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# A RELATIONAL DATABASE MANAGEMENT SYSTEM FOR LIFE-CYCLE COST ANALYSIS OF BIM PROJECTS

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Life-cycle analysis (LCCA) has become a necessary tool for green procurement for construction projects in many countries. Calculating life-cycle costs (LCCs) requires a variety of data that need to be gathered from diverse sources throughout the project life span. This information is usually stored in paper-based documents and are not well organized. These practices cause poor-quality data, which lead to incorrect results. Consequently, current LCCA in practice is extremely challenging. Data management is a major component for executing this sustainable development concept. This paper develops a relational database management system (RDBMS) that can support in calculating the LCCs of building projects. The system is structured to manage a large volume of design and construction data in a multi-parametric form. This allows users to integrate the proposed system with other modern construction platforms, especially building information modeling (BIM). In this paper, *Autodesk Revit*, a most widely-used BIM software, is adopted for authoring BIM models of a building and estimating relevant costs. *Microsoft Access* is used for developing a database management system (DBMS), which is designed to collaborate with the BIM models for LCCA. The system can significantly expedite the LCCA for a building with minimal errors and mistakes in data management and accurate LCCs.

*Keywords*: Sustainable procurement, Multi-parametric model, Construction data management, Building cost estimating, 6D BIM.

## 1 INTRODUCTION

The building industry is associated with sustainability through three aspects: economy, society, and environment (ISO 2008). Most research works about sustainable development focus on the environmental and social aspects. Economic evaluation is a more effective decision making tool for sustainability because cost analysis is a more reliable tool than other analyses. It provides a more direct measure as compared to other scientific measures of energy. In addition, the results of cost analysis are more easily perceived by people, who are not familiar with this discipline.

However, the economic aspect is rarely considered for sustainable analysis in practice due to its complexity (Smith 2014).

The life-cycle cost (LCC) is an economic factor for evaluating the total project cost. It considers all cost items related to the construction, maintenance, and operation of a construction project over a defined period of time (Jrade and Abdulla 2012). It has become an essential requirement of sustainable procurement for construction projects in many countries. The USA, Japan, and many European countries have adopted life-cycle cost analysis (LCCA) as part of their sustainable procurement policies. Other countries such as South Korea, Australia, New Zealand, Singapore, India, and China are using some forms of LCCA in their procurement of new energy-efficient buildings. Ghana, Botswana, Indonesia, Senegal, Mauritius, and Vietnam considered the use of LCCA in their sustainable procurement policy development (Perera 2009, European Union 2014, United States Code 2018).

The application of building LCCA in practice is limited due to the unavailability of required data (Higham *et al.* 2015). In addition, such data are usually recorded in paper-based documents in various sources, which are not well organized (Bull 2003). Inaccurate results caused by data loss and inconsistent data also present a major challenge of conventional building LCCA.

Building information modeling (BIM) encompasses the process of generating, storing, managing, exchanging, and sharing information of a facility among stakeholders in the design, construction, and operation stages. BIM can facilitate building LCCA in many aspects. It can manage information of a facility in 3D view for various purposes such as allow information to be placed on a single module (Autodesk 2005). Thus, for LCCA we can use BIM to store the thermal parameters of construction materials for calculating the heat transfer coefficients and the solar heat gain coefficients of building elements (Likhitruangsilp *et al.* 2019a). Although BIM can facilitate building LCCA, it cannot manage all required data itself. The database of cost accounts and units of measured costs are commonly based on conventional standards, which cannot be applied to typical BIM objects (Thurairajah and Goucher 2012). In addition, it is also difficult to create a formal cost plan with BIM authoring programming because designers usually do not comply with a cost management methodology (Muzvimwe 2011). Quantity surveyors cannot find BIM authoring programming for construction cost estimating because the data structure of typical BIM models is not compatible with the elemental structure required by classification structures (Sabol 2013). Shen and Issa (2010) reported that current BIM tools are not rich enough to handle all data of construction processes. Thus, data management is still a major challenge for executing this sustainable development concept via BIM. This paper develops a relational database management system (RDMS), which can facilitate LCCA of a building. The proposed system can organize and manage a large volume of required data in a multi-parametric form, which supports BIM users to integrate this system with any BIM models for building LCCA. This system is a module of the BIM-database-integrated system for evaluating building life-cycle costs with a multi-parametric model (Le 2019, Le *et al.* 2020).

## 2 DATABASE MANAGEMENT SYSTEM IN CONSTRUCTION

Data are discrete facts, which can be constructed to create information, organized to generate knowledge, and applied to support decision making. Data in construction are generated by various sources during the designing, constructing, maintaining, and operating phases of a project (ICE 2019). Data management is a complex and time-consuming task in in the architecture, engineering, construction, and operation (AECO) industry because of a large amount of data, various data types and sources, as well as data input and output for different functions (Bakis *et al.* 2007, Beyer 2011).

