Cost analysis of equipment in a building using BIM-based Methods

Chuang Lau [a*], Meng-xue Yang [a], Luke Allan [a], and Chiu Jen Ku [a*]

[a] Department of Civil & Environmental Engineering, Shantou University, Shantou, China.
E-mail: 16cliu2@stu.edu.cn, 15mxyang1@stu.edu.cn, allan@stu.edu.cn, cjku@stu.edu.cn

Abstract –

The cost of the operation stage in a project life cycle is much higher than that of other stages in the building lifecycle. Efficient use of facility management can save money. However, the information of the traditional facility management cannot effectively be employed, which in turn affects the quality of the facility management. The emerging technology of building information modelling provides an opportunity to overcome the difficulties of utilizing the information stored by means of facility management. In this paper, the Revit@ platform has been used to build up a BIM model relating to the facility management. Through the Revit API, computer implementation has been developed, based on the programming language C#. This computer implementation can extract the information regarding the costs of equipment from the BIM model. Such information can be further analyzed to support decision making.

Keywords –
BIM; Facility Management; Secondary Development; Economic Analysis

1 Introduction

It has been well known that a significant part of the expenses of the life cycle of a building occurs during the operational stage. [1-3]. Almost all activities during the operations need considering the information of facilities. However, the information cannot be effectively employed by means of traditional facility management. Gallaher et al. [4] indicated that US$15.8B are lost annually in the U.S. Capital Facilities Industry due to the lack of adequate interoperability. As a matter of fact, the market of facility management in China faces the same problem. Hence, the effective use of detailed facility information in a building becomes the rising issue.

Meanwhile, with the advancement of the national development strategy in the informatization of civil engineering, modern technologies have been continuously applied to architecture, engineering, and construction industries in China. One of the promising technologies, Building Information Modelling (BIM), has been in the spotlight since it was introduced. The phrase "Building Information Modelling" is used to describe virtual design, construction, and facility management [5]. BIM provides one model that can store all building information for facility management.

Many research studies have shown the applications of the BIM technology to facility management. For example, Akcamete et al. [3] proposed an envisioned approach for integrating historical information in BIM to support visualization and spatial analyses of various maintenance activities in a facility. Wang and Zhang [6] demonstrated a case study of the maintenance activities for air conditioners in a building by means of a building information model. Liu and Issa [7] proposed a method that can automatically exchange the information of maintenance between building information models and Computerized Maintenance and Management Systems (CMMS). Yu and Li [8] combined the use of Revit@ and Access@ to establish a facility management system that can conduct not only the classification, assignment, and extraction of information, but also the query, location, and economic analysis of information. A case study has been carried out to verify the feasibility of their facility management system.

This study uses BIM technology for facility management along with the economic analysis of facilities. To take the efficiency of the analysis into account, the computer implementation was developed through the Revit@ API to give feedback on the cost analysis of a specific facility in a BIM under the same platform. A case study of a facility has been demonstrated in this paper. 3D building information model of the facility was first built from its 2D drawings. The computer implementation for the cost analysis was then applied to the 3D BIM.

2 Method

In this study, Revit@ was chosen to be the research tool, because it is one of the most popular BIM software in China. In addition, it equipped with a friendly and positive development environment. Based on the environment, the computer implementation was developed by using C# programming language. The flow chart of Revit@ secondary development is shown in Figure 1. Through an Add-In Manager plug-in which existed in the original installation package, the computer implementation was applied to the information of a BIM built in the same platform of Revit@ for the cost analysis of facilities. Results of the cost analysis can further help a facility manager in decision-making.

This computer implementation for the cost analysis is related to the principles of engineering economics, such as the economic life, the time value of money, and so on. A brief introduction is following:

In the first place, the following three points should be satisfied.

