International Journal of Engineering & Technology, 7 (3.7) (2018) 436-439

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

A Process for Integrating Civil and Architectural Data in the AEC Projects: Case Study in South Korea

Jongsung Won[1], Seonwoo Kim[2], Honghyun Kim[3], Jaeyub Kim[1]*

[1] *School of Architecture, Korea National University of Transportation, South Korea*
[2] *Syntegrate Limited, Hong Kong, China*
[3] *Syntegrate LLC., South Korea*
**Corresponding author E-mail: kimjy67@ut.ac.kr*

Abstract

This paper aims to propose a process to efficiently integrate and manage architectural and civil data in the design and construction stages of architecture, engineering, and construction (AEC) projects using building information modeling (BIM) and civil information modeling (CIM) technologies. The proposed method helps practitioners to understand complex geometries and unknown spaces of AEC projects by producing accurate integrated models, thereby reducing the number of design and construction errors detected on site and improving the process of decision making. It can integrate drawings of architectural and civil elements, drawings and maps of geology and topography of earth, 3D survey results, and other measured data. In order to validate the applicability of the proposed process, it was applied to the Gwangmyeong Cave project in South Korea. In the case, dozens of GB of 3D survey data were successfully converted to a less than 100 MB BIM model.

Keywords: *Data Integration; Architectural Data; Civil Data, Building Information Modeling (BIM); Civil Information Modeling (CIM); Process*

1. Introduction

The United States (US) Bureau of Labor Statistics ranks the architecture, engineering, and construction (AEC) industry as having the lowest level of data usage and low productivity growth out of 17 US industry sectors [1]. Moreover, the overall digitalization level of the AEC industry is also the lowest except for the agriculture and hunting industries [2]. There are still overlaps of, duplicated uses of, and dependencies on data since various project participants, such as architects, builders, structural engineers, and civil engineers, participate in an AEC project [3]. Consequently, the cost of inadequate interoperability in the US capital facilities industry is estimated to be US Dollar 15.8 billion per year [4].

To improve the digitalization level and reduce the cost caused by inappropriate data exchange in the AEC industry, efficient data integration methods for projects are required. Since architectural and civil data are fundamental in the design and construction stages of AEC projects, from the perspective of the file sizes of data and the frequency of data usage, they should be integrated for efficient data management.

However, several challenges exist in integrating architectural and civil data in the design and construction stages of AEC projects. First, analogue data, including pictures and hand drawings, should be converted to digital data. Second, due to comparability issues between different types of digital data, including maps of the geology and topography of the earth, architectural and civil drawings, two-dimensional (2D) and three-dimensional (3D) survey data for civil and architecture works, building information modeling (BIM) models, civil information modeling (CIM) models, etc., it is difficult to convert and integrate them into data models. Third, the tolerances of civil data are different from those of architectural data. For example, contour intervals in the topographic maps included in civil data are too large for use in architecture works without appropriate adjustment. Other main challenges for the data integration include the huge file sizes of 3D survey data and inconsistent coordinate systems and datum points of the collected architectural and civil data.

In order to address these challenges, this paper proposed a process to efficiently integrate, utilize, and manage architectural and civil data using BIM and CIM technologies. A BIM model is a digital representation of the physical and functional characteristics of a facility [5]. BIM is a spatial and data communication technology commonly used in the AEC industry and can be systematically and efficiently integrated with identification and data acquisition technologies [6]. The characteristics of CIM are similar to those of BIM because CIM models contains geometry and

