USER-DEFINED PROPERTY SETS-BASED IFC EXTENSION FOR BRIDGE APPLICATION INFORMATION MODEL

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ABSTRACT: This study suggests IFC-based bridge information modeling methods and its application model in BIM environment. Data model extension for bridge structure was achieved using user-defined property sets based on IFC framework. First, identification information was added. Bridge members are identified through physical and spatial semantic information added as property sets. Instances for semantic information were assigned according to standardized rules. Second, CO2 related factors were added for application information model. It can play a role to calculate and manage the quantity of CO2 emission. Third, properties for temporary structure to estimate and manage the construction cost were added. Finally, we investigated proposed methods through implementing the application information model of bridges.

Keywords: BIM; IFC; User-defined property sets; Bridge information model; CO_2 emission; Construction cost

1. INTRODUCTION

Interoperability between related software programs is the core point of Open building information model (BIM). That means implementation of Open BIM must be based on standardized data model. Industry foundation classes (IFC) using ISO 10303 Standard for the exchange of product data model (STEP) Part 11 resources is standard neutral data model for BIM. Therefore, import/export file options according to IFC data model schemas are supported by various software programs for BIM. However, current version of IFC only focuses on lifecycle of building structure. Furthermore, the next version of IFC (IFC4) does not include bridge structure or members. Hence many researchers have studied data models to describe the bridge structure. Halfawy et al. [1], Lee and Jeong [2] have developed STEP-based new data model for bridges. Yabuki and Li [3], Arthaud and Lebegue [4] proposed IFC-based extended data model for bridges. In addition, Lee and Kim [5] extended IFC data schemas for road, bridge and tunnel structures. Model support group (MSG) in buildingSMART International are developing data model for civil infrastructures including bridge structures through IFC extension project or openINFRA project. However, the earlier mentioned STEP or IFC-based data models are research-level products. To improve efficiency in practical usage of bridge data model, more advanced studies and more convenient software environment for implementation of information model are needed. On the other hand, IFC provides a framework for user-defined information supporting additional properties as user-defined property sets (Pset). User-defined Pset is modeled using *IfcPropertySet* entity [6]. Generating the information through user-defined Pset allows for extension of the IFC without changing the data model. Although semantic identification of bridge members can be uncertain, it has advantages for implementing the information model easily using current BIM software program. Using IFC plus user-defined Pset, Seo and Kim [7] studied management method of planning information, and Ma et al. [8] developed application model for cost estimation. However, these researches are focused on building structure, and have limitations for applying to this study due to insufficiency of IFC data model for bridge structure and members.

In this study, we proposed an information modeling method of bridge through IFC extension data model using user-defined Pset. Also, application models for calculation of CO_2 emission and construction cost estimation based on user-defined Pset were implemented.

2. USER-DEFINED PROPERTY SETS

IFC data model includes many types or entities for management of building lifecycle information. However, it particularly has insufficient types to manage bridge information with regard to spatial (e.g. linear feature or arrangement of only bridge members etc.) and physical (e.g. abutment, pier etc.) elements as in Lee and Kim's research [8]. Thus, in this study, insufficiency of IFC data types was supplemented by *IfcPropertySet* entity, which is a container class characterized by features of dynamic extensibility.

