ANALYSIS OF LCC AND FACILITY MANAGEMENT ON EDUCATIONAL FACILITIES IN JAPAN

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ABSTRACT

The life cycle cost (LCC) is considerably important. However, there are some problems related to the assessment of LCC. This research aims to establish an efficient facility management system for educational institutions. First, the analysis of the actual LCC of university facilities clarifies the difference between the theoretical LCC and the actual LCC. In particular, the timing and cost of repairing and renovation is subject to the facility management policy. Second, LCC based on two types of facility management policies is estimated. Finally, this paper discusses the application of building information modelling (BIM) for LCC considering the individuation of projects.

Keywords: building information modelling, facility management, life cycle cost, simulation, university.

INTRODUCTION

The life cycle cost (LCC) is considerably important. Educational institutions such as universities and high schools have many buildings and facilities. They need an efficient investment for facilities because it affects their business situation. A facility management (FM) system that considers LCC is required. The basic concept of LCC for buildings and the basic methods of calculating LCC have already been developed. However, there are certain difficulties related to the assessment of the LCC. The verification of the methods is difficult because it needs a considerable amount of historical data related to actual costs such as construction cost, operating costs, and demolition costs. Recently, global environment, including global warming and biological diversity, has become an important topic in the construction industry. It is necessary for architects to consider the life cycle assessment (LCA), including life cycle CO_2 ($LCCO_2$) and LCC. It is also necessary for facility managers to decrease the operating costs and to improve the indoor environment with a variety of equipment. This consideration is strongly related to LCC throughout the life cycle, including the design stage and the maintenance stage. On the other hand, the application of building information modelling (BIM) with three-dimensional (3D) CAD has gradually increased. BIM can efficiently use building information for the conventional post-process of architectural design. One major area of the use is the support for quantity surveys and the master program for the construction project. Kimoto *et al.* (2008, 2009) reported how to use BIM for the selection of the construction methods of a reinforced concrete structure and the examination of a curtain wall design and an interior design.

AIM AND RESEARCH METHODS

This research aims to establish an efficient facility management system for educational institutions such as universities and high schools. First, it analyses the actual LCC of educational facilities and clarifies the characteristics of each cost. Second, it clarifies the difference between the theoretical LCC and the actual LCC. This study also examines the revision system of LCC with the actual data. Finally, this paper discusses the application of BIM for facility management considering LCC.

Breakdown of Life Cycle Cost

Figure 1 shows a breakdown of the LCC considered in this research. The analysis of LCC such as the comparison among campuses and buildings is based on this breakdown. It is important for architects and facility managers to understand the actual characteristics of each cost.