Database is a storage facility of related documents, which contain information of projects or companies in a structural organization. It provides an easy access for updating, maintaining, and storing data with minimum redundancy (Joseph 2017). A database management system (DBMS) is a collection of programs, which are used to control the data kept in the database and manage the database structure. Five major advantages of a DBMS for the stakeholders in a construction project are: (1) creating an environment to project parties for accessing data and quickly responding when changes occur during the project life cycle, (2) improving data security by providing a framework for increasing enforcement of data privacy and security policies, (3) integrating data of project parties to manage any changes in construction activities, (4) increasing data consistency when different versions of the similar data appear in various places, and (5) improving data quality to promote the accuracy, validity, and timeliness of data (Coronel 2016).

Eken *et al.* (2015) proposed the structure of cost database and information system to capture data during all phases of a construction project. A data warehouse of a project was developed to keep information about performance, materials, estimates, and contracts for medium and large contractors. The structure of this data warehouse consists of data sources, data staging areas, data storage servers, and data access (Rujirayanyong and Shi 2006). For example, a database was developed to manage data for sewer projects. This database was combined with the decision support modules for choosing the optimal inspection and renewal alternatives for pipeline projects (Park and Kim 2013).

## 3 BUILDING INFORMATION MODELING FOR BUILDING LCC CALCULATION

Building information modeling (BIM) is a digital physical representation and functional characteristics of a building. It is a structured dataset that describes a building project. BIM is also referred to the creation and use of information about project design (Volk *et al.* 2014, Handayani *et al.* 2019, Likhitruangsilp *et al.* 2019b).

Although BIM can support building LCC calculation, research studies in this area have been very limited. This is because BIM cannot solely carry out building LCC calculations. The interoperability is an important challenge for applying BIM to provide all required data for building LCCA (Kehily and Underwood 2017). In addition, information exchange is essential to extend the function of BIM technology because data errors may occur during calculation caused by incomplete interoperability (Laakso 2012). The current cost database and unit of measurement are also not applicable to BIM objects because they are constructed based on traditional standards (Thurairajah and Goucher 2012).

## 4 RESEARCH METHODOLOGY

Figure 1 shows five steps for developing the relational database management system (RDMS) for LCC calculation of BIM projects. The first step is to examine the type of database. In this paper, the relational database is adopted due to its simplicity and efficiency for data queries. *Microsoft Access* is primarily used for developing the system's database. It is designed to collaborate with BIM models for evaluating building LCCs. The second step is to develop the structure of the selected database, which consists of database tables and their relations. The third step is to collect raw data from three main data sources. First, we extracted the data from similar projects in the past. The second source is "*Assemblies Cost with RSMeans data 2018, 43rd annual edition*" published by Gordian RSMeans data (Phelan 2018). The last source is "*Life cycle costing for design professionals*" by Kirk and Dell'Isola (1995). The fourth step is to analyze the raw data, which are transformed to the required data. To exchange data between the BIM models and the relational database, *UniFormat* is adopted to integrate the two platforms. *UniFormat* organizes the data by relying on the physical components of a building (called *systems and assemblies*). *Microsoft Excel* is used to arrange the data before being input in the relevant tables of the relational database. The final step is to input data in the developed database.

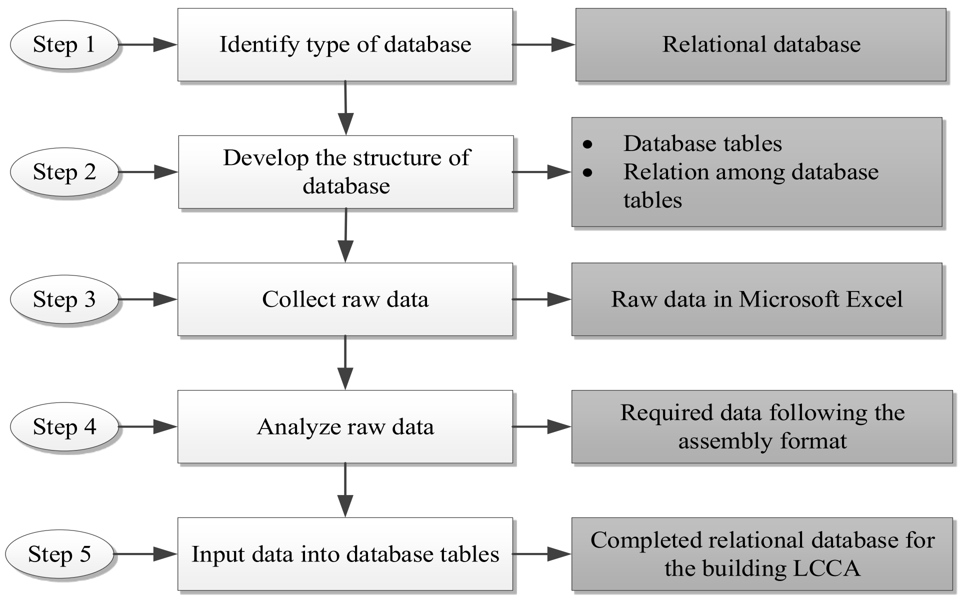


Figure 1. Research methodology.