(1) The operation cost of equipment can be recorded and then statistically analysed;
(2) The annual interest rate is constant; and

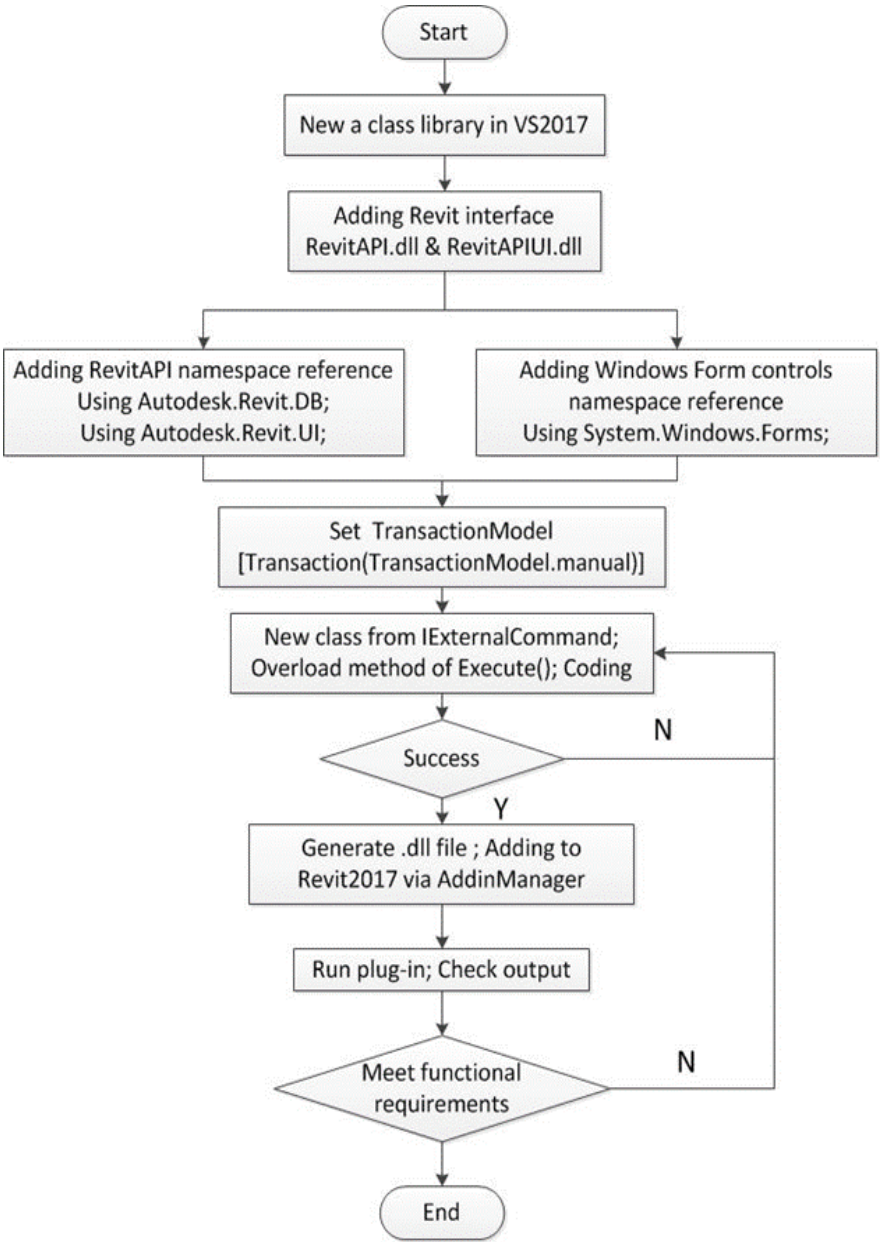


Figure 1. The flow chart of Revit@ secondary development

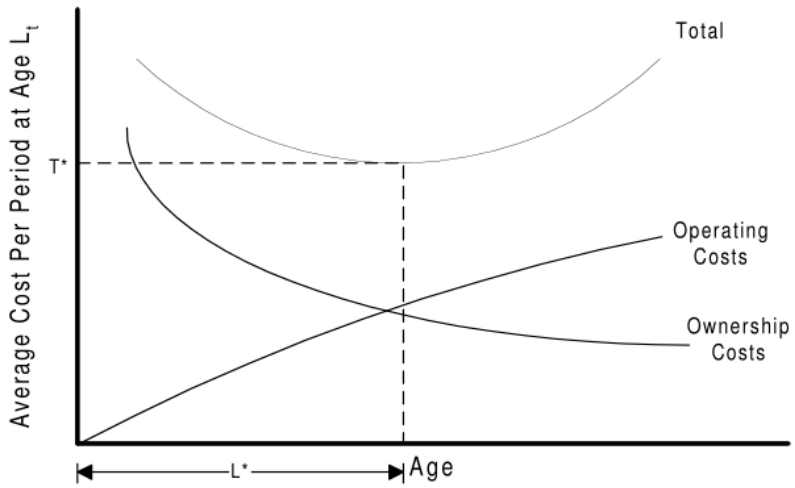


Figure 2. Economic life diagram

(3) The cumulative cost of the equipment in the future can be compared to a reference cost.

Mitchell [9] mentioned that economic life is based on decreasing ownership costs with the increase in operating costs. As shown in Figure 2, economic life gives the minimum value of the total costs on the curve at the point of an optimum age. The total costs consist of ownership costs and operating costs. Usually, the ownership costs merely consider initial costs and depreciation, regardless of salvage value, and the operating costs only take the costs of maintenance, repair, and operation into account.

Park [10] mentioned that "The time value of money means that a dollar today is worth more than a dollar in the future because the dollar received today can earn interest." Hence, the time value of money is one of the key factors in the economic analysis. Table 1 lists some important formulae used for the cost analysis of facilities.

In addition, Park [10] mentioned that the annual equivalent cost (AEC) criterion provides a basis for measuring the worth of an investment by determining equal costs on an annual basis. For the sake of simplification when using the life of various facilities for analysis, this study mainly used the two formulae in Table 1 to convert the original cash flows into the annual equivalent flows.