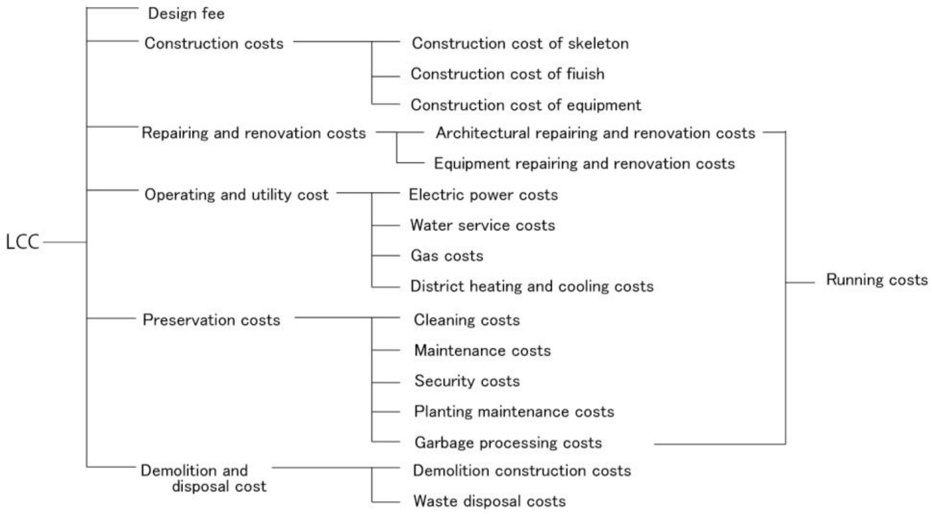


Figure 1: Breakdown of Life Cycle Cost

Outline of University Facilities

This research is aimed at educational facilities in Japan. Table 1 shows the outline of university campuses for the analysis of LCC. They belong to the same educational foundation. There are three university campuses and two junior high and high school campuses. The A4 campus is the renovated campus of the A1 campus. All campuses are located in Tokyo and the neighbouring cities in Japan.

Table 1: Outline of University Campuses

Campus	A1	A2	A3	A4	B1	B2
Division	University	University	University	University	Junior high school High school	Junior high school High school
School ground product (㎡)	7,500	170,700	30,000	2,600	10,000	43,300
Total floor area (㎡)	9,100	50,300	61,270	12,800	10,800	15,400
Number of teachers	—	123	144	11	72	92
Number of staff	—	27	111	8	15	10
Number of students	—	4,288	3,150	167	1,051	1,348
Number of buildings	A1-1～8 8	A2-1～25 25	A3-1～2 2	A4-1 1	B1-1～6 6	B2-1～14 14
Number of total buildings	56					
Period	1943 - 2006	1966-Present	2006-Present	2009-Present	1982-Present	1980-Present

ANALYSIS OF LIFE CYCLE COST AT UNIVERSITY FACILITY

Construction Cost

The left graph in Figure 2 shows a transition of the construction cost of the main buildings in forty years. After 2000, the ratio of equipment to the construction cost is almost 30%.The right graph shows a transition of the construction cost per unit total floor area of a building whose area is larger than 1,000 m^2. The unit cost has increased in the past thirty years. In particular, the cost of the steel structure meets a regression line. The initial costs—design fee and construction cost—are relatively easy for owners to understand.

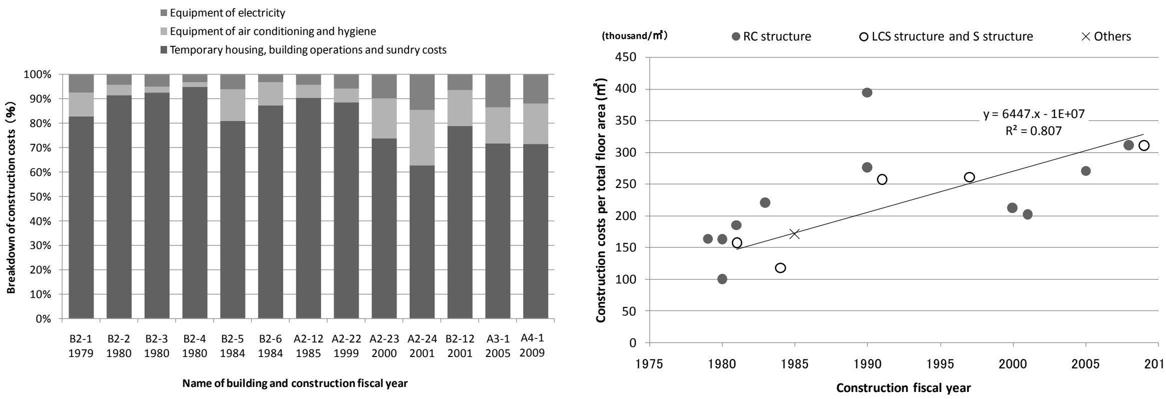


Figure 2: Details of Construction Cost (Left) and Construction Cost per Unit Total Floor Area

Operating and Utility Costs

Figure 3 shows the operating and the utility costs for the total floor area (m^2) of the four campuses. These costs are relatively constant. The costs of A3 are different from those of the others because of the equipment. The costs of A3 declined for the second consecutive year to approximately 4,800 (yen/m^2), down 5% from the previous year because of the energy saving efforts, especially the energy saving related to cooling.

