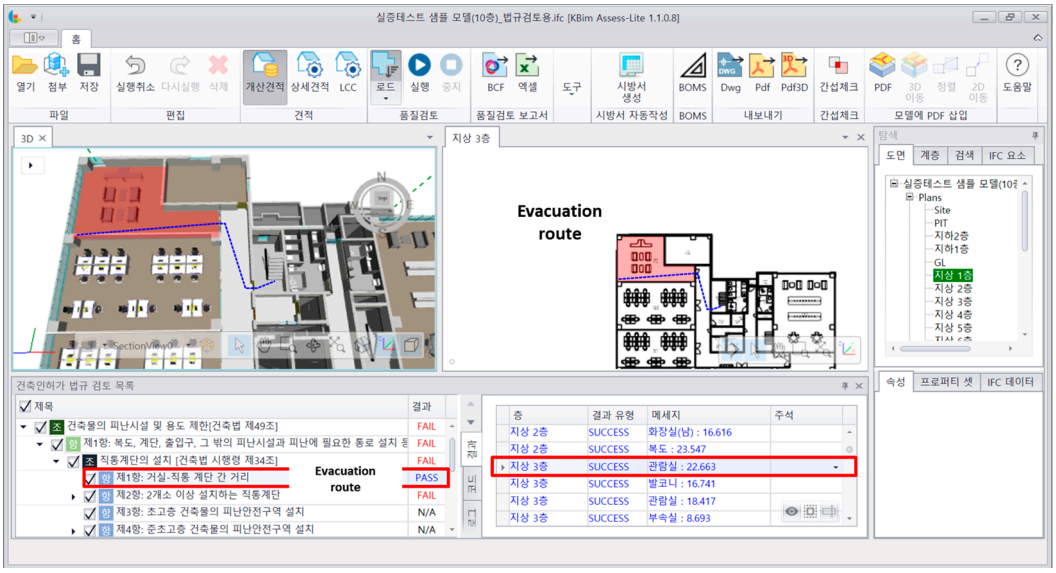

Figure 12. Code checking screen: evacuation stairs' conditions.

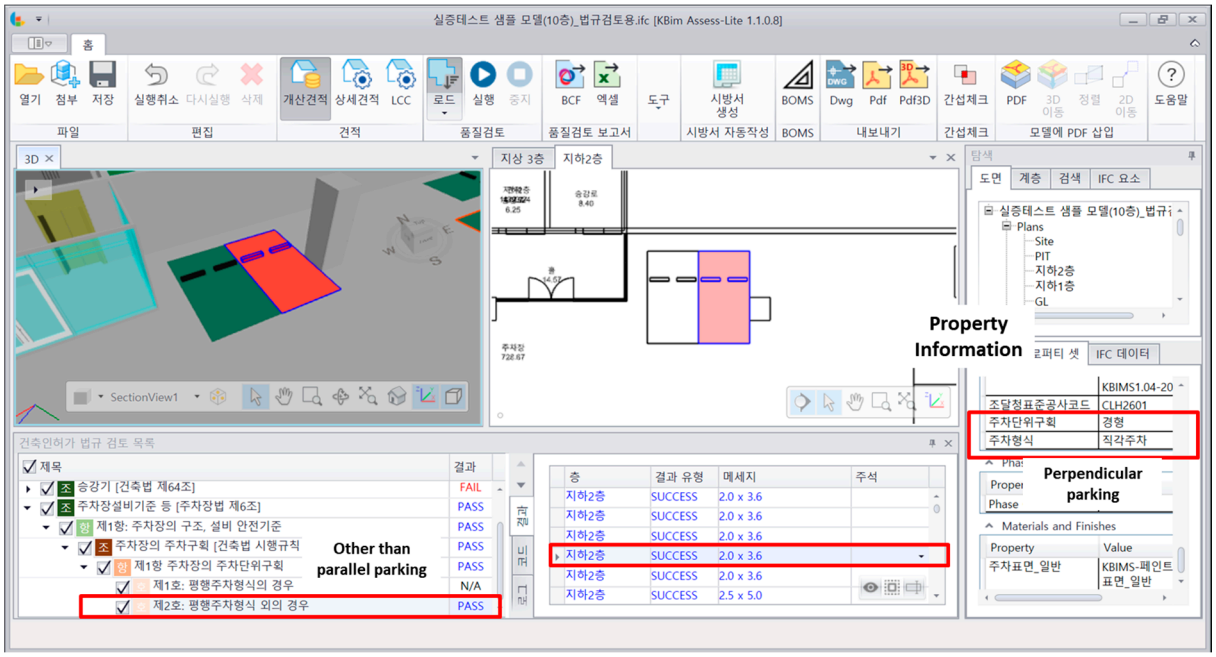

Figure 13. Code checking screen: evacuation stairs' parking lot conditions.

According to the evacuation design conditions, the distance from the farthest point of the space to the direct stairs was confirmed as less than 30 m, such that the evacuation design conditions were satisfied. After the automatic code checking is executed, the user can select the relevant code checking criteria and can check the checking results in the BIM model in detail.

According to the design conditions of the parking lot, the property values of the parking lot and the shape of the object were reviewed. The size of the parking block object did not match the attribute information for the disabled, so it did not meet the parking lot design conditions. Through the developed IFC-based application program, the shape information and property information included in the BIM library reflecting the BIM information standard framework can be checked, and the results can be accurately confirmed by comparing the BIM information and the building code checking criteria.

7. Conclusions

BIM is a complex technology that integrates a lot of information. Therefore, it is difficult to successfully implement BIM technology without standards, i.e., promises shared among many subjects and stages of construction projects. There are many types of standards required for the implementation of BIM-applied projects, and it is very difficult to effectively classify them. This paper tried to find a solution by deriving the necessary information standard elements from the point of view of information integration. Specifically, it was presented as a framework by dividing the layers of work procedures, information technology, and common management to meet the government's information standard direction in the construction field of Korea. Based on this, a method that can be used from one model for multiple uses was suggested through model creation criteria, an object classification system, and attribute specifications, and the possibility and practicality were confirmed through estimates and legal review. This study can be applied to the development of information standards and various guidelines required at the national industrial level in Korea and in regions where the information standard environment is relatively poor.

This study was conducted with the aim of increasing efficiency in the practical environment of architectural design in Korea. Although this study has experimentally confirmed the effectiveness of only some uses of architectural design, research is needed to expand

the range of information sharing step-by-step, such as design-construction-maintenance and subsequent smart city. In addition, because various standards already exist for each country and orderer, it is necessary to study the methods for integrating and reorganizing them. It is necessary to study the complementary role between common standards and individual standards to increase practicality.

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