The Impact of Life Cycle Cost Analysis (LCC) Towards Maintenance Performance for High-Rise Residential Lift System

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Abstract

Building maintenance has become an invaluable process in the field of the built environment with the purpose of retaining building value and quality. Life Cycle Cost (LCC) is important in the maintenance field as it can reduce maintenance costs without affecting the performance of services. However, the application of LCC in this country is limited due to a lack of awareness and knowledge about LCC. This research intends to identify the components of LCC and its impact on the maintenance performance of lift systems in high-rise residential buildings. Lift systems are important for high-rise buildings to transport occupants from the ground floor to upper floors but most lift systems have not been effectively managed and maintained in Malaysia, which has resulted in severe injuries to users and even death. Yet, there is a lack of data regarding high-end high-rise residential buildings. Hence, this research will focus on lift systems in high-end high-rise residential buildings. A mixed-method approach has been adopted whereby questionnaires were distributed to building managers of high rise residential buildings in Klang Valley and interviews were conducted with building managers from the selected case studies. With the application of LCC, the maintenance team can consider all the LCC components of the lift system during the decision-making process and improve the maintenance performance of the lift system by having lower breakdown rates, fewer complaints received and quicker response times.

Keywords: *Life cycle cost, lift, high rise, maintenance performance, residential*

1.0 INTRODUCTION

One of the major maintenances works of building systems in high-rise buildings is the lift system for transporting occupants and goods from one floor to another. Unfortunately, most lift systems in Malaysia are not maintained effectively. According to the Department of Occupational Safety and Health (DOSH), there are 2747 escalators and lifts in Kuala Lumpur and Putrajaya that have failed to meet safety standards required by the Factories and Machineries Act as well as Occupational Safety and Health Act in 2014. Since 2010, DOSH has also recorded 111 accidents related to faulty lifts and escalators in shopping centres, resulting in 11 deaths. Additionally, in September 2010, there were two (2) accidents that occurred in low-cost apartments in Selangor, causing four (4) people to suffer injuries such as spinal and leg fractures, and even death. Although DOSH had recorded many lift accidents, these data are mostly reported from low and medium-cost residential buildings and shopping malls. There is lack of data relating to high-end, high-rise residential buildings. To fill in this gap, this research seeks to investigate the maintenance performance of lift systems in high-end high-rise residential buildings.

The term "high-rise building" generally refers to a multi-story structure in which most passengers rely on lift system to move from one floor to another. Usually, a high-rise building constitutes seven (7) or more floors, however Craighead (2009) argues that national definitions vary widely depending on local fire and building codes. In Malaysia, a building with more than seven (7) floors or a height of more than 30.5 meters is considered to be a high-rise building (UBBL, 1984). On the other hand, the term “high-end” is mostly categorized by buildings that are constructed with high-quality materials and equipped with luxurious facilities as well as being strategically located for the convenience of residents. The price range of high-end residential buildings varies from country to country, but generally exceeds RM762 per square foot in Malaysia. Proper and systematic maintenance is important to ensure the reliability of lift systems in a building.

Barringer (1996) stated that life cycle cost (LCC), which is the sum of costs from design stage to the end of useful life, is important in maintenance to optimize the life cycle of assets without affecting their performance. Yet, the calculation of LCC varies depending on the condition of each of the various building systems. LCC helps asset managers in making decisions at design stage that will impact on maintenance performance in the later part of the life-cycle. It takes into account all the costs over the life of the building and evaluates on a common basis for the specified period by applying discount rate. In order to reduce the long-term cost of ownership for lift systems, LCC is essential in assisting owners to determine the distribution of money throughout the life of the system. The earlier the application of LCC, the more likely it is to reduce the cost commitment. This is because LCC can identify high-cost areas and assess changes that can reduce these costs.

Although LCC provides many benefits, its adoption is low, with lack of standard guidelines and reliable past data (Ardit & Messiha, 1999) together with lack of awareness and knowledge about LCC. Hence, this research emphasises the benefits of LCC in relation to lift systems and impact upon maintenance performance in high-rise, high-end residential buildings.

1.1 LCC Components of Lift System

Life cycle costing (LCC) is a method of evaluating the overall cost of an asset from acquisition to disposal stage. Its application and approach vary between different building systems. For the lift system, LCC elements are initial cost, maintenance cost, energy cost, cleaning cost, overhead and management cost, occupational cost as well as decommissioning cost.