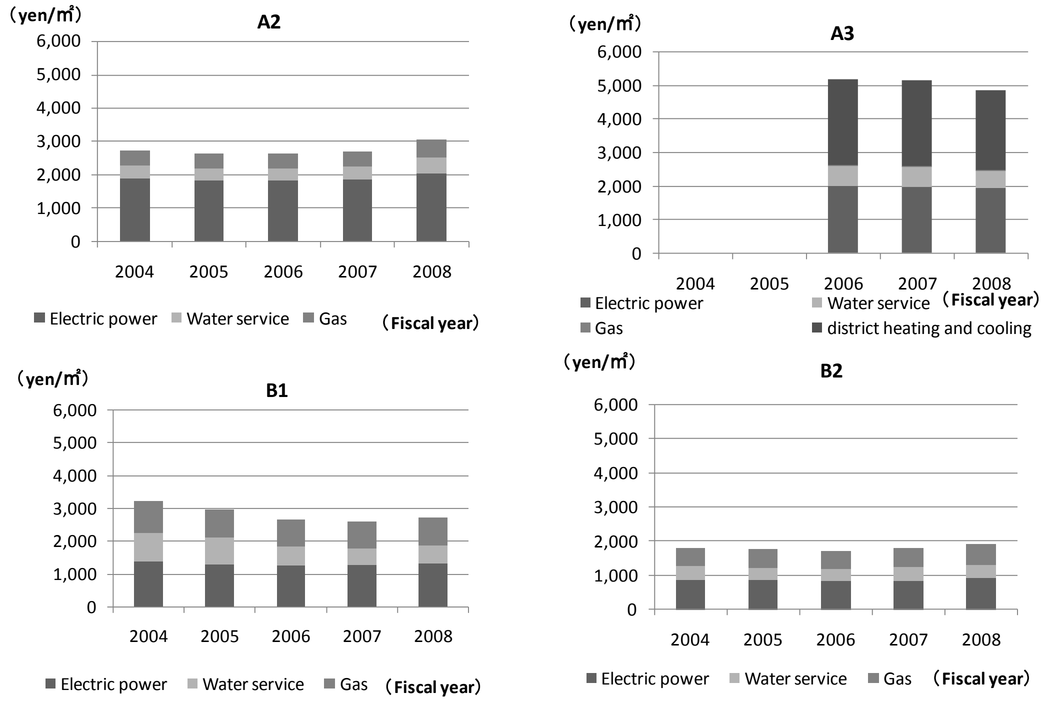


Figure 3: Transition (2004–2008) of Operating and Utility Costs per Unit Total Floor Area

Preservation Cost

Figure 4 shows the preservation cost for the total floor area (m^2) of the four campuses. As in the case of the operating and utility costs, the preservation cost is relatively constant and similar; however, the preservation cost of A3 is considerably high because of the high maintenance cost. Most of the buildings in A2, B1, and B2 are 4-storey buildings. On the other hand, the main building of the A3 campus consists of three buildings with elevators and escalators: a 14-storey building, a 7-storey one, and a 6-storey one.