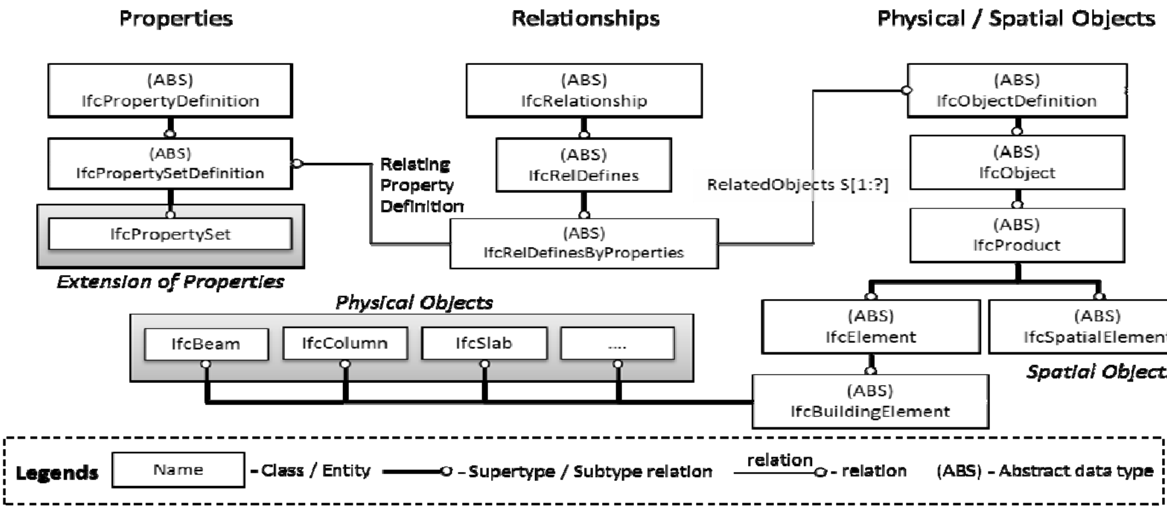

Figure 1. The Concept of the Relationship between Properties and Physical / Spatial Objects

IfcPropertySet plays a role in including user-defined Pset. In other words, external or additional properties can be incorporated into IFC data model schema through *IfcPropertySet* entity as a part that IFC cannot cover. *IfcPropertySet* can assign additional properties to physical / spatial objects as internal attributes through relationship entity *IfcRelDefinesByProperties*. Figure 1 shows the concept of the relationship between *IfcPropertySet*, *IfcRelDefinesByProperties*, and physical / spatial objects. Additional properties can be assigned as subtype of *IfcProperty* entity according to property type by bounded value, enumerated value, list value, reference value, single value, table value, or complex properties, and *IfcPropertySet* is a set of *IfcProperty*. The semantic meaning of additional properties is instantiated through *"name"* attribute in *IfcProperty*. In this study, we supplemented lacks of IFC data model for bridge structure with *"name"* attribute in *IfcProperty* entity assigning physical / spatial semantic information. Figure 2 shows basic framework for IFC-based application model through schema extension using user-defined Pset.

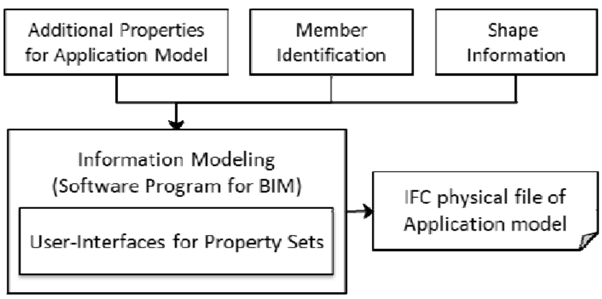

Figure 2. Basic Framework for IFC-Based Application Model

3. IDENTIFICATION OF BRIDGE MEMBERS

Identification of bridge members through user-defined Pset was based on bridge breakdown structures. The physical / spatial information of members is generated in the modeling process as "*name*" attribute in *IfcProperty* according to standardized rules. The spatial information of members is embodied in three elements; Structural system (SS), Span (S), and Lane (L). These denote classifications of super-sub structure, longitudinal direction, and horizontal direction of bridge, respectively. In this study, the physical information of bridge members is separated into Part (P), Parts assembly (PA), and Assembled assembly (AA). These represent a product component, an assembly of parts, and an assembly of assemblies, respectively. The rules for member identification can be possible with linear arrangement which combines with spatial and physical information in SS, S, L, AA, PA, and P order.

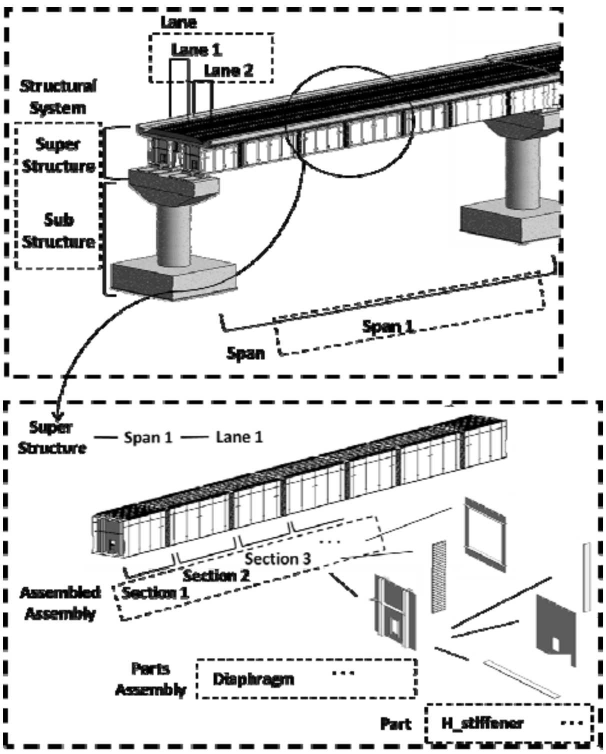

Figure 3. Pset-Based Approach for Identifying the Bridge Members

Figure 3 shows a case of attributes and its instances for identifying the bridge members. In this case, generated list of instance is Super structure - Span 1 - Lane 1 - Section 3 - Diaphragm 1 - H_stiffener. The member identification is a core point for implementing and using an application model in the following chapters.

