Developing BIM-Enabled Facility Management Information System in Interior Design

Ju-Hung Lan(✉)

Department of Interior Design, National Taichung University of Science and Technology, Taichung 404, Taiwan, ROC
jhlan@nutc.edu.tw

Abstract. This study demonstrates how to integrate 2D and 3D information in the various design stages and provides an effective facility management solution from a life cycle point of view based on building information modeling (BIM) techniques. The research proposed a framework of design information structure by examining practical design projects. With the proposed information structure, the research applied Autodesk Revit Architecture and Solibri Model Viewer, which employs parametric modeling and visual design techniques, to develop a BIM-enabled facility management information system. The developed system provided consistent information service in various design stages. In addition, facility managers could make inquiries to acquire comprehensive information related with design components or installed facilities in the design project. The overall system provided an effective decision support mechanism to maintain the facility performance from a project's life cycle point of view.

Keywords: BIM · Facility management · FM · Interior design

1 Motivation and Purpose

In recent years, interior design industry has flourished concurrently with the advancement of information technology. The use of computer-aided design software to render the interior design efforts into three-dimensional and realistic drawings has become a popular trend. However, these computer-generated renderings can only portray efforts in the design stage. They cannot provide acceptable mechanisms for managing/maintaining subsequent indoor facilities. Building information modeling (BIM) can be used to collate and establish information concerning various stages of a building's lifecycle, thereby providing users with consistent project information throughout the entire lifecycle of the building. Under the concepts and technical application of BIM, design projects can not only be rendered into two-dimensional and three-dimensional design drawings, but also include water/power/ventilation pipelines, indoor facilities and systems, and equipment and machines, providing a comprehensive and effective project information communication and integration mechanism for developers in terms of planning and design, building and construction, and subsequent maintenance and management [1].

In this context, the present study aimed to develop a facility management information system (FMIS) for indoor projects based on BIM. By applying BIM techniques, the present study investigated the facility management (FM) of indoor projects to

J. Zhou and G. Salvendy (Eds.): ITAP 2016, PartII, LNCS 9755, pp. 57–69, 2016.
DOI: 10.1007/978-3-319-39949-2_6

elucidate how BIM can be utilized to reduce maintenance expenses and mitigate false information or resource wastage caused by inconsistent information at various stages, thereby improving the effectiveness of developing indoor projects and managing/ maintaining subsequent facilities. The proposed system can be used to satisfy the FM requirements of users, providers, and designers/decision-makers at various stages.

2 BIM and FM

The American Institute of Architects (AIA) defined BIM as a type of "modeling technique for combining the information databases of engineering projects". This technique relies primarily on database technology. The structured file specifications of BIM are searchable and comply with local, national, and international standards [2]. Howell and Batcheler asserted that BIM encompasses geometry, spatial associations, geographic information, and data concerning the properties and quantities of various building components. The researcher also contended that BIM can effectively integrate the drawing and non-drawing data in architectural engineering into an information model [3]. Chien defined maintenance management as a frequent and uninterrupted process to ensure that equipment continues to operate at due performance, thereby improving equipment performance and competitiveness [4].

3 Methodology

Based on the life cycle of buildings, the present study aimed to develop a BIM-enabled FMIS for interior design. First, in-depth interviews were conducted to gain insight into the procedures of the building and interior design and renovation projects. Then, the BIM software development toolkit (SDK), was used to analyze the interior design and renovation element groups and FM functions. Finally, actual indoor projects were incorporated into the system to test system performance and determine overall research results. The research method and procedures are as follows:

1. Expert Interviews: Representative architects and interior designers were invited to participate in an in-depth interview survey to gain insight into the development procedures of the building and indoor projects and highlight various problems concerning the generation and collation of information in the various stages of project development. The interview data was collated and analyzed to clarify the challenges of developing an FMIS for indoor projects.
2. System Function Analysis: A collation and review of extant literature review were performed to analyze the hierarchical structures of group element modules for indoor spaces and the function demands of users. The data was then used to formulate the function modules, including the development of the BIM group elements, FM functions, and the design of the user interface.
3. System Development: The interview and system function analysis results were used to develop the system. The FMIS for interior design was constructed using the Revit software and the file exchange information format announced by the Industry

Foundation Classes (IFC). The proposed system provides users with relevant drawings, model information, usage conditions, and facility management and maintenance decisions.