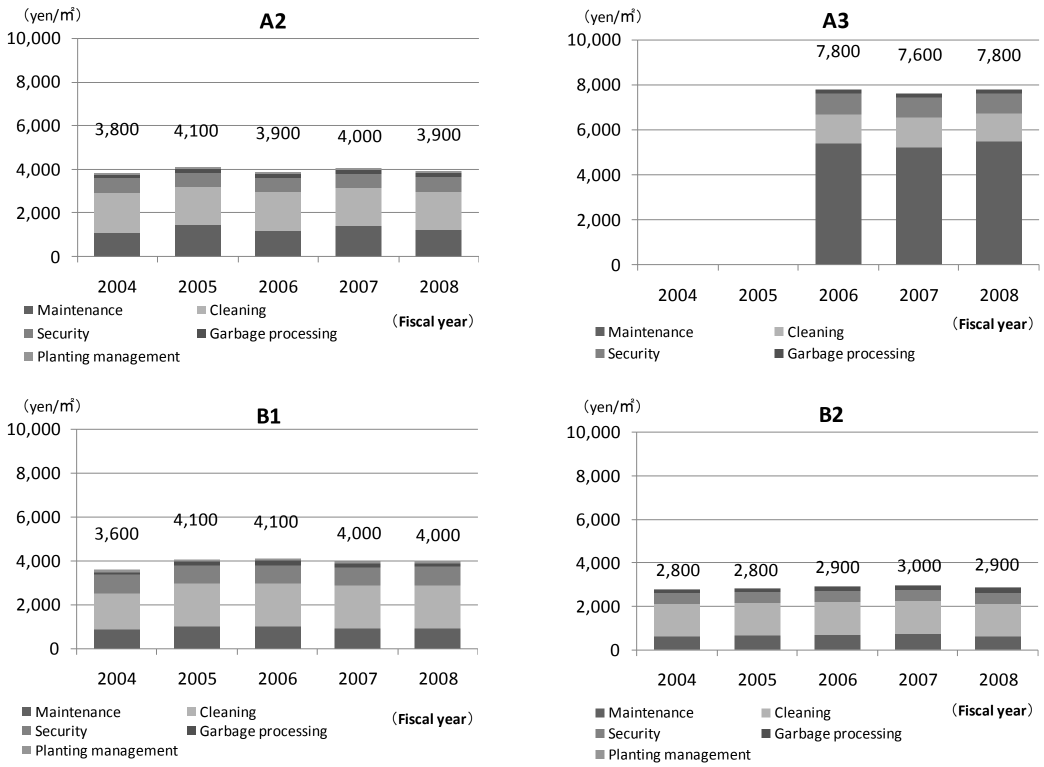


Figure 4: Transition (2004–2008) of Preservation Costs per Unit Total Floor Area

Repairing and Renovation Costs

The upper left graph in figure 5 shows the average of the repairing and renovation costs of the buildings that mainly house classrooms, and the upper right graph in figure 5 shows the repairing and renovation costs of the buildings that mainly house the gymnasiums. In the same way, the lower left graph shows the costs in the case of buildings that mainly house warehouses, and the lower right graph shows the costs in the case of buildings that mainly house cafeterias. The repairing and renovation costs of classroom buildings in the 13th, 23rd, 32nd, 41st, 45th, and 55th years are considerable. On the other hand, the repairing and renovation costs of buildings that house gymnasiums are considerable in the 12nd, 17th, 24th, 29th, and 40th years. The intervals are irregular, and the costs vary. Line graphs in both figures show the accumulated repairing and renovation costs. The ratio of the accumulated repairing and renovation costs to the construction cost in the case of classroom building reached more than 90% in 27 years. That of the buildings that house gymnasiums reached less than 60% in 26 years. The difference in building use shows the different timing and costs of repairing and renovation.

