Development of Conceptual Integrated Construction Information Model

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ABSTRACT

Construction projects have extensively adopted building information modeling (BIM), and various BIM-based technologies have been developed for the management of information through a construction life-cycle; however, construction managers are currently limited in their ability to recognize relationships the various types of BIM-based construction information, such as design, scheduling, quality, safety and field management. Therefore, this paper proposes an integrated information inference model that uses various types of construction information in a project information management system (PMIS). The proposed approach will help managers avoid overlooking important relationships and making the errors that are typically made when the construction information is integrated manually.

Keyword: BIM, Construction Information, Project Management, Integration, Information Management

1. Introduction

Building information modeling (BIM) has been widely adopted to manage the physical and functional characteristics of a building. Since BIM technology can provide an object-based parameter management [1], various engineering analyses of each construction project phase, (e.g., energy analysis, structural analysis, estimation, and scheduling) have been conducted using BIM technology. In the BIM-based data management system, there is an integrated building model throughout the whole life-cycle of the building in the industry foundation classes (IFC) file format [2]. The IFC is an international standard file format used to represent building information in various BIM-based software programs, ensuring the consistency and flexibility of the digital representation of the building information. Because the IFC schema contains relationships between the different types of building information, using the IFC schema to manage the construction has potential benefits as explained in a previous study [3].

Besides, in the last decade, increasing construction productivity has been one of the most important is-sues in construction concerning the knowledge of construction management [4]. In this regard, construction productivity depends on construction in-formation management on the site of the project [5]. Since construction information is used as input data to manage the construction work, accurate information from the construction site must be adopted to plan subsequent activities in time; however, the construction information is created and managed by too many types of required information to integrate easily. On a construction site, there are various types of construction information: 1) schedules of the activities, 2) the design model, 3) total quality management, 4) safety management, and 5) field management. These types of information could be related to each other when managing a construction project using IFC schema.

Although construction management involves many types of related information, construction managers currently face several problems when trying to recognize relationships among the various types of BIM-based construction information, including unfamiliarity with or lack of information management knowledge, a large amount of information, secondary relationships among related information, and subjectivity of the personnel collecting information. Therefore, using a BIM-based approach, this paper proposes an integrated model that considers the various types of construction information on site. To that end, after the types of construction information have been defined through the literature review, the conceptual integrated model for considering the information will be developed with focus on BIM-based information management.

2. Related Works

2.1 IFC-based BIM data

There are three approaches to data exchange: direct link, proprietary file exchange, and public product data model exchange [6]. The direct link approach uses application performance interfaces (APIs) to create property data from one's own design program and export the data using another receiving design program such as geometric description language (GDL, ArchiCAD). However, this approach is limited to BIM-based programs with GDL capability. The second approach, proprietary file exchange, is a file or streaming interface developed by an organization solely for interfacing with that company's programs. An example is design web format (DWF, Autodesk). The third approach, public product data model exchange, is an open and publicly managed schema and language, such as IFC. However, EXPRESS general purpose information modeling language and encoding rules are complex and difficult to parse and recognize without STEP technology [7]. To that end, there are various information management system to extract and directly use the IFC-based BIM information from various engineering categories over the whole life cycle of the building.