4 Data Collection and Analysis

4.1 Collating Project Interview Data

To investigate the research topic, the present study first interviewed representative architects and interior designers that used computer-aided information technologies in managing projects in order to gain insight into the management procedures and information frameworks of design projects in relevant agencies. In addition, representative building and indoor project cases were collected for subsequent analysis. The interview content focused on the information management framework, document content and classifications, and illustration management required in the overall project execution process. Figure 1 illustrates the building project information framework collated from the interview data. The framework comprises seven items, namely planning stages, construction drawings, 3D computer drawings, valuation information, working drawings, completion drawings, and base images. Figure 2 illustrates the indoor project information framework collated from the interview data. The framework comprises six items, namely, planning stages, construction drawings, 3D computer drawings, valuation information, base images, and collection of papers.

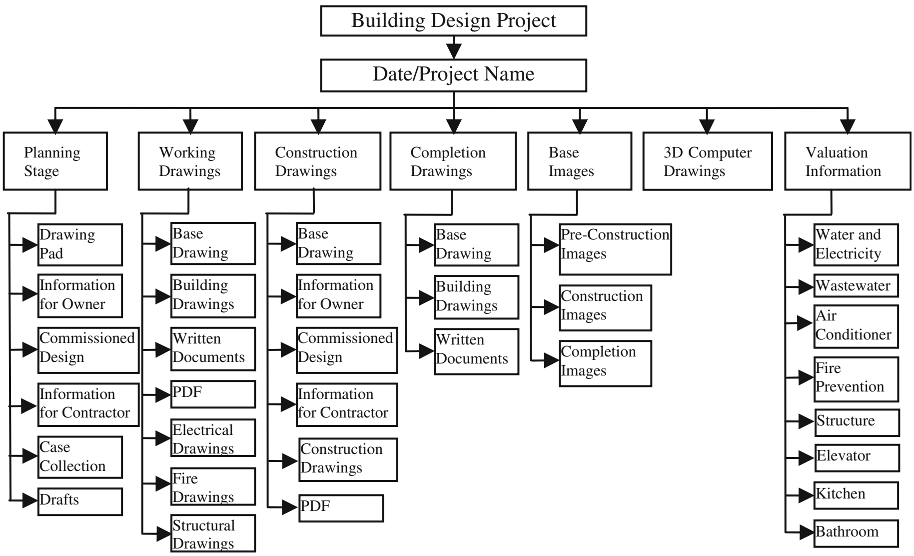

Fig. 1. Building design project information framework

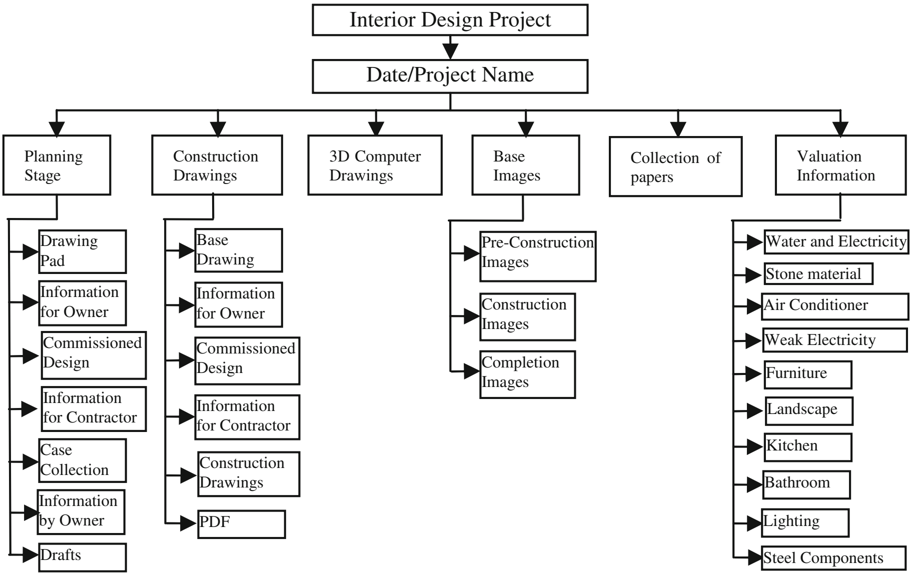

Fig. 2. Interior design project information framework

4.2 Analyzing the BIM-Enabled Group Classification Framework

To determine the feasibility and efficiency of developing a BIM-enabled FMIS for interior design, the present study collated the FM classifications for buildings announced by the International Facility Management Association (IFMA), as well as the building group element classification frameworks proposed in previous studies concerning the Revit Architecture, Revit Seek website, and BIM. Figure 3 illustrates the building facility classifications proposed by the IFMA [5].