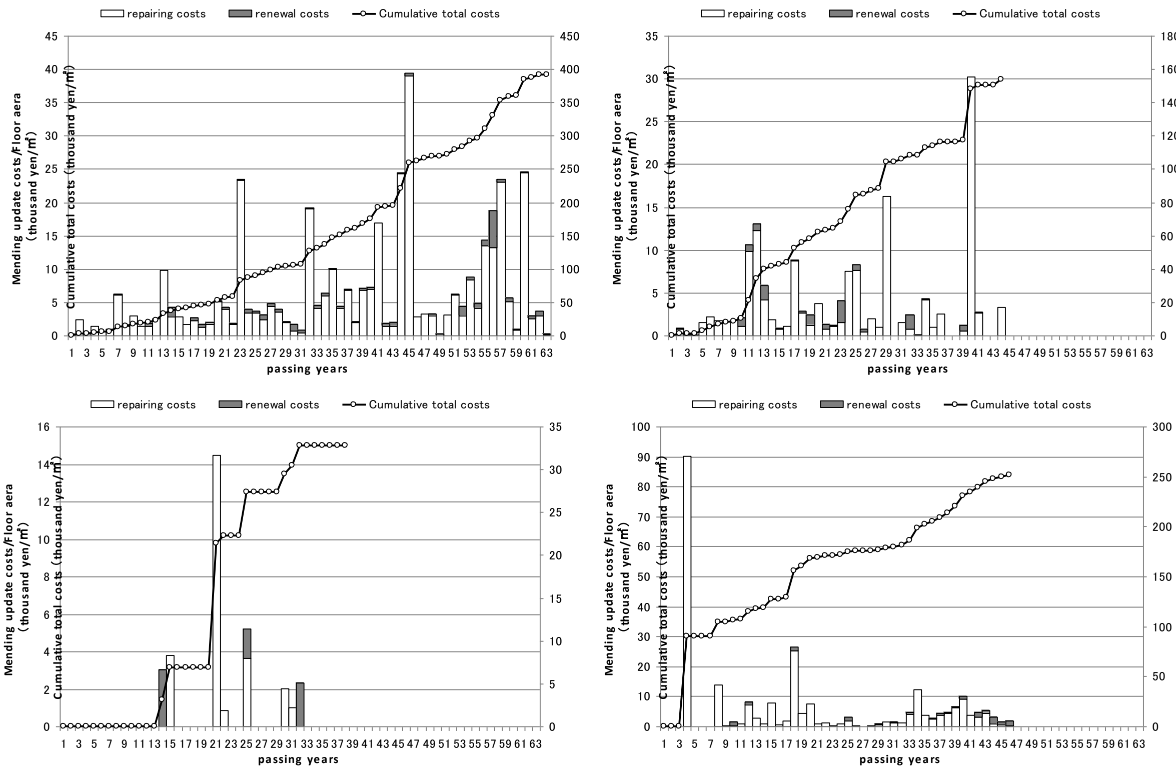


Figure 5: Repairing and Renovation Costs: Classroom Buildings (upper left), Gymnasium (upper right), Warehouse (lower left), and Cafeteria (lower right)

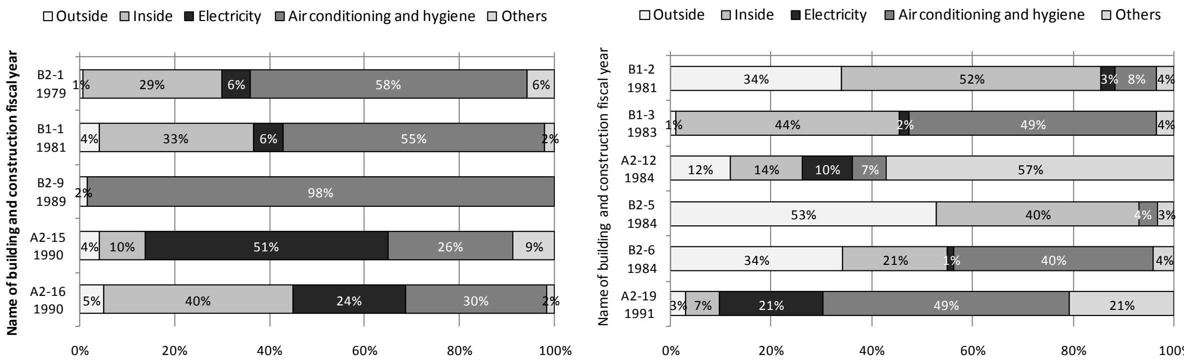


Figure 6: Breakdown of Repairing and Renovation Costs in the case of Classroom (left) and Gymnasium (right)

The left graph in figure 6 shows the details of the repairing and renovation costs of five classroom buildings, and the right graph in the figure shows those of six gymnasiums. These costs exhibit various ratios and no regularity. Therefore, it is important to understand the characteristics and conditions of each building for the prediction of the repairing and renovation costs.