1.1.1 Initial Cost

Initial cost is the cost incurred to purchase lift system, install and own it, including all mechanical and electrical equipment needed, the cost of engineering, inspection and testing as well as any spare parts and training. This includes the cost of installation and commissioning which are the civil work, connection of electrical wiring and instrumentation, constructing the lift shaft, plant room, control system and so on. It also covers the performance evaluations at start-up and should include the installation and commissioning of monitoring and control equipment. (UKEssays, 2016)

1.1.2 Energy Cost

Schroeder (1988) observes that these costs cover the total energy cost to operate the lift system, such as lift motor system, control systems, counter balance and all the power sources. It includes electricity costs such as lighting or ventilation to ensure the users' safety and health when operating the lift system. Since many parameters are involved, it is difficult to define the energy consumption of the elevator system. A study conducted by Hans Bosshardt of Schindler Management AG in 1984 showed that there is a "typical trip" that represents the average daytime energy consumption of the lift system. The typical trip time in seconds must be multiplied by the motor rating (in Kw) and the number of trips performed to achieve energy consumption.

E (Kwh/h) = Motor (Kw) x Starts (1/h) x TP (s)/3600 (s/h)

1.1.3 Maintenance Cost

Once the elevator is installed and running, regular maintenance is required to prolong the life cycle of the system. The cost is directly related to the number of hours spent on repairs and the extent to which spare parts are required. These costs are normally classified into:

- Regular planned or preventive maintenance
- Unplanned or reactive maintenance

Preventive maintenance, a form of planned maintenance can reduce the overall maintenance costs. However, the maintenance cost in a "run it until it breaks" approach is inversely proportional to the downtime cost. Costly unplanned maintenance can be required when the lift system breaks down suddenly, incurring consequential production or operational losses and, potentially, loss of trust from customers or occupiers. Costs can be reduced with the use of appropriately drafted maintenance contracts that ensure regular service to maximize uptime and reduce emergency monitoring. Similarly, control solutions to create early warnings that help prevent downtime rates can be used to good effect. Maintenance can be major component in the total LCC calculation if the lift system is poorly matched to its maintenance requirements (Nurul Afida , I.; Sharifah , N.; Raihan , M, 2018).

To reduce the maintenance costs, planned maintenance should be carried on daily, weekly, monthly as well as yearly.

1.1.4 Cleaning Cost

Lift systems should always be in clean condition due to impact on health and safety of users. The scope of areas involved encompass machinery spaces, machine room, control spaces and control room and top car as well as the lift pit. It should include the condition of windings, all equipment such as hoist way, rails, counterweight, doors and floor of lift as well as making sure the pit is dry and free from rubbish with attention to rust removal and painting or repair as required. The type and amount of cleaning materials or chemicals used should be selected with advice from the lift manufacturer and must fulfil the health and safety's regulations such as Occupational Safety and Health Act 1994 (OSHA) and Factories and Machinery Act 1967 (FMA).

1.1.5 Overhead and Management Cost

These include labour costs associated with normal operation of lift system aking in to account, for example, dealing with normal wear and tear, system supervision and maintaining the lift and lift lobby cleaning. It does not include costs attributable to energy or lift system maintenance. The management cost of the lift is usually divided into 2 parts which are in-house costs and costs of outsourced servvices. In terms of maintenance activities, it is common to outsource services from certain competent personnel whilst for the cleaning functions it is common to apply internal resources.

1.1.6 Occupational Cost

Occupational cost is the cost required to occupy the building such as rental, service charges, insurance and taxes of personal property. In this case which relates to lift systems, the occupational costs are relate to license renewal cost for the system and insurance costs. These costs are important in order to secure the safety of users as well as making sure the lift system functions well.

1.1.7 Decommissioning Cost

The costs at the end of the investment life cycle are incurred due to the need to decommission the building, services and equipment. According to the principles of investment calculation, when the maintenance cost reaches a level that is no longer financially viable, decommissioning becomes the correct option.

One approach to investment calculation is to analyze how much maintenance and downtime costs can be avoided each year by new equipment purchase, compared to the value of a one-time investment. Naturally, decommissioning may also be necessary to increase capacity or implement new technology. Dismantling, scrapping and toxic waste disposal can have associated costs, but equipment and materials may also have residual values, although this is often difficult to estimate in advance.