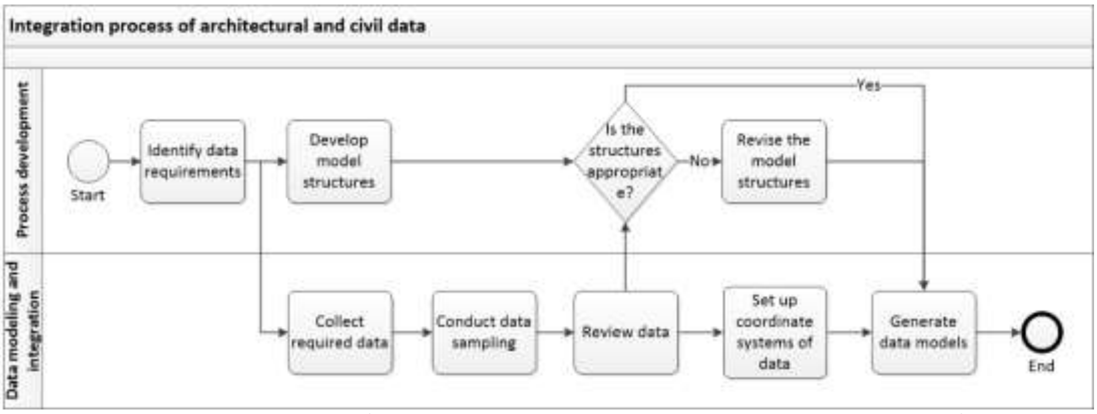

Figure 1: The proposed integration process for architectural and civil data in the design and construction stages of an AEC project.

semantic information as well, like BIM models. However, while BIM focuses more on the generation, utilization, and management of building-level data, CIM focuses on the generation, utilization, and management of civil- and infrastructure-level data, such as tunnels, caves, earth works, and bridges.

Therefore, BIM and CIM can be used to ensure the efficient data integration of architecture and civil works of AEC projects. The proposed method can integrate data included in the drawings of architectural and civil elements, drawings and maps of the geology and topography of the earth, 2D survey data, scanned 3D survey results, and other measured data. It helps practitioners understand complex geometries and unknown spaces of AEC projects by producing accurate integrated models, to reduce the number of design and construction errors detected on site, and to improve the decision-making process. Consequently, it helps project participants efficiently and accurately design the projects and construct them.

The structure of this paper is as follows. The next section reviews previous studies on data integration in the AEC industry. The third section proposes a process to integrate architectural and civil data into data models. The fourth section describes a case study to check the applicability of the proposed process, followed by results and discussions of the case study in the fifth section and conclusions of this paper in the fifth section.

2. Literature Review

Many previous studies have proposed data integration methods in the AEC industry. However, most previous studies have focused on integrating BIM and a geographic information system (GIS) [7-16]. GIS is commonly used for city- and region-level data management and a database system that manage both spatial and non-spatial data [17].

Cheng et al. (2015) and Deng et al. (2016) proposed a semi-automated framework to map BIM and GIS schema. Irizarry et al. (2013) utilized semantic web technology, which allows data to be shared and reused, to integrate BIM and GIS. Developed BIM-GIS data integration methods have been applied to various domains in the AEC industry, such as in the support of construction activities [9] and the visualization of supply chain processes [10].

Although integrated BIM-GIS data could be used to partially manage civil data, they have been not enough to manage general civil data in AEC projects due to the low level of details (LoDs) of integrated data models. They could not provide accurate geometry information regarding civil data models as GIS data do not focus on data generation, utilization, or management in the design and construction stages. Previous studies on BIM-GIS integration have focused more on building-, region-, and city-level information than civil-level information. Consequently, studies on the integration of architectural and civil data in the design and construction stages of AEC projects are still lacking. Therefore, in this paper, a data integration method for architectural and civil data in the design and construction stages of AEC projects was proposed to accurately and quickly generate, utilize, and manage physical as well as non-physical information.

3. Proposed Data Integration Method

The proposed integration process for civil and architectural data was divided into two phases: process development and data modeling and integration phases. Figure 1 shows the proposed data integration process. The details of each phase were explained in this section.

3.1 Process Development Phase

The process development phase was composed of two steps: (1) identification of data requirements and (2) model structure development.

(1) Identification of data requirements
Since BIM and CIM models contain various types of architectural and civil data, through using BIM and CIM technologies, they can be converted into integrated or linked models. Architectural data that might be integrated include architectural drawings and specifications, pictures, BIM models, etc. Civil data that might be integrated include geological maps, topographic maps, 2D survey data, scanned 3D survey data, pictures, CIM models, etc. However, in order to integrate information obtained from pictures, image recognition, extraction algorithms, or photogrammetry technologies are additionally required. A set of architectural and civil data to be integrated into a data model can be differed according to goals and characteristics of the project, its participants, and implemented technologies.

(2) Model structure development
Based on the requirements for integrating the collected data in AEC projects, model structures of integrated data models should be developed before generating the data models. Until integrated BIM and CIM models are fully generated and integrated, the developed model structures are needed to be repeatedly modified according to their file sizes and required LoDs of a master model and its sub-data models. If model structures are modified, their version should be continuously managed for efficient management of data models. Furthermore, prior to developing the model structure, objectives of and relationships between each sub-model, such as which sub-models should be checked together for specific activities, should be considered simultaneously.