Demolition and Waste Disposal Cost

The A1 campus had eight buildings and closed in 2006. The demolition and waste disposal cost of eight buildings in the A1 campus was approximately 3,950 yen per unit total floor area (m^2). Moreover, asbestos elimination and contaminated soil treatment cost was almost 1,550 yen per unit total floor area (m^2). Overall, the total demolition cost was 5,500 yen per unit total floor area. The open information reveals that the demolition cost except the waste disposal cost at that time varied between 4,000 and 9,000 yen per unit total floor area. The result is thought to be lower than the actual value because of the large size of the buildings.

LIFE CYCLE COST PLANNING FOR UNIVERISTY FACILITY

Seeley (1996) classified LCC into three types of payments: initial, annual, and periodic. As a result of the analysis of LCCs of university facilities, the construction cost and the design fee are considered to be the initial costs. The demolition cost, including the waste disposal cost, is not defined as an initial cost but considered a necessary cost in the life cycle of the project; hence, it is considered to be an initial expense in this study. These costs significantly depend on the specifications and volume of the building. Their influence on the LCC is limited because they are the initial expenses in each project. The prediction of initial costs is comparatively easy.

The operating and utility costs and the preservation costs are annual. They are almost uniform every year. However, in the case of the buildings in the A3 campus, the necessary cost depends on the specifications of the equipment. The influence of these costs on the LCC is large because they are annual expenses. Some three-dimensional simulation tools for the indoor environment have enhanced the accuracy of the prediction of the operating and the utility costs of the equipment. On the other hand, the repairing and renovation costs are irregular and not uniform. LCC planning normally assumes that the timing of this expenditure is a cycle. However, the analysis of actual data shows that the expenditure is extremely irregular. There are many differences between the plan and the result related to these costs. One difficulty in LCC planning is the prediction of these costs.

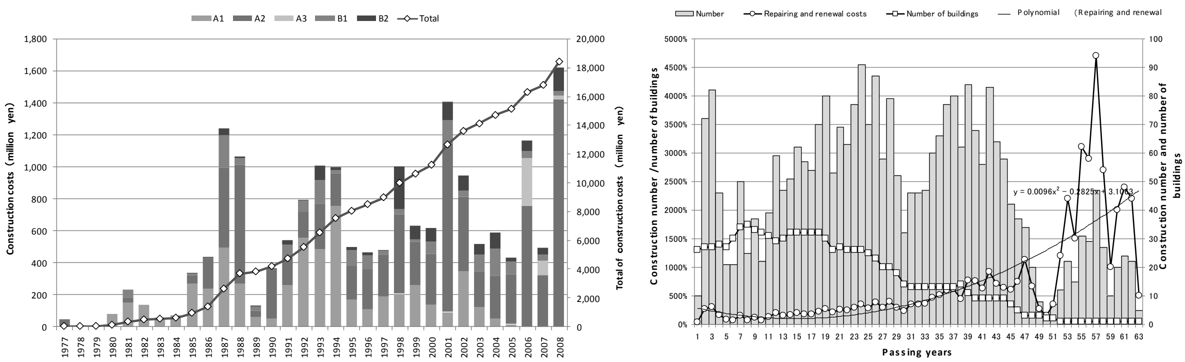
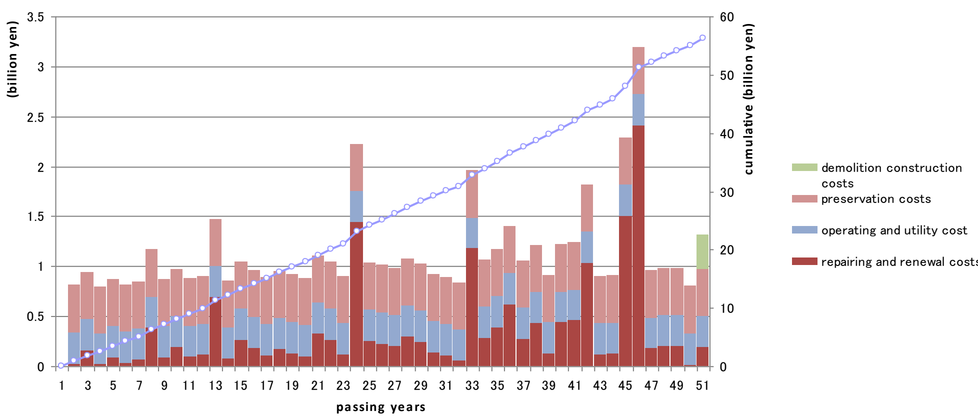