2.0 METHODOLOGY

This study is conducted using a mixed-method approach where both quantitative and qualitative data collection methods are applied. The quantitative approach applied is by questionnaire survey, whilst the qualitative element is done through a structured interview. In the first phase of data collection, the questionnaire survey was distributed to the maintenance staff of the selected case studies.
All the data collected via questionnaire surveys were analysed using Statistical Package for Social Sciences (SPSS) software. The purpose of these questionnaire surveys was to obtain information regarding the LCC components to be considered in lift systems and their impacts on the maintenance performance of lift systems. The relationship identified from the literature review between LCC and maintenance performance of lift systems is shown in Figure 1.

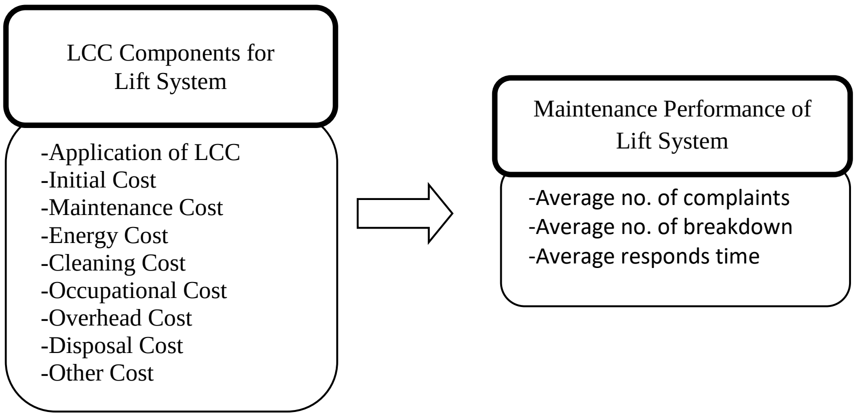

Figure 1: Relationship between LCC and Maintenance Performance of Lift System

Three (3) interviews were conducted with stakeholders such as building managers from the selected case studies. The purpose of these interviews is to have a deep understanding of the reasons for the use of selected LCC components. The issues and challenges faced in the application of LCC to improve maintenance performance and the ways in which LCC can impact maintenance performance were also identified.

3.0 FINDINGS AND ANALYSIS

The majority of the respondents were building managers which account for 66%, of the sample followed by maintenance staff (20.7%) and others (14%) as shown in Table 1. The respondents in the category of "others" are building executives, operation executives and building administrators. In terms of work experience, 43% of respondents have 1-5 years of work experience, followed by 5-10 years of experience (37%), more than 10 years of experience (17%) and lastly below 1 year of experience (3%).

Table 1: Respondents Profile

Item		**Percentage (%)**
Position	Building Managers	66
	Maintenance Staffs	20.7
	Others	13.3
	Total	100
Working Experience	<1 year	3
	1-5 years	43
	5-10 years	37
	>10 years	17
	Total	100

The respondents were asked to rate the importance of LCC on the scale from 1 (least important) to 5 (most important). Table 2 indicates the mean scoress of the respondents' opinions regarding the importance of LCC, it was found that the highest priority of LCC application is to improve the maintenance performance of any building systems, the mean score obtained was 4.19, followed by reduced maintenance cost (3.78), then to assess the extent of money expended (3.54) and for decision-making in replacement or repair (2.35), followed by decision-making in selecting the system (1.84).

Table 2: Mean Scores for Importance of LCC

Importance of LCC	**Mean**	**Std. Deviation**
Reduce maintenance cost	3.78	.976
Decision-making in replace or repair	2.35	1.317
Decision-making in selecting the system	1.84	1.191
Improve maintenance performance	4.19	.908
Know the weightage of money outflowed	3.54	1.095

Table 3 shows the LCC components considered for lift system. The respondents indicated that initial cost (92%), maintenance cost (95%) and energy cost (84%) are the most important components of LCC in the context of lift systems. 8% of respondents responded that the other costs considered are the costs for upgrading the lift system over a certain time, insurance and downtime cost. The reason for the LCC components such as cleaning cost (3%), overhead cost (16%), occupational cost (8%) and disposal cost (5%) were not considered by respondents.