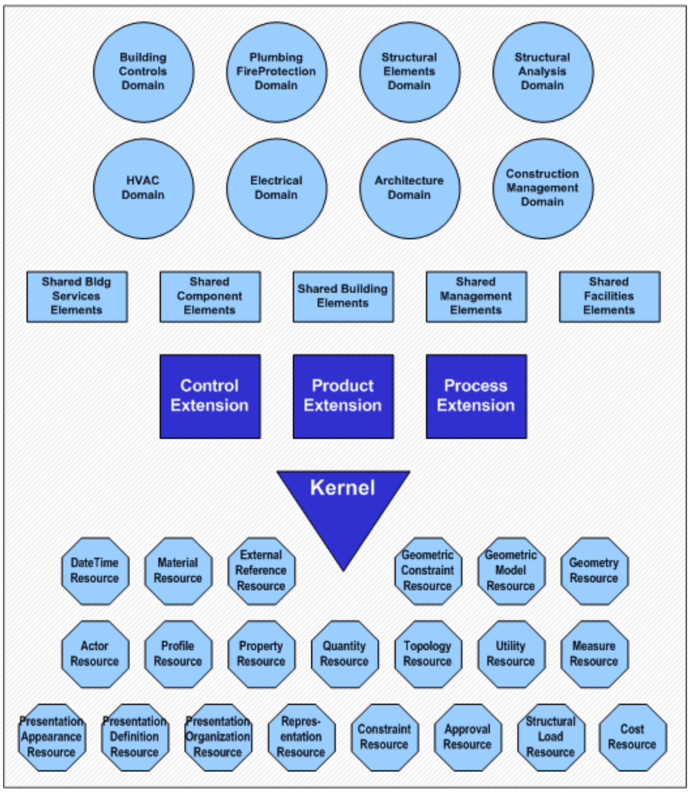

Figure 1. IFC4 schema [2]

2.2 Design management

Currently, there are five dimensions of BIM contents in a construction project, grouped by objectives and methodologies of adoption. Each dimension of BIM provides the following functions [8]: 1) 3D BIM (virtual model) provides existing conditions models, safety & logistics models, various types of animations, prefabrication, and field layout; 2) 4D BIM (scheduling) provides project phasing simulations, lean scheduling, and visual validation for payment approvals; 3) 5D BIM (estimating) provides real time conceptual modeling and cost planning as well as quantity extraction to support detailed cost estimates, trade verifications from fabrication models, value engineering, and prefabrication solutions; 4) 6D BIM (sustainability) provides conceptual energy analysis, detailed energy analysis, sustainable element tracking, and green building tracking; and 5) 7D BIM (facility management) provides life-cycle BIM strategies, BIM as-built model, BIM embedded operation and maintenance manuals, construction operation building information exchange (COBie) data population and extraction, and BIM maintenance plans and technical support.

2.3 Schedules of the activities

To conduct a construction project systematically and effectively, the scheduling plan must be developed within the proper scope and period. In general, the scheduling plan is organized by work breakdown structures (WBS) of the subjective building model. In this regard, management of the project schedule involves several issues: 1) milestones of the critical activities in the scheduling, 2) master plans of each activity on a monthly and weekly basis, 3) actual data on the execution of each activity, 4) change management and 5) mitigation plans for construction schedule delays. From the perspective of data management, the various types of building elements can be referenced to recognize the sequences of the activities, and the quantity and construction method information of each building element can be referenced to calculate activity durations [9].

2.4 Total quality management

The manufacturing industry has developed total quality management (TQM) concepts, first adopted in Japan and then used globally, to increase productivity, decrease product cost and improve product reliability [10]. In TQM, there are seven factors that manage quality through the project process: 1) management commitment and leadership, 2) training, 3) teamwork, 4) statistical methods, 5) supplier involvement, 6) customer service, and 7) cost of quality. Furthermore, there are three factors related to construction industry: 1) quality of codes and standards, 2) drawings and specifications, and 3) constructability analyses. Currently, TQM-based quality management systems are commonly used on construction projects.

2.5 Safety management

Before initiating the construction work on site, the construction manager has to consider the required construction operations when planning construction work. In this regard, the manager should systematically and adequately analyze and recognize the risk factors related to each construction activity with appropriate measures, including the following [11]: 1) number and location of office facilities, personnel rooms and storage locations, 2) placement of machinery and equipment, 3) placement of excavated earth and filling earth, 4) placement of areas for loading, unloading and storing of the construction materials, 5) traffic in the construction site area, 6) collecting, storing, removing and disposal of waste and hazardous materials, 7) firefighting, and 8) arranging storage areas and handling of hazardous materials.

