Open BIM-based Information Modeling of Railway Bridges and its Application Concept

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ABSTRACT

As an initial stage study to effectively apply Building Information Modeling (BIM) to railway infrastructure, this study proposes measures of Industry Foundation Classes (IFC)-based information modeling of railroad bridge, which is a representative structure of railway infrastructure, and provides conceptual methods to utilize this measure. For this, firstly, IFC additional entity reflecting functional properties of the railroad bridge was suggested. Secondly, information modeling and management methods of railroad bridges using the current version of IFC were proposed. Thirdly, a connection method of external information and IFC-based railroad model was presented. Here, the study utilized necessary information for calculation of carbon dioxide production. Lastly, the applicability of information model of railroad bridge based on BIM was examined by applying the abovementioned methodology to two types of actual railroad bridge.

INTRODUCTION

Due to its safety, mass transit, punctuality, and environmentally friendliness, railway transport is receiving attention as a vital transportation for future federal transportation policies, and particularly in Korea, promotion of increase up to 50% of the total investment in transportation is expected by 2020. However, the railway infrastructure is a general basic industry made up of various domains such as structural, geotechnical, system and control. Therefore, innovation of the railway infrastructure industry comes slowly relative to other industries' changes due to difficulties of introduction and integration with new constructive technologies. Meanwhile, the railway bridge, which is a representative structure in railway infrastructure, has an advantage of a fast spread of new technology such as Building Information Modeling (BIM) since the type and construction of bridges according to span is relatively standardized. Hence, after introducing and applying the new management method to railway bridge, it is possible to apply this methodology to other railway infrastructure.

Worldwide, there are not many actual cases of applying BIM to railway industry, but recently efforts are being made to introduce with the goal of improved productivity and reduced costs. In England, railway BIM was introduced to the Crossrail project and is in progress to examine 3D visualization and construct ability in design and construction phase (Stasis *et al.* 2012), whereas the Westside subway extension project in the United States (Clark 2012), MRT project in Hong Kong (Aedas 2010), and Hallandsås Railway project in Sweden (Päiviö and Wallentinus 2001) are also utilizing BIM in railway infrastructure construction. On a more academic perspective, study on application measures of Open BIM based on standard data model for effective management of information during the lifecycle of railway infrastructure is under active progress. Europe's Infrastructure for Spatial Information in the European Community (INSPIRE) is conducting a study to combine transport network information based on standard data model (INSPIRE 2010). Similarly, buildingSMART, who developed Industry Foundation Classes (IFC), are developing a data model appropriate for civil infrastructure through openINFRA project, an IFC extension(Castaing and Benning 2011). This results from the actively utilized standard data model not including parts for railway infrastructure, and this requires some time to apply the data model of the present research stage to an actual work.

To effectively manage information created during the lifecycle of railway infrastructure, the present study, as an initial phase to introduce Open BIM, proposes methods to manage information for the railway bridge based on standard data model, and examine usability by applying to cases of calculation of carbon dioxide production.

DATA MODEL-BASED INFORMATION MANAGEMENT

Adding new IFC entities for the railway bridge. With relevance to current BIM, as the data model registered as standard is not focused on buildings, many organizations and researchers are developing data model for structures other than buildings. In particular, as IFC is a standard data model (ISO-TC184/SC4 2013) for ISO designated BIM, many civil structures including railway bridges are an expanded form of IFC. This study's research team also contemplates the advantage of maintaining compatibility with building information by an IFC-based data model for civil structure. Hence, in this study, to apply methodology mentioned by Lee *et al.* (2013b) to railway bridge, additional entity that is not supported in IFC is being developed. As explained by Lee *et al.* (2013b), necessary information of the relevant domain must be classified and identified to form a worthy data model. ISO 12006-2 (ISO-TC59/SC13 2001) provides standards for classification of construction information, and it is currently categorized into three major parts; 'Construction Resource,' 'Construction Process,' and 'Construction Result.' The three parts, as individual objects, are interconnected by methods of inheritance and reference according to object-oriented concept. IFC was also developed by this concept, and the IFC entity addition for the railway bridge also followed identical concept. Here, in developing data model for railway bridges, the most conspicuous difference with buildings is the 'Construction Result', and the present study placed focus on the spatial and physical object of 'Construction Result' to manage design information of railway bridges. The major spatial and physical objects considered in the present study are as below:

1) Spatial objects: site, railway, bridge, slope, lane, track gauge
2) Physical objects: base layer, railway signal, slab, prismatic members

(e.g., girder, beam and column), segment, cable, tendon, anchorage, bridge shoe, sole plate, abutment, pier, anti-seismic device, expansion joint, monitoring devices (e.g., electric circuit and sensors), splice, track (rail, sleeper, ballast / ballastless, subgrade)

Objects for addition were examined for usability in existing IFC resource, while functional parts, such as beam and column, which did not differ between objects, were not considered, with the focus placed on railway bridge, and control facilities were grouped into large objects.

IFC user-defined property sets-based information modeling of the railway bridge. New data model suitable for the railway bridge must consider the resource, process, and result during the entire lifecycle to make it possible to manage precise information, but needs development of relevant software to apply to work and requires a relatively long time. Meanwhile, IFC provides environment to connect IFC and user-defined property sets through meta-model called *IfcPropertySet* to support specific external properties that are difficult in provision by IFC (Liebich 2009). Generating information through user-defined property sets can be used directly to current BIM software since it does not alter the IFC data model itself. The present study used this point to propose a method to use information model of the railway bridge in the current BIM environment in application domain. For this, firstly, semantic information for component comprising of bridge was created. Methodology proposed before by the author Lee *et al.* (2013c), was followed for creating semantic information using IFC user-defined property sets. According to the proposed method, spatial information of bridges was distinguished as Structural system, Span, and Girder, while the physical information was classified as Part, Parts assembly, and Assembled assembly. The classified information is added to the “name” attribute of *IfcProperty*. This information is presented as property set based on XML, as according to method proposed by IFC, and the major information categories are the previously mentioned identification property of spatial and physical information. Figure 1 shows the basic concept composing of information model by reassigning semantic information of railway bridge component in BIM software.

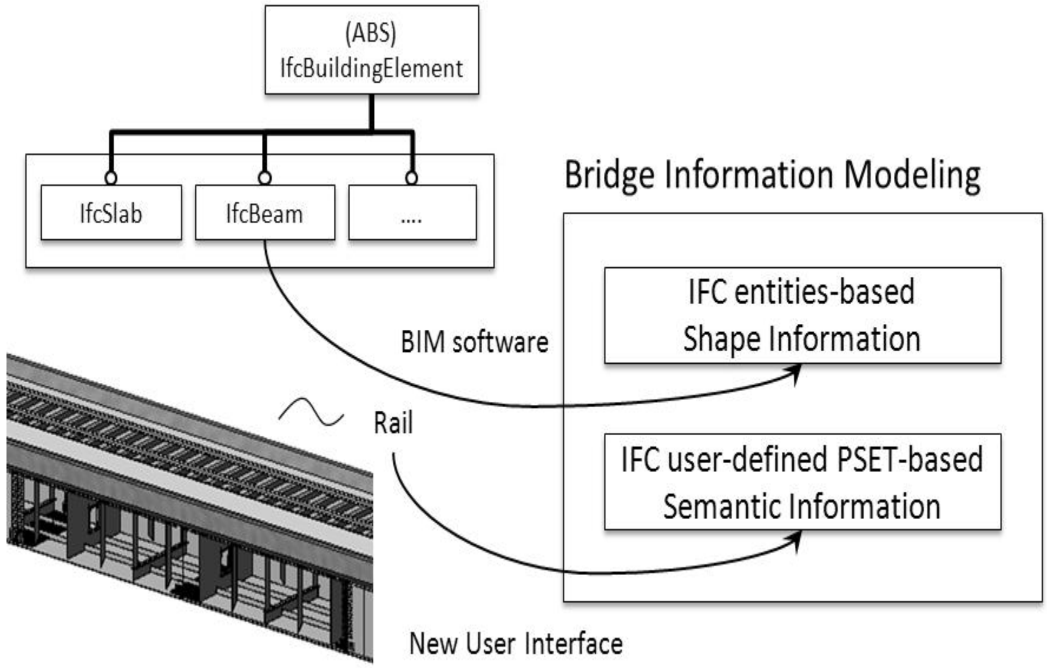

Figure 1. Information reassigning concept for railway bridge information modeling (Lee *et al.*, 2013c)