## 5 RESULTS

Figure 2 shows the structure of the relational database for the LCC calculation of BIM projects. There are eight database tables, which store all organized data for the BIM models, namely, *ExteriorWalls, ExteriorWindows, Floors, Roofs, InteriorWalls*, *InteriorWindows*, *Doors*, and *Assembly*. For every table, except for the *Assembly* table, seven fields are used to keep the necessary data. The seven fields are *ElementTypeCode*, *Description*, *Unit*, *ConstructionUnitRate*, *ExpectedServiceLife*, *AnnualServiceUnitRate*, and *AssemblyCode*. The *ElementTypeCode* field keeps the code of each type, by which it is quicker to identify the type than by its name. The *Description* field keeps the attribute title of each type. The *Unit* field presents the calculating unit of each type. The *ConstructionUnitRate* field stores the value of the construction cost unit of each type. The *ExpectedServiceLife* field keeps the useful year of each type. The *AnnualServiceUnitRate* field stores the value of the annual service unit rate of each type. The one-to-many relation is adopted for linking any two of these database tables.

## 6 CONCLUSION

This paper presents a methodology to develop the relational database management system for LCC calculation of BIM projects. This is the first module of the BIM-database-integrated system for evaluating building LCCs using a multi-parametric model. Its main function is to organize the required data in BIM models. It also offers a systematic approach for organizing and managing LCCA data for BIM projects. The system can eliminate the limits of the conventional building LCC calculation, increase the consistency of information for calculating building LCC, and reduce data waste in construction information management.

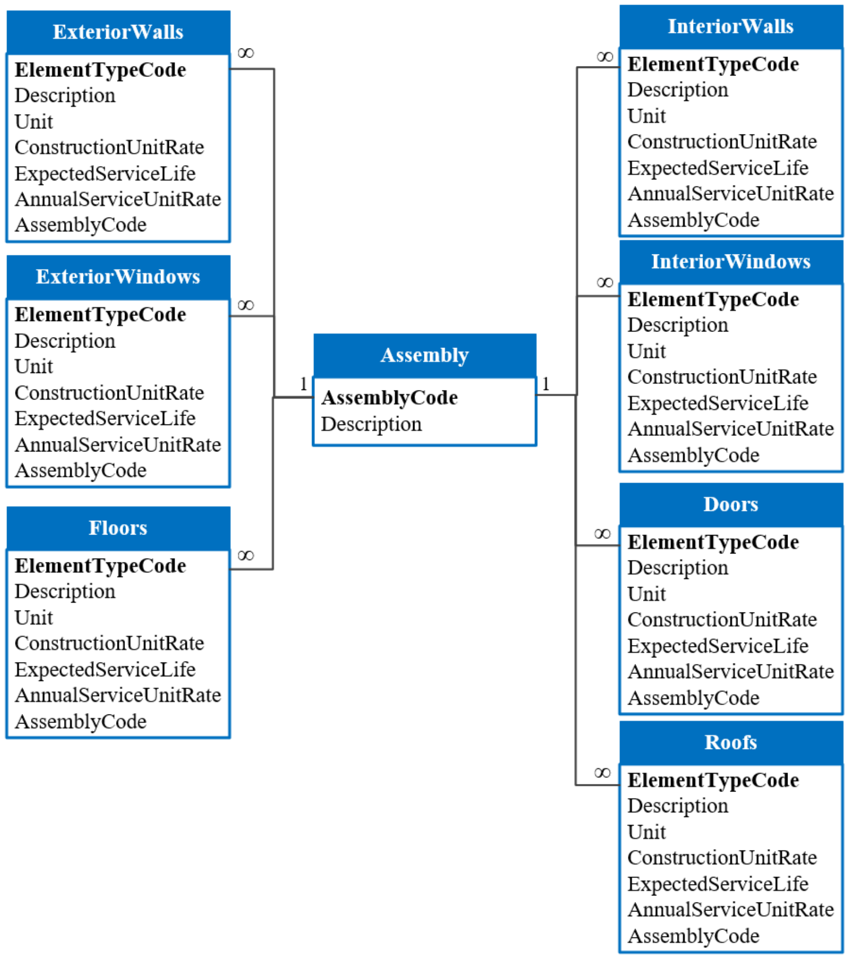


Figure 2. Structure of the relational database for building LCCA.

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