Table 3: LCC Components Considered for Lift System

LCC Components Considered for Lift System	Percentage of Respondents (%)	
	Yes	No
Initial Cost	92	8
Maintenance Cost	95	5
Energy Cost	84	16
Cleaning Cost	3	97
Overhead Cost	16	84
Occupational Cost	8	92
Disposal Cost	5	95
Other Cost	8	92

The average number of complaints received per month was analyzed and the results are set out in Table 4, below. 58% of respondents stated that the average number of complaints received monthly is less than 10 while 42% received 11-30 complaints. None of the respondents received 11-30 complaints per month.

Table 4: Performance of Lift

Item		Percentage (%)
Average Number of Complaints	<10	58
	11-30	42
	>30	0
	Total	**100**
Average Number of Lift System Breakdown	<5	76
	6-10	18
	11-20	6
	>20	0
	Total	**100**
Average Responds Time of Lift System During Breakdown	< 10minutes	42
	11-30 minutes	26
	31-60 minutes	26
	>1 hour	6
	Total	**100**

Moreover, the respondents indicated that in resepect to the average number of lift system breakdowns per month , fewer than 5 times accounted for 76%, followed by 6-10 times (18%) and lastly 11-20 times (6%). None of tthe respondents in the case study received more than 20 reports of lift breakdown per month. The majority of the respondents (42%) stated that the average response time of the lift system during breakdown is less than 10 minutes while the fewest respondents (6%) stated that the average response time is more than 1 hour. Both 11-30 minutes and 31-60 minutes of response time got the same percentage of respondents which was 26%.

In addition, the respondents opinions on the impact of LCC towards maintenance performance of lift system is shown in Table 5. According to Gray & Kinnear (2012),fewer than 0.3 points of correlation coefficient is a weak relationship; 0.3-0.5 coefficient means a medium relationship and lastly 0.5 or higher points of correlation coefficient reflected a strong relationship between two variables. Yet, SPSS states that correlation is significant at the 0.05 level or below. The application of LCC significantly correlated with the maintenance performance of lift systems such as average number of breakdowns per month, with a coefficient of 0.001522 ($p < 0.05$). The statement of Martin (2010) was proven, which mentioned that LCC can improve maintenance performance of lift systems as it can liberate more detailed understanding of input trends over the expected life cycle. With the application of LCC, building owners or representatives of owners will know the allocation of money expended and can concentrate more on the important parts of system. By doing so, action can be taken to repair or maintain elements before the system breaks down. Hence, the application of LCC can reduce the average number of breakdowns of lift systems, at the same time improving the maintenance performance of lift systems.

The correlation coefficient of 0.019378 ($p < 0.05$) indicated a significant correlation between initial cost and average number of breakdowns of lift systems. This analysis supports the statement of writers of UKEssays (2016) who state; "In providing quality services for a building there must be two cost considerations. One is the initial cost and the second is the return from investment over the economic life of the building". The initial costs include materials cost, equipment costs, furnishing costs and others.

Moreover, the correlation analysis computed a significant correlation coefficient of 0.001522 ($p < 0.05$) between maintenance cost and average number of breakdowns of lift systems. Brade (2018) mentioned that maintenance costs are an important part of the asset's life cycle costs and that everyone needs to identify and manage them. Without doing so, it is impossible to reach the common goal of efficient operation. The findings of Afida *et.al.* (2018) also state that the efficiency of lift systems is dependent upon the maintenance activities executed. The maintenance work is important to keep the lift systems working sufficiently as well as enhancing their lifespan. These statements matched the result of analysis, which demonstrated that the importance of considering maintenance cost as one component of the LCC in improving the maintenance performance of lift systems and reducing the average number of breakdowns.

Lastly, the correlation analysis also demonstrated that energy cost is significantly correlated with the average number of breakdowns (0.000639, $p < 0.05$) and response time (0.008426, $p < 0.05$). Acaddrafting (2017) states that by considering the energy cost as one of the components of LCC, the property owner can have a deep understanding of the energy used and then able to delevop or plan ways for efficient use of energy for the system. By doing so, energy conservation is promoted. This can at the same time prolong the lifespan of the system, improve the maintenance performance by reducing the breakdown rate and shorten the response time.