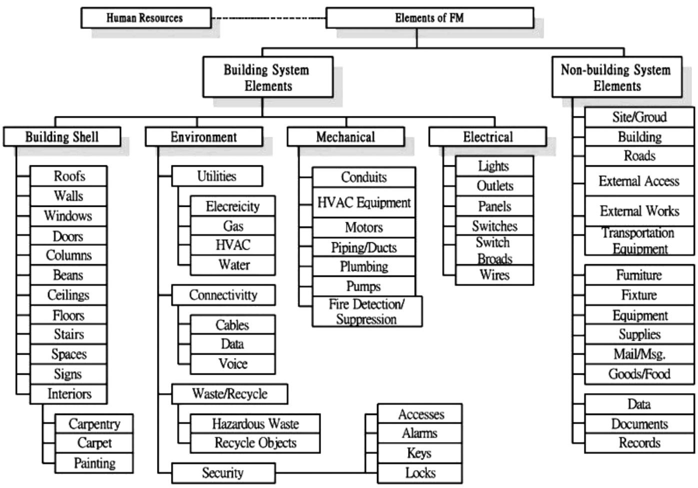

Fig. 3. IFMA group classifications

Table 1. Revit Group Classifications

Building	Indoor	Equipment	Landscape
Volume	Sofas	Ladders	Vehicles
Bases	Tables	Escalators	Plants
Columns	Chairs	Elevators	Sports Venues
Beams	Beds	Kitchen	Site components
Trusses	Cupboards	Bathroom	Views
Walls; Curtain Walls	Lighting	Cupboards	
Doors	Software accessories	Counters	
Windows	Appliances	Sports equipment	
Railings		Instruments	

Table 2. Revit Seek Group Classifications

Building	Indoor	Mechanics	Appliances	Pipes	Facilities
Beams	Beds	Air conditioners	Electricity cables	Water pipes	Benches
Columns	Tables	Air conditioner pipelines	Cooking equipment	Faucets	Parking
Ceilings	Chairs	Air regulators	Electricity boxes	Washing basins	Trees
Walls; curtain walls	Cupboards	Air processor	Lighting	Toilets	Streetlights
Doors	Lighting		Switches		
Windows			Refrigerators		
Stairs					
Trusses					
Gutter					

The group classifications included in the Revit software are tabulated in Table 1 [6]. The group classifications for Revit Seek are tabulated in Table 2 [7]. The group classifications proposed in previous BIM studies are tabulated in Table 3 [8].

4.3 The BIM-Enabled Group Classification Framework for Interior Design Projects

After summarizing the aforementioned figures and tables, the present study found that the groups in Revit were based on building design and lacked interior design group elements and classifications. This issue was improved in the database on the Revit Seek website by including interior design-related group elements. However, most of the elements were furniture group elements and lacked renovation ones. Therefore, the group database was relatively insufficient. A number of previous studies proposed classifications of BIM group elements based on building. However, certain classifications were different to

Table 3. Group Classifications Proposed in Previous BIM Studies

Structure	Door and window	Curtains	Decoration	Mechanics	Water and electricity	Air regulators
Columns	Doors	Curtain walls	Ceiling accessories	Elevators	Water intake/Discharge components	Regulator host
Beams	Windows	Curtain windows	Floor accessories	Mechanical parking	Sewage pipes	Ventilation system
Floors			Wall accessories		Rainwater pipes	Refrigerant pipe system
Walls					Water intake/Discharge systems	
Stairs					Hygiene equipment	
Roofs					Lighting	
					Weak electricity	
					Pipes	
					Ground	
					Switches	
					Fire prevention	
					Fire pipes	

those for interior design projects. Therefore, the present study collated the aforementioned classifications and independently classified interior design project groups into eight classifications, specifically, structure, doors and windows, building, renovation, water and electricity, ventilation, machines, and equipment. Associating elements were then allocated into these classifications, as shown in Table 4.

5 The Development of a BIM-Enabled FMIS for Interior Design

5.1 Incorporating Projects

To develop the system, the present study first incorporated the information of an actual interior design project. The information was then organized based on the framework illustrated in Table 4. The Revit Architecture was used to establish the relevant group elements for the interior design projects. At this stage, the group elements were established using the dimension style of two-dimensional construction drawings. Once the group elements were established, the object information within the project model was verified (e.g., size, specifications, and material properties).