The second stage in the method of applying information model of railway bridge in the current BIM environment in application field is the connection with external information. Results from Lee *et al.* (2013a) shows the 3D shape model, M, of bridge to be as following.

$$M = \cup\{\mathrm{L}, \mathrm{E}_M, \mathrm{A}_M, \mathrm{P}_M, \mathrm{RL}_M\} \qquad (1)$$

where, L denotes a set of information that directly indicate bridge and its components; E represents a set of environmental information; A is a set of the activity information; P is a set of the physical body information of a bridge; and RL represents a set of relations among information objects. The calculation of carbon dioxide production using information model of railway bridge can be shown, fundamentally, by quantity of material and the multiple of carbon dioxide emission coefficient of material, and the external information, C, used for the calculation of carbon dioxide production can be shown as below.

$$C = \cup\{\mathrm{A}_C, \mathrm{P}_C\} \qquad (2)$$

The basic concept for connection between shape model of railway bridge and external model can be shown by Figure 2.

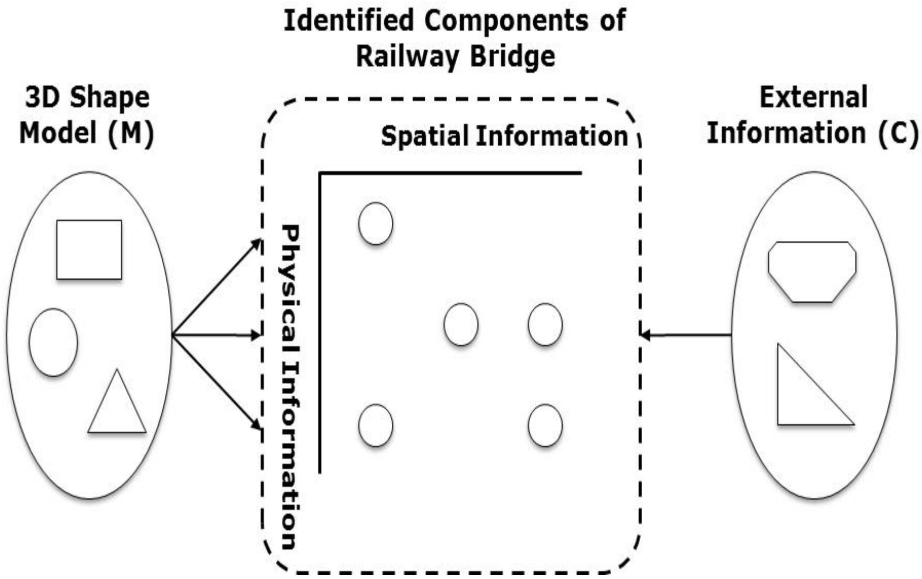

Figure 2. A concept for interface between 3D railway bridge shape model and external information for calculating the quantity of CO2 emission

COST ESTIMATION WITH CONSIDERATION FOR THE CO2 EMISSION

3D shape model of the railway bridge was created by the proposed method in Section 2.2, and the total carbon dioxide emission was calculated by connecting the information of carbon dioxide emission coefficient. The basic concept for calculating the carbon dioxide emission was to calculate and add each carbon dioxide emission for lower components that comprises the bridge, as shown in Figure 3, and by focusing on the design phase, the carbon dioxide produced during construction was excluded from this study.

The bridges used in the present study was the composite steel box girder bridge and PSC box girder bridge, which are actual railway bridges that passed structure analysis for 40m span. Table 1 shows the construction cost and carbon dioxide emission from the bridges, where sub structure does not appear to have a considerable difference, but super structure shows a difference.