Figure 7: Repairing and Renovation Costs and Number of Construction in All Campuses



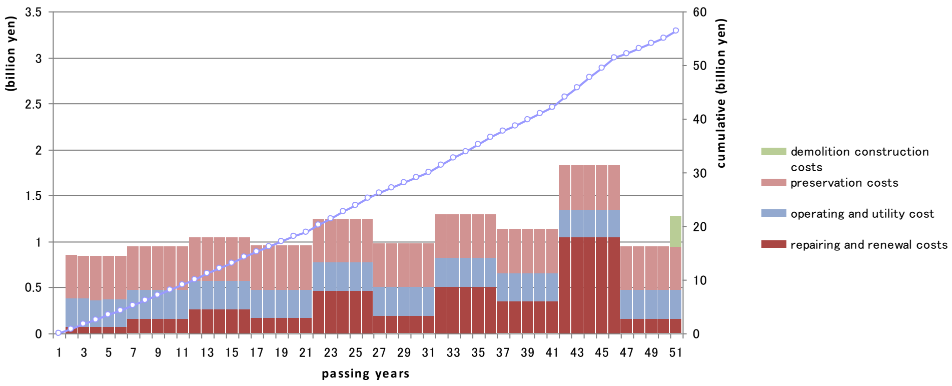


Figure 8: Prediction of Life Cycle Cost of A3 Campus Building

The left graph in Figure 7 shows the actual repairing and renovation costs per year in all campuses. The right graph in Figure 7 shows the number of the repairing and renovation in all campuses. From the viewpoint of university administration, the annual expenditure depends on the university operation policy. For instance, there are planned maintenances such as a scheduled maintenance and unplanned maintenances such as a conditioned-based maintenance. From another viewpoint, there is a policy that averages all expenditure per year. There is a policy that gathers the construction costs in specific years. The actual cost in Figure 7 is classified into a conditioned-based FM policy.

The upper graph in Figure 8 shows a simulation of LCC except the initial costs in the A3 campus, on the basis of a conditioned-based FM policy with the result for the case of classroom buildings. However, the actual expenditure is subject to the university operation policy and the condition of the other buildings. The coordination of the repairing and renovation costs is unavoidable under the policy. In this situation, the detailed plan such as the upper graph in Figure 8 is not effective. For instance, the lower one in Figure 8 is a simulation based on an FM policy considering the annual coordination of expenditure. The repairing and renovation costs in the simulation are averaged for every five years.