5.2 Establishing Group Elements

The present study established group elements in the structure, doors and windows, building, and renovation classifications. The manufacturing method, material, and

Table 4. The Group Classification Framework for the BIM-Enabled Interior Design Project (Collocated in the Present Study).

Structure	Door and window	Building	Renovation/Decoration	Water and electricity	Air regulators	Mechanics	Equipment
Columns	Doors	Curtain walls	Ceiling renovation	Water intake/Discharge components	Regulator host	Elevators	Furnaces
Beams	Windows	Curtain windows	Floorboard renovation	Sewage pipes	Ventilation system	Mechanical parking	Lighting controller
Floors		Outer wall accessories	Floor renovation	Rainwater pipes	Refrigerant pipe system		Air conditioner controller
Walls		Umbrellas	Wall surface accessories	Water intake/Discharge systems			
Stairs		Fences; railings	Wall accessories	Hygiene equipment			
Roofs			Cupboard renovation	Lighting			
			Fixed partitions	Weak electricity			
			Arranged displays	Pipes			
				Ground			
				Switches			
				Fire Prevention			
				Fire pipes			

information of each element are presented in the description page. Once the classifications were established, the interference checking function was executed to check for erroneous information among the groups and elements in the project model and overlapping error dimensions. Establishing group elements were completed once no errors were confirmed.

1. Structure group:
   (a) Establishing the structural column: The structural column in the design project was a reinforce concrete (RC). Thus, the element was modified from the structural column group in Revit by changing the group type, element information, and properties, thereby completing the establishment of the structural column for the design project.
   (b) Establishing the floorboards: The floorboards in the design project were RC structures. Thus, the element was modified from the floorboard group in Revit. The floorboards in the design projects were paved with a terrazzo surface. Thus, the presents study modified the group type to RC material. The original floorboard group in Revit did not include a field for surface material properties. Therefore, the present study included a terrazzo surface layer to create a new structural floorboard.

(c) Establishing the walls: The wall group in Revit was modified. The wall was constructed with RC concrete with cement painted on the surface, hence RC concrete was chosen as the structural material in the edit wall type settings, and a layer of decorative cement paint layer was added to both the interior and exterior to create a new wall.

2. Door and window group:
   (a) Establishing doors and windows: The door and window group available in Revit was modified. After selecting the type of door/window, its properties are edited according to the project and added as a new door or window.
3. Decoration group:
   (a) Establishing elevated floorboards: The group elements in Revit are used as the components in the construction. Since there are no floorboard renovation components for interior design, this study must establish a set of group elements related to interior design. Hence the original floor components in Revit were used as a foundation for further modifications. The elevated floorboard consists of three layers, sequentially they are the elevated base layer, the shockproof structural layer and the surface layer. This is done by duplicating the original floorboard characteristics and using the component editor to insert the base layer and the shockproof structural layer into the internal structure. After modification according to the specified dimensions required in the project, the elevated floorboard component is added to the interior design, as shown in Fig. 4.
   (b) Establishing Light partition wall: Light partition walls are created by modifying the walls that are originally available in Revit. Light partition walls can be constructed as single-sided or double-sided. Single-sided walls are used as decorative walls fixed on the original walls. Double-sided walls are used for dividing spaces. Single-sided light partition walls consist of three layers, sequentially they are: Type-C aggregate, the calcium silicate board, and surface paint; Double-sided light partition walls consist of five layers. From the interior to the exterior, sequentially they are: Type-C aggregate, calcium silicate boards on both sides, and surface paint on both sides. The original wall properties are duplicated as single and double-sided light partitioning walls, and their properties are modified with the component editor, and after inserting the layers into the internal structure and making modifications according to the specified dimensions required in the project, a new light steel frame partition wall component is added for interior design use, as shown in Fig. 5.
   (c) Establishing waterproof brick partition wall: The waterproof brick wall was constructed using the brick wall originally available in Revit as a foundation. In the construction of the waterproof brick wall in the bathroom, the wall is divided into four layers. The sequence is: the brick layer, the cement layer, the waterproof layer, and the surface layer. However, an extra decorative board was added on top of the surface and so there are total of five layers. The component characteristics were edited on the original brick wall type to become a waterproof bathroom wall. After the internal structure of the layers is altered in

sequence, modified and edited for the project, they are added as waterproof brick partition wall component, as shown in Fig. 6.

