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Development of Railway Infrastructure BIM Prototype Libraries

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Abstract: Building Information Modeling (BIM) can act as a solution to improve various difficulties faced in the construction industry. BIM is expanding into infrastructure facilities for integrated information management, productivity improvement, and risk management. There are many cases where BIM is applied to buildings with horizontal and linear characteristics, but the infrastructure is different from the method of applying BIM to buildings with vertical characteristics. Using premanufactured libraries in BIM-based design can shorten the design time and simplify the design method, thus increasing the 3D design productivity. This paper develops BIM prototype libraries based on the standards from the Ministry of Land, Infrastructure, and Transport (MOLIT) of South Korea for railway infrastructure. BIM tools such as Civil 3D, Revit, and AECOsim were used by reflecting the characteristics of each facility, and the libraries, with a total of 762 types in 363 files, were constructed. The specifications were created by linking the common and facility-specific attribute items to the libraries. The result of the test modeling using the developed library showed significant productivity improvement, such as an average difference of 38.2% was observed for roadbed modeling and a mean difference of 50.2% for bridge modeling.

Keywords: BIM; library; railway infrastructure; civil engineering

1. Introduction

Building information modeling (BIM) has been recognized as a tool for overcoming the difficulties faced by the architecture, engineering, construction, owner, and operator (AECOO) industries [1]. As well-prepared and information-abundant BIM models support not only visual shapes but also the management of schedules (4D) and costs (5D), the use of BIM can facilitate the construction process [2]. BIM is a building-oriented technology, as the term denotes, and is also referred to as civil information modeling (CIM) when it is applied to the civil engineering field. BIM and CIM, however, have different modeling processes. In many cases, BIM is created perpendicular to the floor, and it is not significantly associated with the surrounding terrain. For infrastructures such as roads and bridges, the cross-section is defined, and then horizontal expansion is performed along the designated path for modeling. Aside from these differences, BIM and CIM have similar data management and exchange systems [3].

In the construction field, the application of BIM has already been expanded to include both public and private projects. In particular, studies have verified that BIM is useful for vertical construction, such as for the construction of buildings. The use of BIM allows stakeholders to make important decisions using diverse information, and the results can be easily computerized. In addition, the stakeholders can derive a common understanding of the project through collaboration that helps decrease design and communication errors, thereby reducing the risks and responsibilities. Furthermore, the use of BIM may increase efficiency and safety as well as decrease the time that it takes to routinely collect and record data by avoiding data dispersion and overlapping efforts, thereby reducing the costs of the building owner and improving the structural safety of assets [4].

Recently, research has been conducted to apply BIM to civil engineering infrastructures such as roads, railways, and ports. The application of BIM to infrastructures managed on a national level is effective for their life cycle management, covering several stages from design to construction and maintenance, as well as for improving productivity [5,6]. Among the BIM users related to infrastructure, 67% have predicted a positive return on investment (ROI) if BIM is introduced to the infrastructure field [7]. According to Blaine [5], the introduction of BIM to bridges will result in a 5–9% cost reduction effect owing to the reduction of design changes and to the need for rework. In particular, the application of BIM to infrastructure has considerable potential for adding the value of asset management in the maintenance stage.

Meanwhile, the BIM library may improve design productivity and help ensure uniform quality. The BIM library is a systematic collection of BIM content that is frequently used in BIM-based design tasks. And this means that all information generated and extinguished during the facility's life cycle should be maintained and recyclable in other BIM models. While two-dimensional (2D) standardized drawings generate errors in terms of dimensions or quantities owing to simple typing errors, the BIM library does not introduce such errors because its parameters are automatically calculated. Therefore, more accurate and faster quantity calculation is possible [6]. When shapes must be changed for other projects, it is also possible to utilize the standardized library because these shapes can be easily converted by resetting the parameters. For the three-dimensional (3D) design of structures unique to each project, project libraries can be created based on the developed library. If this method is established, a flexible design environment for various shapes can be provided [8].