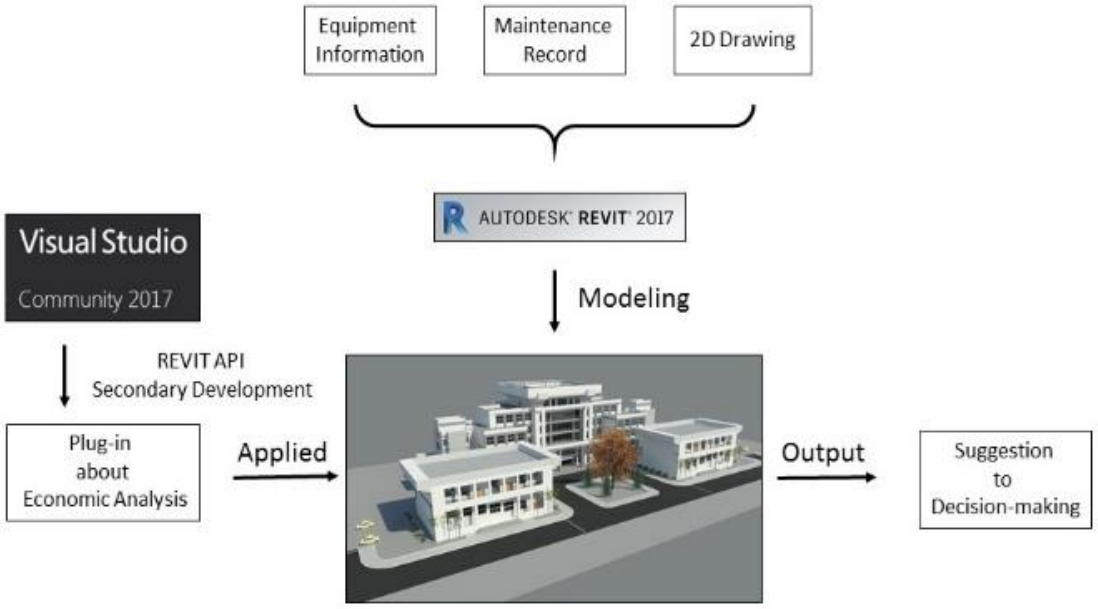


Figure 3. The application procedure of the computer implementation

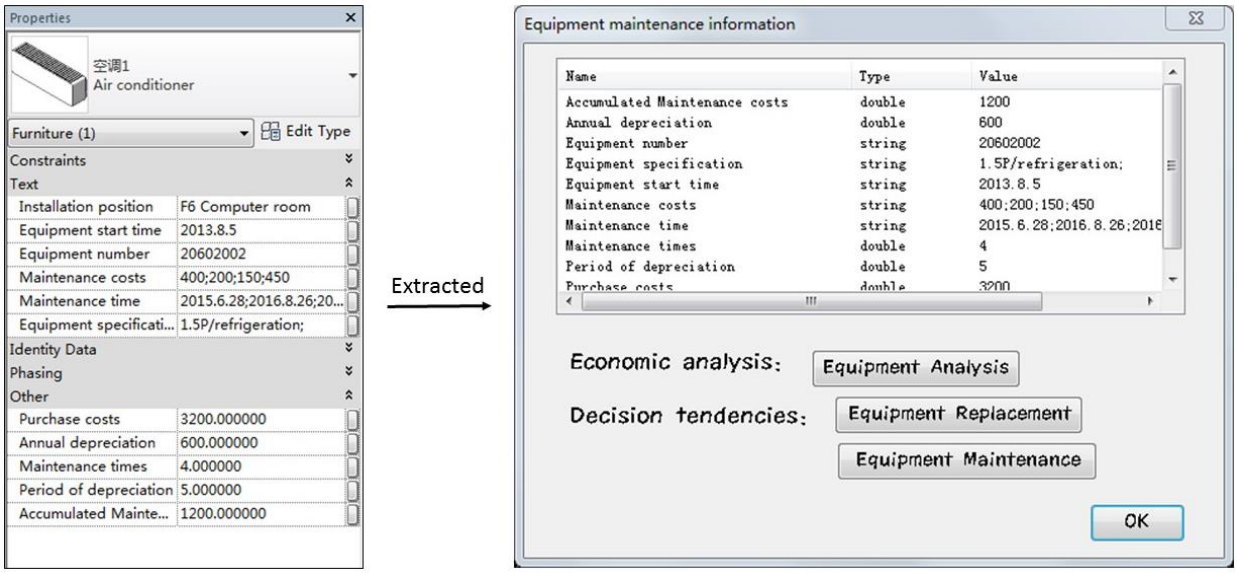
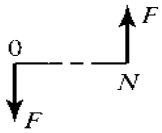
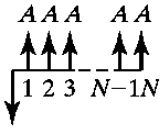


Figure 4. The main interface of the computer implementation.

Table 1. Some important coefficients related to economic analysis

Factor Notation	Formula	Cash Flow
Present worth ($P/F, i, N$)	$P = F(1+i)^{-N}$	
Capital recovery ($A/P, i, N$)	$A = P[\frac{i(1+i)^N}{(1+i)^N-1}]$	

3 Results

The application procedure of the computer implementation is illustrated in Figure 3. Once a building information model has been built, the computer implementation in the procedure can automatically extract the specific equipment information. Shown in Figure 4 is the main interface of the computer implementation. The left window of Figure 4 displays the partial information of the equipment in the BIM. The right window of Figure 4 displays the main interface of the computer implementation, on which the upper and the lower parts illustrate respectively the information extracted from the BIM and the functions of several application modules.