(d) Establishing movable glass partition: Partitions are created by modifying walls, doors or windows that are originally available in Revit. In our case, we used a movable glass partition, hence the window group was modified. The window component was imported and its properties modified according to the specified dimensions required in the project. The movable glass partition component is added for interior design use, as shown in Fig. 7.

(e) Establishing cabinet: The constructions of cabinets are carried out using the group elements that are already available in Revit. However, hollow bodies and countertops are separate components and require manual configuration. This study imported the cabinet and then the countertop component and modified their properties. The cabinet component is added for interior design use, as shown in Fig. 8.

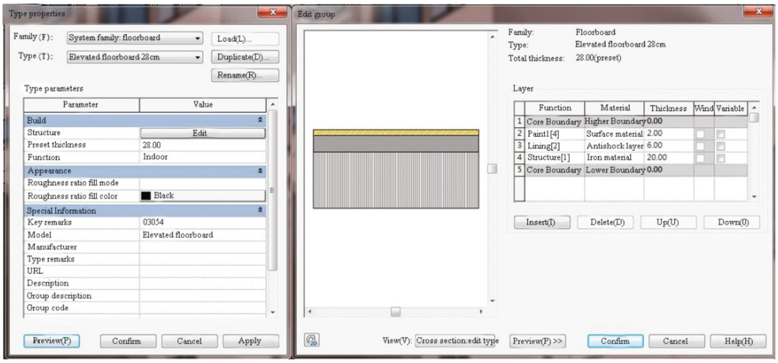

Fig. 4. Elevated floorboard group element

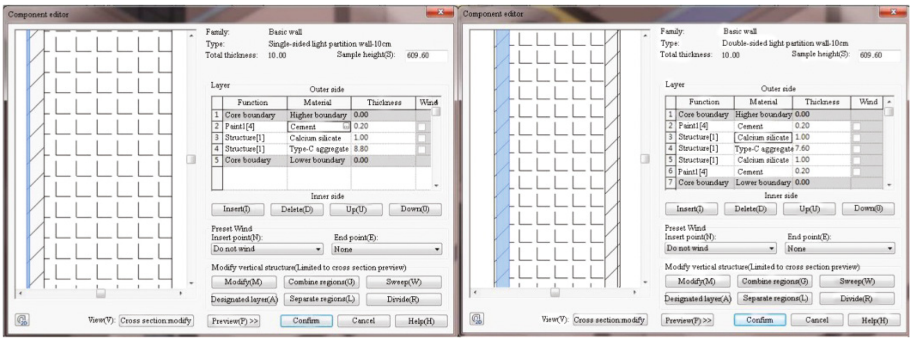

Fig. 5. Light partition wall group element

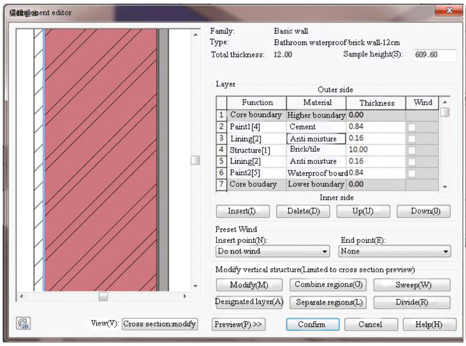

Fig. 6. Waterproof brick partition wall group element.