It is necessary to develop BIM library in order to improve design productivity and help ensure uniform quality. Furthermore, it is required to create BIM libraries that reflect the horizontal elements of the civil engineering field. Therefore, the purpose of this study is to construct BIM prototype library for roadbeds, tracks, bridges, tunnels, electricity, and signals based on the standardized drawings of the Korea Rail Network Authority (KR) and railway project cases.

2. Literatures Review

The research on the existing BIM library was centered mainly on the architecture field and they are largely divided into library standardization, library repository, and application technology. Park and Kim [9] researched the classification system of BIM library and Shin et al. [10] developed framework for BIM library to efficient management. Lee et al. [11] and Kim et al. [12] developed BIM libraries and used energy simulation in building. Han and Nam [13] researched estimation method using BIM library. Bridge and Carnemolla [14] designed and developed library components in social inclusion. Additionally, in the field of architecture, an environment in which related design companies can construct and utilize their own 3D library systems has been established owing to the activation of the public and private sectors. Recently, Salvatore et al. [15] has studied road infrastructure with a focus on the railing and retaining wall modeling for BIM-based design. This research is similar to this study in the use of parametric techniques as it developed the BIM library of civil structures, but the scope of this study is different from that of this study, as it was done only with the center of the railing and retaining walls. Ángel et al. [16] has a study that provided LOD BIM elements in the manual for railway turnout systems risk optimization. The General Service Administration (GSA) of the U.S. operates the national 3D-4D-BIM program, which was established by the Office of the Chief Architecture (OCA) in 2003. Through the program, GSA provides BIM guidelines and standardized library formats. In the UK, the National Building Specification (NBS) also provides the national BIM library [17]. Autodesk Seek also provides free libraries for the construction elements required for BIM design, as with other BIM library portals [18]. A website called "RevitCity" provides 14,229 Revit Families with detailed information regarding the members, equipment, and components of buildings, and at the same time, all BIM libraries are structured by MasterFormat [19]. In South

Korea, buildingSMART Korea also released the demonstration version of the BIM standard library. This library provides objects and templates for basic structures (e.g., foundations, columns, and beams), secondary structures (e.g., stairs and ceilings), and the finishing areas of structures.

On the other hand, the cases for developing and utilizing civil engineering BIM libraries are not sufficient. BIM Stop in the U.S. provides schematic models that use Revit Families for bridges, equipment, and railway tracks, but these are utilized simply for identifying the visual types of shapes because the shapes are not standardized [20]. Cho et al. [21] proposed a holistic BIM library system that contains the geometry, properties, and product information based on parametric modeling for efficient quantity takeoffs of tunnels constructed using the New Austrian Tunneling method (NATM). However, it does not provide a standardized library because it is limited to tunneling methods for specific projects. In South Korea, there was a case in which civil engineering structure BIM libraries were constructed for the standardized drawings of the Ministry of Land, Infrastructure, and Transport (MOLIT), but the libraries were limited to certain models and types [8]. Additionally, owing to their public characteristics, infrastructures have a limitation: the modeling guidelines and standards as well as the library contents must be provided by the country [9]. For infrastructure, it is important to secure consistency in accordance with the standards and guidelines, which can improve construction and maintenance productivity. Civil engineering structures with linear characteristics, such as bridges, tunnels, and roads, are difficult to standardize with stylized 3D shapes owing to the variability of their cross-sections. For this reason, it is not easy to utilize the existing object-based standardized libraries used in the construction field. Furthermore, in the infrastructure field, standardization is difficult because linear stylized shapes, including structures, are different in each section owing to their linear-based characteristics.

3. Methods

This study aimed to develop BIM prototype libraries that could be generally used for railway facilities, among other public infrastructures. Railway infrastructures are classified into various facilities, such as tunnels, bridges, tracks, stations, electricity, and signals. In this study, roadbeds, tracks, and tunnels, most of which change according to the linearity, as well as bridges, signals, and electricity, which are combinations of objects, were focused on. Stations were excluded because they have strong vertical elements and can thus be regarded as buildings.