The main function of the "Equipment Analysis" module is to analyse the status of the selected equipment for supporting the maintenance planning decisions. In case the facility manager considers replacing the equipment, the "Equipment Replacement" module can help to make a right decision. When the equipment is broken, the "Equipment Maintenance" module gives rise to the analysed results based on the costs of the repairs and maintenance for the equipment. A window appears in Figure 5 resulting from the analysis of the "Equipment Maintenance" module for an example.

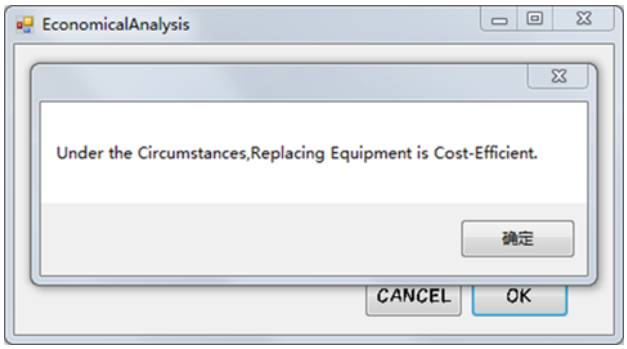


Figure 5. An analysis module result.

4 Conclusions

In China, most of the maintenance work in a facility is reactive. This practice is not effective from the perspective of facility management, because the reactive maintenance typically increases the costs of repairs and maintenance. To reduce the number of the reactive maintenance, there is a need for supporting the planned maintenance work. The emerging technology of building information modelling provides an opportunity to support such work. BIM can collect the information of

facilities during their life cycles. As a matter of fact, the proposed method can be globally used unless the selected BIM software does not have an open development environment.

In this study, the computer implementation for the use of a BIM to analyse the costs of equipment was developed using the programming language C#. This computer implementation can simplify the process of the cost analysis to further improve the efficiency of decision-making. In addition, it can provide the secondary development of a building information model with some experiences in a future.

Acknowledgments

The sponsorship of the STU Scientific Research Foundation for Talents is gratefully acknowledged.

References

[1] Clayton, M.J., Johnson, R.E., and Song, Y. Operations Documents: Addressing the Information Needs of Facility Managers. Durability of Building Materials and Components, 8 (4), 2441-2451, 1999.

[2] Rondeau, E. P., Brown, R. K., & Lapides, P. D. Facility management (2nd ed.). Wiley Publishing, Hoboken, New Jersey, 2006.

[3] Akcamete, A., Akinci, B., & Garrett, J. H. Potential utilization of building information models for planning maintenance activities. *Proc. Proceedings of the International Conference on Computing in Civil and Building Engineering*, Nottingham, UK, 2010.

[4] Gallaher, M. P., 'Connor, A. C. O., Dettbarn, J. L., & Gilday, L. T. Cost analysis of inadequate interoperability in the U.S capital facilities industry. *Building & Fire Research Laboratory*, 2004.

[5] Eastman, C., Teicholz, P., Sacks, R., & Liston, K. BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors (2nd ed.). Wiley Publishing, Hoboken, New Jersey, 2011.

[6] Wang, T. K., & Zhang, R. Y. Plant Visualization Management Based on BIM. *Journal of Civil Engineering and Management,* (3):32-36, 2014. (in chinese)

[7] Liu, R., & Issa, R. R. A. Automatically Updating Maintenance Information from a BIM Database. *Proceedings of the International Conference on Computing in Civil Engineering*, pages 373-380, Florida, USA, 2012.

[8] Yu, W. T., & Li, X. S. BIM-based Information Extraction and Application of Building Facility Management. *Journal of Civil Engineering and Management, 33*(1): 85-89, 2016.(in chinese)

[9] Z. Mitchell. A Statistical Analysis of Construction Equipment Repair Costs Using Field Data and the Cumulative Cost Model. Virginia Polytechnic Institute. Blacksburg, VA, 1998.

[10] Chan, S. P. Contemporary engineering economics (4th ed.). Pearson Education Publishing Upper Saddle River, New Jersey, 2007.