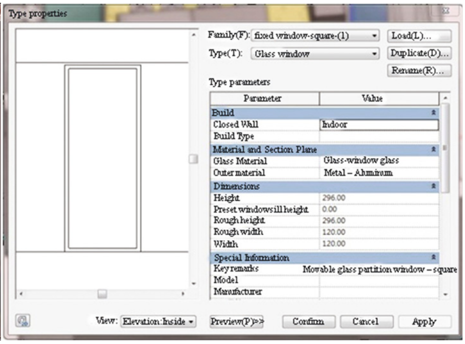

Fig. 7. Movable glass partition group element

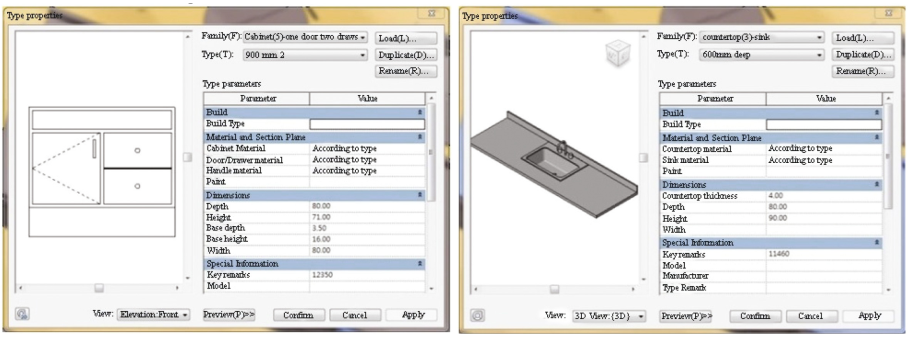

Fig. 8. Cabinet group element

5.3 The Facility Management System Interface

Industry Foundation Classes (IFC) is a model data exchange system proposed by the International Alliance for Interoperability (IAI) targeting the data exchange standards in the AEC/FM design fields. Its objective is to allow all the information and groups within a building's life cycle to have a common protocol with IFC construction information files that are convertible so as to increase the convertibility and reusability of data. After the file was exported, this study attempted to use the BIM model inspection system, Solibri Model Viewer, which was developed by Autodesk, as an intermediary software between building information model and facility management queries. Solibri Model Viewer model inspection system is able to read IFC files, and all the model data within the group elements can be displayed and is a stable and practical intermediary software. This study used Solibri Model Viewer as the system query interface, where our building information models were exported as IFC files and were used with Solibri Model Viewer. The system interface is shown as Fig. 9. Using this model inspection system's control interface to display all the data and illustrations from our building information