In this study, the following research was conducted to construct BIM libraries for railway facilities. The standardized drawings (roadbeds, tracks, electricity, and signals) provided by Korea Rail Network Authority (KR) were analyzed to select BIM library construction targets. As standard drawings were not available for tunnels and bridges, the target facilities were selected by analyzing two railway project cases. The various standards provided by MOLIT were analyzed to create the attributes and specifications to be included in the BIM libraries. The forms of the BIM libraries were modeled for the selected facilities, and the defined attributes and classification systems were entered. The constructed libraries were tested for certain roadbed and bridge sections.

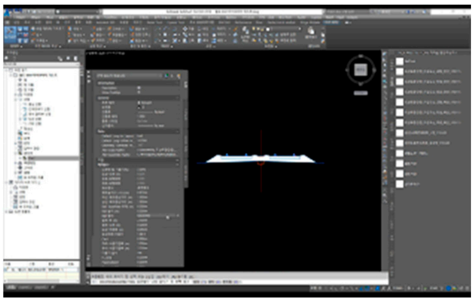
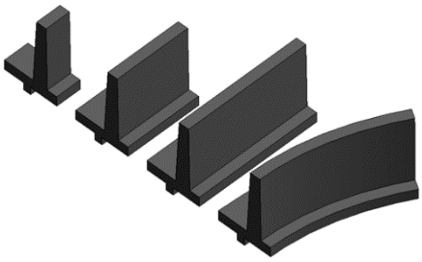
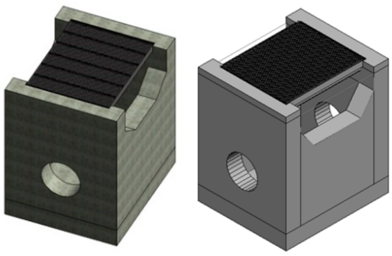
To construct the BIM libraries of railway infrastructures, it is important to identify the types of target facilities as well as the characteristics. Therefore, the characteristics, shapes, and uses of the target facilities were identified in this study by analyzing the drawings related to such facilities, and a library construction strategy that reflected the results was established.

For railway facilities such as roadbeds, tracks, and tunnels, the libraries must consider the effects of the cant that occurs in a curved path. Therefore, the use of a software program capable of considering the effects of a cant as well as the linear path is essential, and 3D libraries alone cannot consider such effects. The parametric elements of 3D libraries alone cannot implement linearly changing shapes and cannot be utilized for various future projects. Therefore, it is necessary to create 3D libraries based on 2D cross-sections, which linearly change in connection to the path based on 2D cross-sections and thus can implement 3D models.

3D object libraries also cannot be applied to structures with certain shapes, such as retaining walls, gutters, and soundproof wall foundations, for which changes in the length direction must be considered, in addition to linearly changing facilities, because each project has different directions and lengths. Therefore, library types based on 2D profiles are necessary to implement the shapes required by the users for each project. In addition, there are single-object-type libraries without linear characteristics.

Based on the results of such analysis, libraries can largely be divided into three types, as shown in Table 1. The first is the library type with 2D cross-sections, which can implement 3D models containing linearly changing shapes and quantity calculation. The second is the library type that implements 3D models based on 2D profiles for facilities changing in the lengthwise direction. The third is the library type that has a unique shape and quantity and that uses individual 3D models regardless of the linearity.

Table 1. Library types.

1. 2D-cross-section-based 3D type	
	• 3D modeling and quantity estimation of linear facilities (e.g., bed track, earthwork standard drawing)
2. 2D-profile-based 3D type	
	• 3D modeling and quantity estimation with the 2D profile (e.g., soundproof foundation, breath wall)
3. Single-object 3D type	
	• 3D object modeling and quantity estimation of linear facilities (e.g., collecting well, rail sign)

All of these library types are consequently expressed in 3D forms. In addition, to construct these three library types without encountering problems, it is necessary to use both a software program capable of considering linearity and an object-based software program capable of constructing 3D models.