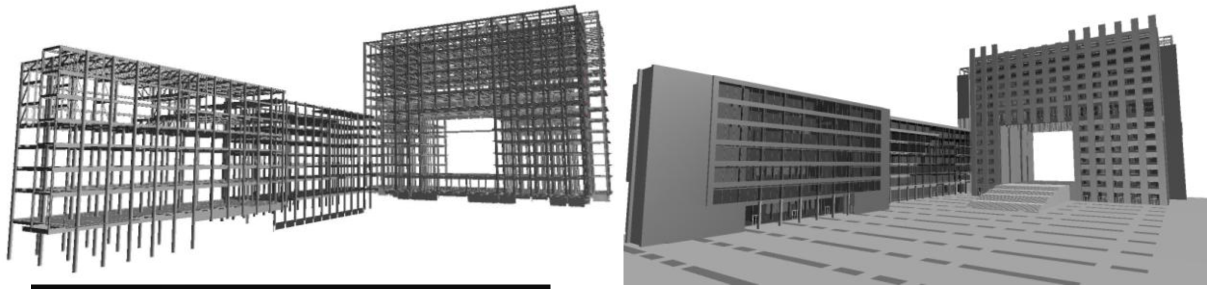
PREPARATORY RESEARCH OF BIM FOR FACILITY MANAGEMENT

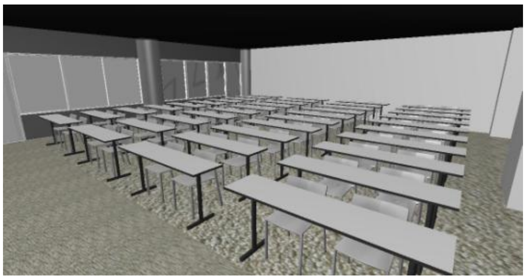
LCC Planning and BIM

LCC analysis in this research shows that the actual results of the repairing and renovation costs vary in timing and scale, and those of the individuation of projects has a large influence on the LCC. In order to realize the detailed LCC Planning, a BIM based on the individual building information will be effective.

Figure 9 shows the building information model of the A3 campus: skeleton (upper left) and completed (upper right). All structural members and finishing of the building elements can be described in the BIM. They are tied to the information for LCC planning with respect to their quantity, their specification, and their timing of each cost.

Figure 9 also shows a detailed model of a classroom in the A3 campus (lower left) and the related information, including components, building elements, attributes, and the quantity per component with BIM (lower right).





Component	Building Element	Arribute	Quantity	Unit
RC Wall	Wall	Area	157.3	m2
Carpet Tile	Floor	Area	130.7	m2
Gypsum Board	Ceiling	Area	124.1	m2

Figure 9: A3 Campus: Skeleton (Upper left) and Completed (Upper right)
A classroom in the A3 campus (Lower left) and its quantity (Lower right)

CONCLUSIONS

This research aims to establish an efficient facility management system for educational institutions such as universities and high schools. First, this research analyses the actual LCC of educational facilities in Japan and clarifies the characteristics of each cost. The LCC analysis shows that the costs are classified into three categories: one time, annual, and irregular.

Construction Cost. After 2000, the ratio of equipment to the construction cost has reached almost 30%. The construction cost per unit total floor area of a building has increased in the past 30 years. The initial costs, including the construction cost, are relatively easy for owners to understand.

Operating and Utility Costs. These are relatively constant. The costs of the A3 campus are different from those of the other campuses because of the equipment. The costs declined for the second consecutive year, down 5% from the previous year because of the energy-saving efforts.

Preservation Costs. As in the case of the operating and utility costs, the preservation costs are relatively constant and similar, but the cost of the A3 campus stands out because of the maintenance cost. The main building in the A3 campus consists of three sub-buildings with elevators and escalators.

Repairing and Renovation Costs. The intervals are irregular, and the costs vary. There is no regularity. Therefore, it is important to understand the characteristics and conditions of each building for the prediction of the repairing and renovation costs.

Demolition and Waste Disposal Costs. There is an insufficient amount of data, particularly for large buildings.

Secondly, this research clarifies the difference between the theoretical LCC and the actual LCC. It also examines the revision system of LCC with actual data. LCC planning normally assumes that the timing of repairing and renovation costs is a cycle. However, the analysis of actual data shows that it is extremely irregular. One difficulty in LCC planning is the prediction of these costs. From the viewpoint of university administration, the annual expenditure depends on the university operation policy. The coordination of the repairing and renovation costs is unavoidable under the conditioned-based FM policy. This research proposes a plan based on an FM policy considering the annual coordination of expenditure.

Finally, this paper discusses the application of BIM for facility management considering LCC to be preparatory research. BIM can consider the individuation of projects. This research shows that all structural members and finishing of building elements can be described in BIM, and that quantity per component of a classroom in the A3 campus can be calculated. This preparatory research shows that the system can support LCC planning.

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