3.2 Data Modeling and Integration Phase

Data modeling and integration phase was composed of five steps, which are (1) data collection, (2) data sampling, (3) data review, (4) setting up coordinate systems of data, and (5) data model generation.

(1) Data collection
Based on the identified data requirements of AEC projects, project participants can collect various types of architectural and civil data. However, according to project characteristics, part of architectural and civil data required for integration might not be collected.

(2) Data sampling
The file sizes of 3D civil survey data are relatively larger than other types of data. 3D civil survey data with more than dozens of gigabytes are commonly found in the AEC projects if they include site or mountain information. Due to performance limitations of BIM and CIM software as well as hardware, it is occasionally difficult to efficiently manage BIM and CIM models with huge file sizes. Therefore, a set of necessary data to be integrated into a data model should be partially extracted from 3D civil survey data to reduce data size and to achieve efficient data management. For this step, data sampling might be required.

(3) Data review
The collected data should be reviewed since they have different formats, standards, and LoDs; in particular, survey data might have different standards and original settings if different systems and software are used. From the perspectives of scale and standards, architectural drawings are different from civil ones. Therefore, in order to integrate various data and models from various sources, their coordinate systems, the file sizes of the architectural and civil data models, and the design limits of the software used to generate, utilize, and manage data should be checked before the data integration.

(4) Setting up coordinate systems of data
They can have different coordinate systems if architectural and civil data are generated or collected from different software packages. For example, there are two types of coordinate systems commonly used for civil survey data, which might have different location coordinate values. They are Geodetic Reference System 1980 (GRS80) and World Geodetic System 1984 (WGS84). Different coordinate systems might cause inconsistent geometry information in an integrated data model. Therefore, if different coordinate systems are used for each model, they should be unified to efficiently integrate and manage collected data. Coordinate systems can be converted into other ones using software, such as Leica Cyclone.

(5) Data model generation
Using adjusted model structures and coordinate systems, integrated architectural data models (i.e., the BIM models) and civil data models (i.e., the CIM models) can be generated. Since the developed model structures also define the relations among their sub-data models, the generated BIM and CIM models are integrated and linked without additional works in the data model generation step.

4. Case Study

The proposed data integration method was applied to Gwangmyeong Cave project in South Korea to check its applicability. Gwangmyeong City Government have redeveloped a big mining cave and its surrounding areas as a cultural heritage theme park since 2011. The area for master-planning of the project was 861,456.912m2. The area is composed of a mountain with rocks and stones, caves, a square, access roads, and other facilities including a resource recycling facility. The Gwangmyeong City decided to adopt BIM for master-planning of the project to generate model data for each component and integrate and manage them in the design, construction, and operation stages. 3DExperience was used as a BIM authoring tool in this project.

In the project, collected architectural data were a set of architectural drawings and civil ones were a set of geological maps, topographic maps, 2D/3D survey data, and pictures of construction sites, the mountain and the caves with different data formats. 3D survey data were collected using the Leica 3D scanner. Based on the plans of cave development and characteristics of collected data and sub-data models, the structure of the integrated data model for the project was developed. The integrated model was classified into three sub-models for its efficient management: (1) Mountain (civil data), (2) cave (civil), and (3) facility models (architectural).

In the early stage of the project, although file sizes of survey data for the inside of the cave were larger than 20GB, it was reduced through extracting a set of necessary data from collected survey data without loss of data quality using Leica Cyclone. The details of collected data were analyzed first for data different from those of architectural data due to their different characteristics. Since origin points of topographic maps, geological maps, and survey data were inconsistent, their location information was also adjusted before integrating the collected data (Fig.2 and Fig.3). The integrated model was utilized to design and construct stairs and canopies in the square in front of the cave entrance, monorails on the mountain, and 3D theater in the cave.