The level of development (LOD) specification is very important for the construction of BIM libraries. As each railway construction project has specific site conditions, it is difficult to construct standard libraries that can be used in any construction. If libraries with a high LOD are constructed and used for a project, they cannot be used for other projects with different construction and terrain conditions, or to be used, they would need to undergo many modifications. In terms of time, the modification of such libraries may not be significantly different from creating new models.

This study aimed to construct prototype libraries as the first step in the construction of railway construction libraries. The target LOD is between 200 and 300, which is the level that can be commonly used in various projects performed by designers. Designers will be able to use prototype libraries such as these for planning and basic design, but they must construct more detailed libraries based on the prototype libraries for working design.

4. Selection of Railway Infrastructure Targets

As mentioned earlier, this study aimed to construct BIM libraries for roadbeds, tracks, tunnels, bridges, electricity, and signals. Target facilities for library construction were defined by analyzing the railway standardized drawings (2015) of KR on roadbeds, tracks, electricity, and signals. The shapes of the selected facilities can be constructed in 3D because their stylized dimensions are available. In the case of the steel reinforcement model, only representative types were selected among the drawings containing steel reinforcement details. There are a total of 27 earthwork drawings in roadbed standardized drawings, and they consist of standard cross-sectional drawings and earthwork drawings, such as for drainage and fences. For roadbeds and tracks, all the aforementioned three library types exist depending on the facility characteristics. In particular, for the main waterway concrete and side gutter included in the standard cross-section, among drainage facilities, libraries were constructed using the 2D assembly and 2D-profile-based 3D types. Facilities that are flexible depending on the earthwork change at the site, such as main stone-filled drains, conduits, and slope maintenance ladders, were excluded from the libraries. As shown in Table 2, proper BIM tools and LOD were selected for each facility based on the roadbed standardized drawings. Most of the facilities in the bridge, tunnel, signal, and electricity fields can be expressed using the 2D-profile-based 3D type and the single-object 3D type. Targets were selected, and the LOD was defined in the same way as in Table 2.

Table 2. Library types and earthwork scope.

Standard Drawing	Drawing Name	Drawing Code	2D Sub-Assembly	2D Profile	Single Object	LOD
2100 Standard cross-section	Cross-section	CRE2111-CRE2113	O	X	X	200
2200 Reinforced roadbed	Reinforced roadbed	CRE2201	O	X	X	200
2300 Drainage	Drainage concrete	CRE2301	O	O	X	200
	Collecting well	CRE2311	X	X	O	300
	Dummy ditch	CRE2331	X	X	X	-
	Waterway	CRE2341-CRE2351	X	X	X	-
	Side gutter	CRE2361	O	O	X	200
2400 Stiffened barrier	Stiffened barrier	CRE2401-CRE2402	X	X	O	200
2500 Fence	Fence	CRE2501-CRE2521	X	X	O	200
	Fence entrance	CRE2531-CRE2532	X	X	X	-
2600 Soundproof wall	Soundproof wall	CRE2601-CRE2607	X	O	X	300

5. BIM Library Attribute Classification and Specification Creation

5.1. Overview of Library Attributes and Specifications

In BIM, attributes represent the physical and logical characteristics of the target object and are important information items that determine the usability of a library. In addition, there can theoretically be infinite lists of attribute information for one shape object, and attribute information can be additionally defined by the user when needed, in addition to the basic items provided by the basic BIM tools. Furthermore, the specifications include the description and characteristics of the library, the parameters and shape characteristics that can be modified by the user, and instructions for use. They enable library search and the integrated management of the library.

The attribute information was constructed so that that it could link classification systems to standardized drawings and calculate the quantities presented in the standardized drawings. It may help in the BIM design work and can make management of the library possible. In particular, the codes of the railway construction unit price standards and construction standard market unit prices were linked so that quantity calculation and construction cost estimation could be made possible. The library attribute and specification data are summarized in Table 3.

Table 3. Library attribute and specification data.