4. IFC-BASED BRIDGE APPLICATION MODEL

4.1 Modeling framework for carbon dioxide Emission information

In this subchapter, we proposed an IFC-based framework of application modeling process for calculating CO_2 emission of bridge.

Figure 4 shows a basic principle for managing the information of CO_2 emission. The entire quantity of CO_2 emission can be induced by combining the of calculation results of each member. The information of member identification and calculation result combination is generated and managed according to proposed method in chapter 3. Additional properties such as volumes of member, kinds of material, strengths and unit weights of material, and emission factors of CO_2 considering characteristics of material are needed for calculating the quantity of CO_2 emission. And each property was included in our IFC extension data schema though user-defined Pset. The quantity of CO_2 emission can be calculated multiplying emission factor and member information, which would be assigned as volumes in case of concrete etc., or can be assigned as weights in case of reinforcing bar and so forth. Also, another user-defined set of property such as member_CO2_quantity and total_CO2_quantity is added for storing calculation results of CO_2 emission separately in attribute of PA, AA, and SS. Properties for result of CO_2 emission are also included in IFC data model through user-defined Pset.

4.2 Modeling framework for construction cost estimation

It is possible to estimate the construction cost with appropriate combination of *Cost Resource*, *Quantity Resource*, and *Construction Management Domain* Schema etc. in IFC data model. However, there are few software programs for BIM to support the above mentioned schema elements. Thus, in this subchapter, we proposed a basic concept to estimate the bridge construction cost using user-defined Pset. One of the difficulties for estimating construction cost based on complete information modeling product is consideration about temporary structures only used on construction process. Therefore, reflection of temporary structure is one of the important points for cost estimation. The necessary properties which are not included in complete information model for estimating construction cost were deduced through analysis of construction works. The necessary properties are form, spacer, scaffold, staging, reinforcing bar processing, concrete pouring, water proofing, curing, and deck finisher, which were defined as each property set, respectively. The identification of construction work such as concrete pouring and water proofing can be possible through property instance SS, and information was assigned spatial level identification. Each property set for estimating construction cost has its own detailed properties. In this study, estimation is matched under the planning and design phase, and cost of labor and equipment was included in related physical members. The additional properties for result of cost estimation was defined independently as property set, and merged in IFC data model through user-defined Pset.

5. IMPLEMENTATION OF APPLICATION INFORMATION MODEL OF BRIDGE

We implemented a bridge application information model according to the previous chapters.

Geometric model was implemented using IFC entities such as *IfcBeam* and *IfcSlab* which are provided by software programs for BIM (Autodesk Revit Structure 2012). The bridge members which have different physical and spatial semantic information were replaced by most similar classes among IFC entities. The physical and spatial information mentioned in chapter 3 was inputted after completing geometric modeling using software application programming interfaces (API) about each member. Here, semantic information generated by original IFC entities was ignored. The additional properties mentioned in chapter 4 were inputted after generating semantic information about each member. Here, external database built beforehand provides CO_2 emission factors and unit weights when necessary. Figure 5 shows 3D geometric model and graphical user-interfaces (GUI) for additional properties of bridges.