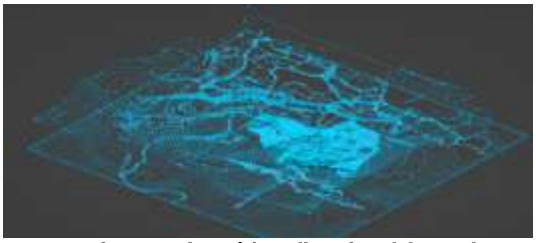

Figure 2: Original contour data of the collected civil data in the case (copyright: Syntegrate LLC and Gwangmyeong City)

Figure 3: Generated terrain data model in the case using the collected contour data (copyright: Syntegrate LLC and Gwangmyeong City)

5. Results and Discussions

Face-to-face interviews with project participants in the case were conducted to collect their opinions about the proposed data integration process. Most of them agreed that the integrated data model was helpful to improve the accuracy of geometric information and work efficiency. Especially, error issues detected in the early stage of the case were successfully resolved through using the data model integrated by the proposed method. However, several limitations were identified as well. The adjusted data still contained a small range of errors because of the low accuracy levels of the collected data, such as 5m-contour intervals and manual survey data. It can be improved by accurate surveying systems, such as a 3D laser scanner or total station, in the future.

6. Conclusions

This paper proposed a process for integrating architectural data, including BIM models and architectural drawings, and civil data, including CIM models, 3D survey data, and maps of the geology and topography of the earth. The proposed process helps to explain complex geometries, to reduce the number of design and construction errors detected on site, and to improve decision making processes by providing accurate geometry information of AEC projects. The proposed method was applied to an actual project to check its applicability and was validated. However, its quantitative effects on the project were not analyzed in this paper. Therefore, it will be implemented to various projects to quantitatively analyze its impacts on cost and schedule of the projects.

Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP; Ministry of Science, ICT & Future Planning) (NRF-2017R1C1B5016643). The authors would like to express thanks to Gwangmyeong City Government for their supports and data sharing.

References

[1] Manyika, J., et al., Big data: The next frontier for innovation, competition and productivity. Mckinsey Global Institute, 2011

[2] Manyika, J., et al., Digital America: a tale of the haves and have-mores. MacKinsey Global Institute, 2015

[3] Woldesenbet, A., et al., Framework for integrating and assessing highway infrastructure data. Journal of Management in Engineering, 2015. 32(1).

[4] Gallaher, M. P., et al., Cost analysis of inadequate interoperability in the US capital facilities industry. National Institute of Standards and Technology (NIST), 2004.

[5] NIST National Building Information Modeling Standard Version 2. US National Institute of Building Science, 2012.

[6] Won, J., et al., Identifying potential opportunities of building information modeling for construction and demolition waste management and minimization. Automation in Construction, 2017. 79: p. 3-18.

[7] Cheng, J. C. P., et al., Mapping BIM schema and 3D GIS schema semi-automatically utilizing linguistic and text mining techniques. Journal of Information Technology in Construction, 2015. 20: p. 193-212.

[8] Deng, Y., et al., Mapping between BIM and 3D GIS in different levels of detail using schema mediation and instance comparison. Automation in Construction, 2016. 67: p. 1-21.

[9] Liu, R., et al., 3D visualization of sub-surface pipelines in connection with the building utilities: Integrating GIS and BIM for facility management. Computing in Civil Engineering, 2012. : p. 341-348.

[10] Irizarry, J., et al., Integrating BIM and GIS to improve the visual monitoring of construction supply chain management. Automation in Construction, 2013. 31: p. 241-254.

[11] Kang, T. W., et al., A study on software architecture for effective BIM/GIS-based facility management data integration. Automation in Construction, 2015. 54: p. 25-38.

[12] Isikdag, U., et al., An investigation into the applicability of building information models in geospatial environment in support of site selection and fire response management processes. Advanced Engineering Informatics, 2008. 22(4): p. 504-519.

[13] Kwan, M. P., et al., Emergency response after 9/11: The potential of realtime 3DGIS for quick emergency response in micro-spatial environments. Computers, Environment and Urban Systems, 2005. 29(2): p. 93-113.

[14] Lee J., GIS-based geocoding methods for area-based addresses and 3D addresses in urban areas. Environment and Planning B: Planning and Design, 2009. 36(1): p. 86-106.

[15] Karan, E. P., et al., BIM and GIS Integration and Interoperability Based on Semantic Web Technology. Journal of Computing in Civil Engineering, 2016. 30(3).

[16] Elbeltagi, E. et al., Integrated visualized time control system for repetitive construction projects. Automation in Construction, 2011. 20(7): p. 941-953.

[17] Poku, S. E. et al., Construction scheduling and progress control using geographical information systems. Journal of Computing in Civil Engineering, 2006. 20(5): p. 351-360.