	Attribute Classification and Common Attributes	Specification Data
Major purpose	• Identification of the object type in the 3D model • 3D modeling • Quantity estimation and table creation • Information management for analysis	• Library search • Library management
Main category	• Identification of the object type in the 3D model • Measurement of shape • Quantity for the material table • Properties of the material	• Description of facility • Identification of library type and shape information • Library function and scope • History management

5.2. Library Attribute Classification

In this study, the attribute items were largely classified into library identification, shape-related dimensions, material table item quantity, and material properties. The basic structure/facility names, the construction information breakdown structure (MOLIT), and the product breakdown structure (KR) were defined as attribute items for library identification. The shape-related dimensions were defined as the parameters that can be variably modified for each structure/facility. For the parameters that can be modified for each structure/facility, standardized drawings were consulted. The items for shapes and material quantities, among the attribute types of each library, were defined as the attribute items for each library according to the facility type or the material table of standardized drawings. The rest of the attribute items were defined as the common attribute items applied to all libraries. In particular, the material table items were linked to the construction standard market unit prices so that quantity calculation and making rough estimates could be made possible in the future using BIM data constructed as libraries. For material properties, the kinds of main materials were defined as attribute items by referring to the material tables of standardized drawings.

5.3. Attribute Items and Parameters for Each Facility/Type

The attribute items for each facility/type are different depending on the shape and material characteristics of the target facility. When the parameters for the dimensions are defined, it is easy for the user to arbitrarily modify the size of a cross-section for the same shape. In this study, dimensions were entered for standardized drawings. When dimension values for the facilities used in the field are entered, however, such values can be changed into the values of the facilities used at the corresponding site. The quantities of the material table items, which are calculated according to the dimensions, can also be automatically estimated. Tables 4 and 5 show examples of actual attribute items and parameters created using such concepts.

Table 4. Example of library attribute (ballasted track).

	Attribute	Description	
Library identification	Facility type	Ballasted track	
	Facility name	Ballasted double track	
	Facility size	High-speed railway (200 < V ≤ 350)	
	Standard drawing name	Standard drawing for railway 2015	
	Standard drawing code	CRG1231, CRG1232, CTS1101, CTS1103–CTS1105	
	Construction information breakdown structure	F12100, E12100, W3300	
	Product breakdown structure	BA ballasted track	
	Version (year)	V.1.0 (2017)	
Quantity estimation	Standard price	-	-
	Standard quantity and cost of railway	Ballast grading	KRQP C-14030_1_17
		Ballast spreader	KRQP C-14030_1_18
General	Institute name/URL	Korea Institute of Civil Engineering and Building Technology	

Table 5. Example of library parameter for (ballasted track).

Name	Type	Description	Unit
Side	Enumeration	Left or right direction	-
Formation level slope	Grade	Slope of formation level	%
Drainage type	Enumeration	Drainage type of formation level	-
RL-FL	Double	Vertical distance from the formation level to the top of the rail	m
Track center of the southbound lane	Double	Horizon distance from center to track center of southbound lane	m
Track center of the northbound lane	Double	Horizon distance from the center to the track center of the northbound lane	m
Rail base plate	Double	Thickness of the rail base plate	m
Rail height	Double	Vertical distance of the rail	m
Rail type	Enumeration	Rail type	-
Sleeper width	Double	Sleeper width	m
Sleeper thickness	Double	Sleeper thickness	m
Width of the ballast shoulder	Double	Distance from the end of the sleeper to the ballast shoulder	m
Slope of the ballast shoulder	Slope	Slope of the ballast shoulder	-
Cant for validation	Double	Cant for validation	m
Width of the left formation level	Double	Horizon distance from the center to the left formation level	m
Width of the right formation level	Double	Horizon distance from the center to the right formation level	m
Net thickness of the roadbed	Double	Net thickness of the roadbed	m

In the ballasted track library, the user can determine various parameters, such as the track central distance, the variables according to the design speed, and the drainage type, rail type, and track transverse width. The values for the cant can be checked only in the libraries. As the values entered for the linear paths used by the libraries, they are automatically applied in the Civil 3D software.