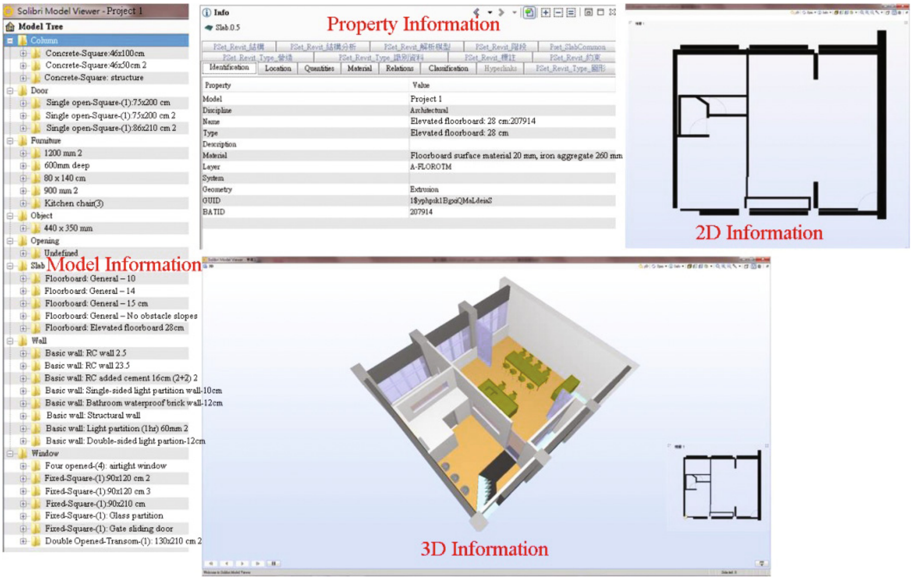

Fig. 9. The system interface

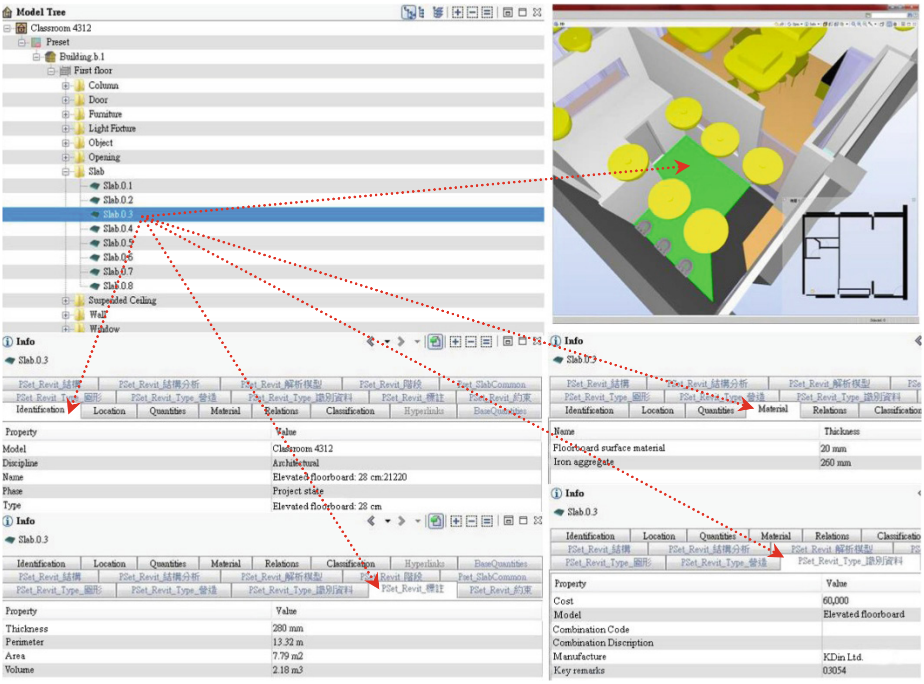

Fig. 10. Information windows for inquiry

model, it allows all users to share the contents of this model and also to select the model contents that the individual user would like to investigate further, as well as provides users with a high degree of interaction.

5.4 Facility Management Inquiry Function Development

This study formulated the facility management system functions for managers and general users according to the users' requirements. For the manager, system inquiry interface functions include IFC model information and project information contents. Project name and building space name inquiries can be done. In addition, for instance, managers who inquire for related information for elevated floorboard facilities can utilize the tree chart as shown in Fig. 10, to inquire about elevated floorboard components within the elevated floorboard group elements. The system will then highlight spatial location in the 3D window, and in the data window, the user can inquire for the facility name, category, material, surface area, floors, location, quantity and other data.

6 Conclusion

This study used BIM techniques to develop a set of interior design facility management information systems, and investigated data and maintenance management issues related to interior design life cycles. This study also proposed a solution with an effective interior design project facility management system. The study results include:

1. By analyzing literature and interviews and summing up the group elements classification framework analysis used in interior design projects, exclusive group elements were created through the frameworks. The project content specifications and information were structured into an integrated database for group elements, and the life cycle concept and BIM techniques were introduced into interior design projects to make it easier to establish information, modify, operate, analyze, communicate designs, perform maintenance and modify designs and manage facilities in the future for buildings with similar life cycles.
2. This study was guided by realistic interior design projects, and used Revit to perform system development and to construct a building information model and group element system for interior design use. After constructing the interior design information model, the file is exported as an IFC data model, which verifies the feasibility of using IFC data model files. Group classification and data contents show that there are no errors and that they are consistent.
3. Solibri Model Viewer was used as a facility management information system and inquiry interface. After function testing according to users' requirements and user interface design, it was found that the system differs from other facility management systems in that this system can display floor data, positions and all facilities, furniture, and hardware decorations within the space in the system window as well as illustrate 2D and 3D drawings. In installation queries, the installation in question will be highlighted in the window, and the positional relationship between the installation and space can be observed and the name, shape, dimensions, amount

and other properties of the installation will be shown. These are some of the differences with other facility management systems that contribute to user friendliness.

Acknowledgements. This study is supported by Ministry of Science and Technology, Taiwan, R.O.C., MOST 104-2221-E-025-013. The author is grateful to this support.

References

1. Eastman, C., Teicholz, P., Sacks, R., Liston, K.: BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. Wiley, New Jersey (2008)
2. AIA KnowledgeNet. http://network.aia.org/technologyinarchitecturalpractice/home/bimstandards
3. Howell, I., Batcheler, B.: Building Information Modeling Two Years Later – Huge Potential, Some Success and Several Limitations, The Laiserin Letter (2005)
4. Chien, S.K.: Use BIM to Construct Building Facility Management System (in Chinese), Master's Thesis, Department of Construction Management, Chung Hua University (2011)
5. International Facility Management Association. https://www.ifma.org/
6. Autodesk Revit Architecture User Guide (2014)
7. Autodesk Seek: BIM Content Catalogue. http://seek.autodesk.com/
8. Wang, C.S.: A Study to Develop Decoration Component based on BIM (in Chinese), Master's Thesis, Department of Civil Engineering, National Cheng Kung University (2009)