2.6 Field management

On a construction site, the actual information on the executed activities is collected by a project information management system (PMIS) [12]. In general, the PMIS provides various functions for a construction project on site, including electronic approvals, scheduling, earned value, and quality. To integrate construction information related to quality and safety management, the information collected on site has to relate with building elements based on objects. In addition, the construction site information can also be related to each activity in order to plan reports, mitigate delays, and ensure quality, and safety.

3. BIM-based Integrated Information

3.1 Conceptual integration of information

Because integrated construction information requires various types of management information on site, BIM-based design, scheduling management, quality management, safety management, and field management information might be considered together in order to conduct efficient and systematic construction management. In this regard, BIM-based design information can contain various dimensions of BIM, such as 4D, 5D, 6D, and even 7D. To integrate the information throughout the whole building life cycle, IFC-based BIM information should contain all of the data within a single integrated BIM-based building model. Figure 2 illustrates the conceptual integrated construction information model.

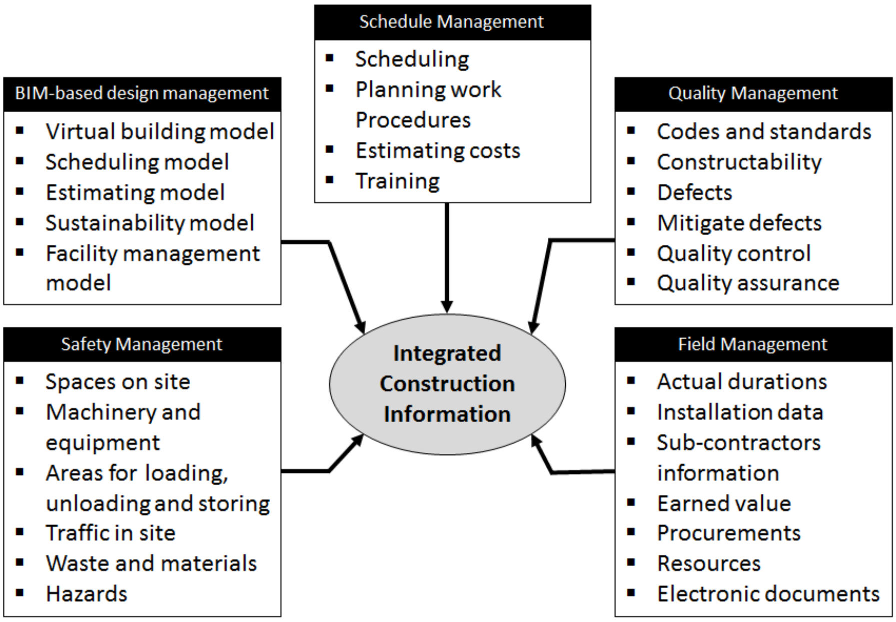

Figure 2. Conceptual integrated construction information model

Besides, quality and safety management required information about activity-oriented management knowledge. For this reason, the codes and standards, constructability, defects and mitigation measures related to the quality management of a building element can be linked to BIM-based design information, like safety management, including the locations of work spaces, the nature of various machinery and equipment, traffic, locations of waste and materials, and hazard reports. In addition, the information collected on site such as actual installation of the building elements, information on sub-contractors that participated in any activities, procurements, and resources, is linked to real time quality and safety management.

3.2 Process of information integration

Since the BIM-based design information is managed by objects, the activity information can be related to an object, which in turn has relationships with other objects as building elements. In this regard, a construction manager can conduct scheduling analysis using WBS with quantity information about the work packages as a set of activities based on an object. In addition, after generating a work packages using BIM-based design information, the quality and safety data can be applied to the activities in the procedure for relationship inferring with collected field information as an actual information of a work performance, including information of PMIS on site. Subsequently, the construction information can be merged upon considering the relationships of the information using the inference algorithm. Consequently, the integrated construction information updates the PMIS on site for construction management updating an as-built building model. The integrated construction information can be used in the facility management phase of a project life-cycle. Figure 3 shows the process of BIM-based information integration.