5.4. Specification Creation

Based on the analyzed library attribute classification systems and parameters for each facility, the specification items are summarized as shown in Table 6. As the specifications must be stylized and managed unlike the attribute information, there is no item that changes by facility, and all the items falling under each classification are used for library description. The specifications are divided into facility description, library description, library use, design conditions, and library and specification management.

Table 6. Description of specifications.

Group	Specifications
Facility description	• Facility type, name, size • Standard drawing name and code • Construction information breakdown structure • Product breakdown structure levels 1–4 • Image of 3D model
Library description	• Detail level • Rebar inclusion (yes or no) • Library type • File type • S/W type and version
Use library	• Type list included in the library • Quantity item • Name/code of the standard price for building construction • Definition and description of shape parameter • Parameter item considering user revision • Library description and constraints
Design condition	• Standard drawing design condition (NOTE)
Library and specification management	• Institute and URL • Version and year

The facility description can be checked simultaneously with the software program by providing the user with classification items according to the facility type and classification system. Library description describes the library files and the type of the corresponding library. Library use was created so that the user could review in advance the descriptions of the quantity calculation items and the shape parameters supported by the library as well as the library use restrictions. Design conditions were created to check the design conditions specified in standardized drawings so that the user could use the libraries that exactly match such standardized drawings. Finally, library and specification management were created as the information item for creation institutes, management institutes, and versions.

6. Library Development and Test

6.1. Library Development

The libraries were created based on railway standardized drawings, which are the basis for the work scope, so that the 3D models that could be applied to actual tasks could be implemented. Practical applicability was secured by enabling the creation of various shape models and the reuse of BIM models through the definition of the attribute items and parameters for each facility type. In addition, modeling was performed on a level at which the libraries and construction costs could be managed by linking the related items, such as the classification codes and construction costs.

In accordance with the railway standardized drawings of KR, the libraries were created for the geometries of roadbeds, earthwork, bridges, tunnels, secondary work, and tracks. As explained earlier in the construction scope, for the formation level of the geometry of roadbeds and for tracks, one library is created for each task or type, and a drawing number is given to each file. As such, libraries for the ballasted track were created.

Depending on the library type, the 2D-cross-section-based 3D type was constructed using Civil 3D while the 2D-profile-based and single-object 3D types were constructed using the two software versions of Revit and AECOsim. The libraries that used Civil 3D contained a total of 237 types in 43 files; the libraries that used the Revit software contained 525 types in 320 files (including the steel reinforcement model); and the libraries that used the AECOsim software contained 517 types in 312 files, resulting in a total of 762 types in 363 files. Table 7 shows the library status by standardized drawing task and facility type.

Table 7. Developed building information modeling (BIM) libraries.