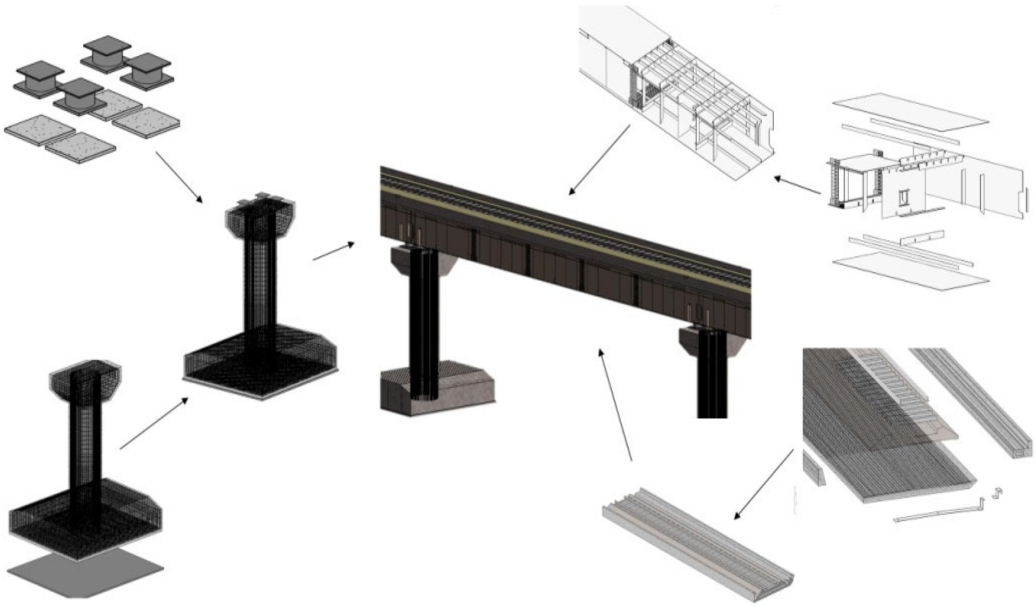

Figure 3. A basic concept for calculating the quantity of CO2 emission of the railway bridge

Table 1. Construction cost and quantity of CO2 emission

Bridge type	Composite Steel Box Girder Bridge: A type		PSC Box Girder Bridge: B type	
Component	Super Structure	Sub Structure	Super Structure	Sub Structure
Construction Cost (unit: 10^8KRW)	12.78 Total: 16.13	3.35	10.69 Total: 14.98	4.29
CO2 Quantity (unit: tCO2)	456.18 Total: 1010.17	553.99	862.95 Total: 1460.42	597.47

Table 2 shows the total construction cost considering for the average trading price of carbon credit, 19.73 EUR/tCO2 (~=39,460 KRW/tCO2), suggested by The European Climate Exchange (ECX) during 2005 to 2011. After consideration for the cost of carbon emission, the difference in construction cost between composite steel box girder bridge and PSC box girder bridge decreased. This result means that it can be economical to change the bridge type according to a rise in carbon credit trading price or an increase in the length of bridge spans.

Table 2. Total construction cost with consideration for CO2 emission cost (unit: 10^8KRW)

	A type: (b)	B type: (b)	(a) / (b)
Const. Cost	16.13	14.98	1.08
Const. Cost + CO2	16.53	15.56	1.06

CONCLUSIONS AND DISCUSSIONS

The present study, as an initial study to apply BIM effectively to railway infrastructure, proposed rough methods to utilize current IFC and measures to add entity to information modeling based on existing IFC to manage design phase information of the railway bridge. In addition, proposed methods were used for composite steel box girder bridge and PSC box girder bridge to connect an external information, carbon emission coefficient, to calculate quantity of carbon emission for each component and examined the significance of the results.

As the application of railway infrastructure usually continues for over 70 years, the initial plan and design is an important stage that continuously affects the next stage. Hence, by introducing an already proven BIM to railway infrastructure industry, decision making is required for longer-term viewpoint. For this, continuous research, as shown below, is needed.

1) Urgent development of standard data model considering lifecycle of railway infrastructure.
2) Improvement of accuracy and efficiency of information connection between each facility in railway infrastructure.
3) Development of information modeling software for railway infrastructure that supports standard data model.
4) Development of operation system based on BIM for the lifecycle management of railway infrastructure.
5) Development of standard platform based on BIM for project management of railway infrastructure
6) Development of asset and disaster management of railway infrastructure based on BIM.
7) Development of disposal and reuse system of railway infrastructure based on BIM.

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