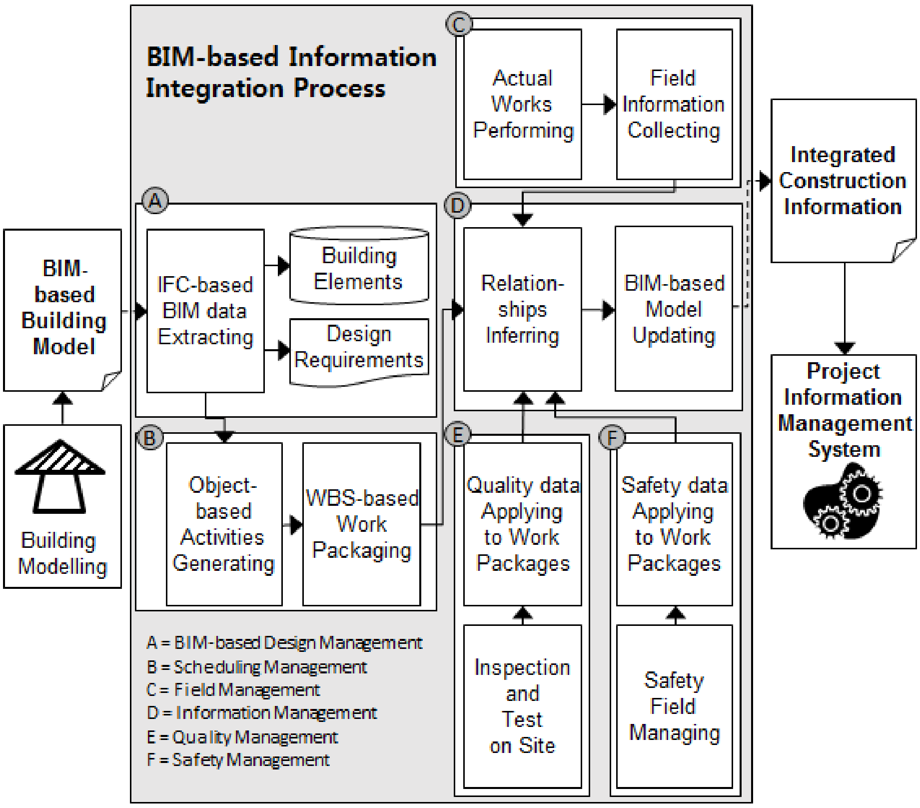

Figure 3. BIM-based information integration process on site

4. Conclusion

Since there has been increasing interest in information management using various technologies throughout the entire building life-cycle, various types of construction information can be generated and managed by PMIS in the construction phase. According to the literature review, various types of construction management can be achieved using BIM-based technology and dimensions ranging from 3D to 7D. In addition, BIM-based design, scheduling, quality, safety, and field management are integrated as construction information for use in PMIS and updated the integrated as-built building model in practical perspective. To increase the efficiency of the application of information, this paper proposes an integrated model that considers various types of construction information on site, including the design, scheduling, quality, safety, and field management.

The contributions of this study include the elimination of the errors and omissions that typically happen when the construction information is integrated manually. The proposed approach can be developed to automatically infer the relationships among various types of information in construction management that is focused on BIM-based objects. In addition, using the computerized inference approach, the integrated information of construction management can ensure consistency and accuracy simultaneously.

Since this is a basic study aiming to develop the integrated information model of construction information, a conceptual integration model is developed for the integration process. To develop the proposed model into a more sophisticated and practical form, the detailed types of each management category must be defined in order to infer the specific relationships from a pragmatic perspective. In addition, the proposed approach must be verified and validated by various experts and practitioners through reliability and validity analysis.

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