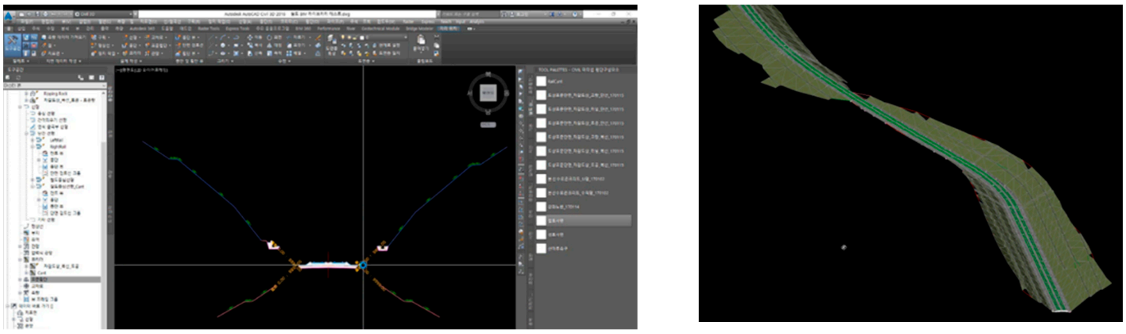
Standard Drawing			Form Number			Type Number		
	Group	Drawing Name	Civil 3D	Revit	AECO-sim	Civil 3D	Revit	AECO-sim
Roadbed	1. Geometric structure	Gravel roadbeds	12	-	-	84	-	-
		Concrete roadbeds	5	-	-	34	-	-
	2. Civil engineering	Standard cross-section and drainage	8	8	6	17	28	26
		Rockfall prevention fences	-	8	8	-	8	8
		Soundproof wall foundation	-	3	2	-	8	7
	3. Bridge	Waterproofing and drainage	-	2	2	-	2	2
		Common pipe channel	-	2	2	-	2	2
	4. Tunnel	Tunnel cross-section	12	-	-	34	-	-
		Electric railcar	4	-	-	56	-	-
		Drains and conduits	-	6	4	-	8	6
	5. Retaining wall	Gravity retaining wall	-	2	2	-	9	9
		Semi-gravity retaining wall	-	2	1	-	10	9
		Reverse T-shaped retaining wall	-	2	1	-	16	15
		L-shaped retaining wall	-	2	1	-	16	15
	6. Subsidiary works		-	5	5	-	23	23
	Total		41	42	34	225	130	122
Track	1. Gravel roadbed		-	-	-	-	-	-
	2. Concrete roadbed		2	-	-	12	-	-
	Total		2	-	-	12	-	-

Table 7. *Cont.*

Bridge	Upper structure	PSC BEAM		8	8		8	8
		IPC GIRDER		8	8		8	8
		RPF BEAM		20	20		34	34
		Rahmen bridge		2	2		2	2
	Lower structure	Abutment		8	8		8	8
		Pier		16	16		16	16
		Pile foundation		2	2		4	4
	Others			4	4		6	6
	Total			68	68		86	86
Tunnel	General section	Lining		4	4		4	4
		Shotcrete		4	4		4	4
		Rock bolt		4	4		4	4
		Steel rib		6	6		8	8
		Side drainageway		2	2		2	2
	Open-cut section	Open-cut tunnel		4	4		4	4
		Portal		8	8		8	8
	Total			32	32		34	34
Electricity	Catenary	Feeder		19	19		19	19
		Protective wire		6	6		6	6
		Catenary pole and catenary pole foundation		34	34		102	102
		Fixed beam		6	6		6	6
		Beam suspension		12	12		14	14
		Catenary pole substitute		7	7		10	10
		Drop tube		12	12		13	13
		Cantilever		4	4		22	22
		Straining device		5	5		5	5
		Strain pole crossarm		10	10		10	10
	Electric equipment	Hand hole		18	18		18	18
		Concrete trough		6	6		6	6
	Total			139	139		231	231
Signal	Signal device			39	39		39	39
	Trope			1	1		6	6
	Total			39	39		44	44
Gross total			43	320	312	237	525	517

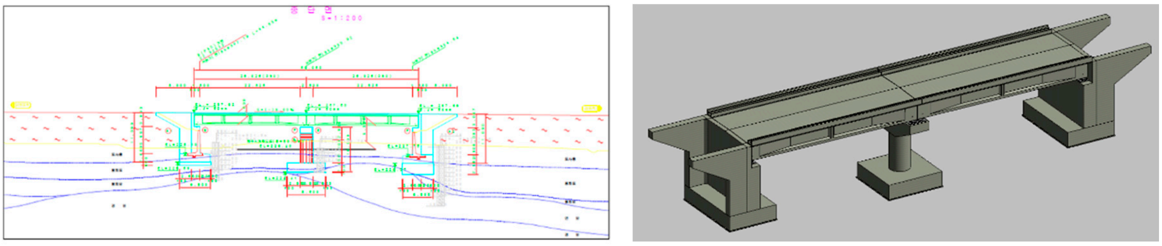
6.2. Modeling and Test

Modeling and testing were conducted on four designers who could design using BIM. The expert group consisted of one year, three years, seven years, and twelve years of experience. Testing quantitatively compared the time modeled without using the developed library with the time modeled using the library. We also received opinions from experts who participated in the test and received qualitative opinions on the results of this study. Figure 1 is the test data modeled in this test. Figure 2 is a 3D drawing modeled using libraries developed by reference to existing 2D drawings and 2D drawings.