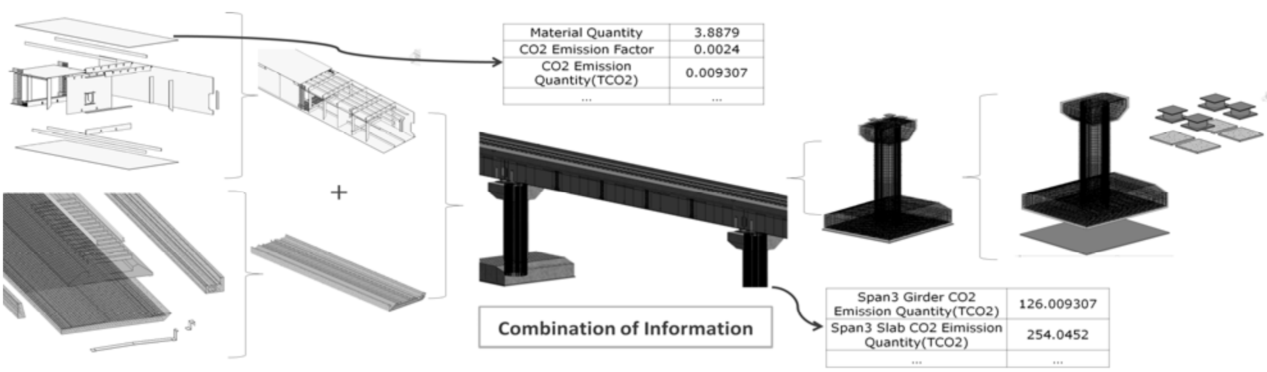

Figure 4. A Basic Principle for Managing the Information of CO_2 Emission

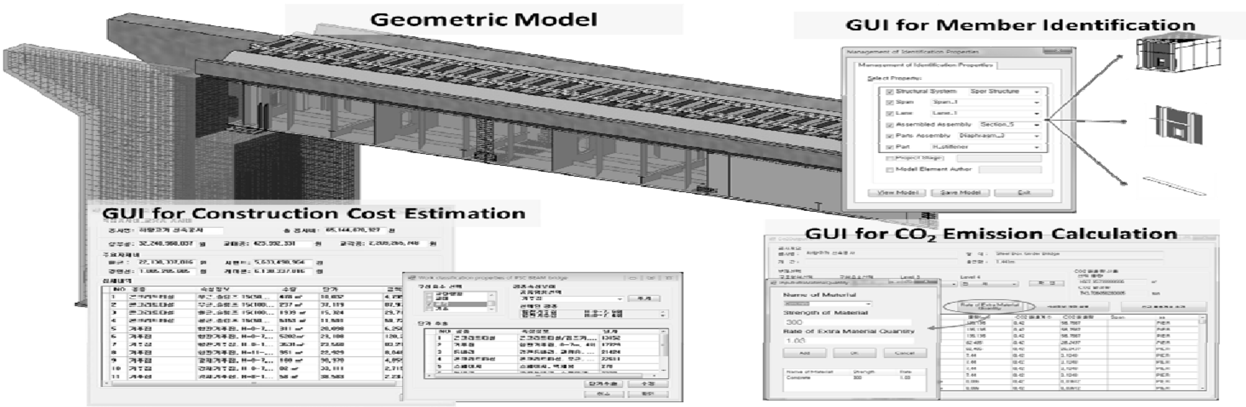

Figure 5. 3D geometric model and GUI for application information modeling

We estimated quantity of CO_2 emission and construction cost according to proposed application information modeling processes. Table 1 shows the results of CO_2 emission estimation based on an application model. Each quantity of emission of bridge member was calculated in SS, AA, PA levels. Table 2 shows the results of construction cost estimation including temporary structure based on the application model. Also, cost each of bridge members could be calculated.

Table 1. Results of CO_2 Emission (some parts, TCO_2)

SS		AA		PA / P	
Super Structure	41.8	Deck	40.56	Slab	28.83
				Protective Wall	8.77
				Cover Plate	0.69
				Track	2.27
		Main Support	1.27	Girder	1.26
				Rib	0.01
		Sub Support	1.26	Diaphragm	0.003
				Stiffener	0.002
				Joint	1.25

Table 2. Results of Cost Estimation (some parts, KRW)

AA	PA	Identification (Spatial)	Cost
Pier	Footing	Concrete Pouring (Deck)	118,572
		Form (Deck)	53,157
		Concrete Pouring (Footing)	2,287,238
		Form (Footing)	1,595,610
		Spacer (Footing)	33,039

6. CONCLUSIONS

IFC data model is a key point of Open BIM. Although IFC-based BIM is gradually spread in bridge information modeling phase, the speed is slow. One of the core factors is the absence of IFC entities for bridge structure. In this study, we proposed an IFC-based bridge information modeling method using user-defined property sets based on IFC framework. In this way, bridge information modeling can have advantages to use current software programs for BIM. The key points to use user-defined Pset for extending the IFC data model schema are to select suitable properties, assign the properties as semantic information, and standardize the rules for applying. As we have seen, we clearly identified the bridge members, and proposed modeling method to estimate the CO_2 emission quantity and the construction cost. Finally, we investigated proposed methods through implementing the application information model of bridges.

Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology(2010-0024404).

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