Table 5: Correlation between LCC and Maintenance Performance of Lift System

		Average No. of Complaints	**Average No. of Breakdown**	**Average of Respond Time**
Do you apply LCC in lift system?	Correlation Coefficient	.276	.522**	.274
Initial cost	Correlation Coefficient	.146	.378*	.123
Maintenance cost	Correlation Coefficient	.276	.522**	.274
Energy cost	Correlation Coefficient	.215	.639**	.426**
Cleaning cost	Correlation Coefficient	.140	.091	.175
Overhead cost	Correlation Coefficient	.215	.080	.119
Occupational cost	Correlation Coefficient	.250	.162	.189
Disposal cost	Correlation Coefficient	.201	.130	.103
Other cost	Correlation Coefficient	.250	.162	.066

Interviews were conducted with 3 interviewees, identified as Interviewee A, B and C selected from among the respondents of the questionnaire survey to determine the issues and challenges faced when applying LCC in the maintenance field. According to Interviewees A and C, the data required for calculating the LCC of lift systems was obtained from various authorities and requires cooperation between clients, lift companies and maintenance personnel. This is because some comparisons will be made among the situations of higher investment, lower future cost or lower investment, higher future cost. Hence, it requires constant follow up. However, some companies' privacy policies lead to those involved in calculating the LCC refusing to provide the data accurately. This situation influences the feasibility of LCC calculation.

Moreover, lack of trained staff with LCC knowledge is also one of the challenges. According to Interviewees B and C, there is controversy about who is responsible for calculating the system's LCC in practice. This resulted in no one taking action for self-improvement, or equipping themselves with LCC knowledge. This is because most of the authorities believe that the LCC calculations are done by clients, so the maintenance personnel lack motivation to have in-depth understanding about LCC. This leads to the lack application of LCC as maintenance personnel, including some building managers, are not aware that LCC is essential in order to improve the maintenance performance of any system.

In addition, there is also lack of guidelines for Malaysian builders to refer to when calculating the LCC of systems. Based on the statements from Interviewee A, the calculation of LCC is not simple as it considers the future cost and discounted rate. Beyond that, LCC components also differ between individual systems. The person involved in LCC calculations requires considerable time to survey different companies or types of system in order ensure efficient decision-making in investment of initial cost. Besides, lack of enforcement and awareness given by Government will also reduce the implication of LCC in construction.

All the interviewees opined that it is difficult to obtain the data accurately; lack of LCC knowledge and lack of guidelines are the main issues and challenges faced during the application of LCC in maintenance. There are some recommendations and suggestions on raising the awareness and implication of LCC in maintenance suggested by the interviewees as shown in Table 6.

Table 6: Recommendations and Suggestions

Issues & Challenges	Recommendations and Suggestions
Difficulty to obtain data accurately	• All authorities involved know their responsibilities on LCC calculations. • Organize meetings to achieve some mission and vision among all authorities involved so that they know better the situation.
Lack of LCC knowledge	• Raise awareness on importance of LCC in maintenance field. • Establish each authorities' roles in calculating LCC so that all authorities can cooperate with each other. • Training to staffs to have in-depth understanding on LCC.
Lack of guidelines for LCC calculations	• Government establish guidelines and standards for LCC calculations methods. • Government enforcement the application of LCC by giving incentive.

4.0 CONCLUSION

The findings of the research have proven that there is a significant relationship between LCC and maintenance performance of lift systems in term of average number of breakdowns. The LCC, which includes the application of LCC, initial cost, maintenance cost and energy cost are significantly correlated to the average number of breakdowns per month. Energy cost also significantly correlated to average response time. Moreover, the results highlighted the LCC components considered in lift systems which are initial cost, maintenance cost and energy cost. In order to smoothen the process of LCC calculations, all parties should give full commitment and be willing to provide the data accurately. Meetings or discussions could be effected to understand and achieve the mutual goals of all parties. In order to raise awareness of importance of LCC, government or local authorities can organize seminars to widen the knowledge of LCC for all Malaysian builders. During these seminars, parties' responsibilities in LCC calculations can be established clearly so that all parties know their roles and are able to give cooperation wisely. Government can also raise awareness on the importance of LCC by giving incentives to those who applied LCC in maintenance. By doing so, it can encourage more building managers to use LCC as it can reduce maintenance cost and improve maintenance performance. Government should also establish guidelines and standards for LCC calculations to assist building managers in the implementation LCC in maintenance. Overall, LCC is essential in maintenance as it brings many of advantages, especially the improvement of maintenance performance and reduction in maintenance costs. Awareness of the importance of LCC should be raised so that the application of LCC in Malaysia can be increased.

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