(a) (b)

Figure 1. (**a**) Standard crossing creation and (**b**) corridor model creation.



(a) (b)

Figure 2. (**a**) 2D drawing and (**b**) BIM Model (using the library).

To test the constructed libraries, roadbed and bridge sections were modeled. Roadbed modeling consists of (1) initial topography creation; (2) linear information input; (3) standard crossing creation; (4) corridor creation; (5) corridor surface creation; and (6) planned terrain creation (initial topography + corridor terrain). BIM libraries based on 2D cross-sections can be utilized for standard crossing creation.

2D-profile-based 3D libraries were utilized for bridge modeling. The target bridge was a PSC beam type.

The time that it took four experts in BIM tools (Civil 3D and Revit) to perform modeling with the libraries was compared with the time (minutes) that it took them to perform modeling without the libraries. As a result, a 38.2% average difference was observed for roadbed modeling, and a 50.2% average difference was observed for bridge modeling (Table 8).

Table 8. Result of test.

Category		1		2		3		4	
PSC BEAM bridge (Revit)	Drawing Time	190	82	255	160	160	71	235	115
	Difference	108		95		89		120	
		56.84%		37.25%		55.63%		51.06%	
Roadbed (Civil3D)	Drawing Time	50	30	110	80	40	15	65	50
	Difference	20		30		25		15	
		40.00%		27.27%		62.50%		23.08%	

The qualitative opinions of the experts involved in this test are as follows.

1. As a result of modeling using developed libraries, the time required to model a typical type of structure can be greatly reduced.
2. Developed library models are basically made up of parametric modeling, which can reduce errors that occur when modeling.

3. The developed library can be constructed only with parameter input, and the area such as the bridge's copping and bridgework considering the type of model layout is made on the facet, so it is convenient to use.
4. However, the use of this library requires proficiency in BIM. Therefore, it is necessary to present detailed utilization guidelines.

To sum up these opinions, the developed library presented in this study is considered to be highly useful in practice. However, it is believed that the development of utilization guidelines will be necessary for the future because the user's ease of use varies depending on their proficiency.

7. Conclusions

In this study, BIM prototype libraries were constructed for roadbeds, tracks, bridges, tunnels, electricity, and signals based on the standardized drawings of the Korea Rail Network Authority (KR) and railway project cases. The libraries were classified into the two-dimensional (2D)-cross-section-based three-dimensional (3D) type, the 2D-profile-based 3D type, and the single-object 3D type according to the facility type. BIM tools such as Civil 3D, Revit, and AECOsim were used by reflecting the characteristics of each facility, and the libraries, with a total of 762 types in 363 files, were constructed. The libraries were linked to the unit price codes so that the quantities and costs could be estimated when performing design using the libraries.

The specifications were created by linking the common and facility-specific attribute items to the libraries. The created specifications included the descriptions and utilization methods of the facilities and libraries as well as the information on the design conditions and shapes that enabled the integrated management of the libraries. In addition, guidelines for the utilization of each library were created.

As prototype libraries with a low level of development (LOD) were constructed for universal use in various railway construction projects, it is difficult to use them without modifications in the design stage, including in working design. In addition, opinions are continuously being reflected through field testing. Therefore, further studies will continue to develop BIM library items that can be reflected on-site, apply them to the site in various cases, verify them, and continuously reflect opinions. It will also expand the scope of the developed library to civil engineering facilities that are different from all areas of the railway.

It is expected that the construction of railway infrastructure BIM libraries will improve the 3D design productivity of designers and maintain uniform drawing quality.

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