Kajavathani, P. and Ramachandra, T., 2022. An assessment of maintenance cost of residential apartments in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, K.G.A.S. (eds). *Proceedings of the 10th World Construction Symposium*, 24-26 June 2022, Sri Lanka. [Online]. pp. 89-101. DOI: https://doi.org/10.31705/WCS.2022.8. Available from: https://ciobwcs.com/2022-papers/

AN ASSESSMENT OF MAINTENANCE COST OF RESIDENTIAL APARTMENTS IN SRI LANKA

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ABSTRACT

Buildings require maintenance for their continuous operation at a higher level through their extended life. Early prediction of maintenance costs (MC) would enable efficient maintenance and smooth operations of the buildings and thereby ensure achieving value for the investment. The effects of factors on MC provide a chance to refine the design to ensure the optimisation of MC during early design development. Thus, this study aims to analyse the MC of high-rise residential apartments along with the effects of factors influencing MC in Sri Lanka. Initially, a questionnaire survey was conducted to assess the factors' impact on the MC elements based on a 1-5 Likert scale. Then, a case study approach was employed using three high-rise residential apartments with above 30 floors located in Colombo to analyse the costs of MC elements. The data collected from semi-structured interviews and document review were analysed manually as a percentage of MC. The findings revealed that MC accounts for 30% of running costs (RC). According to Pareto analysis, 11 out of 29 sub-elements including lifts and escalators, maintenance management, repairs and replacement, and electric power and lighting contribute to 80% of MC. Further, most of the building design factors and technical factors highly affect the MC. The annual MC per GFA is about Rs. 350.00. It is expected that these findings would enable the designers to forecast the MC and focus on the relevant design and technical factors to optimise the maintenance costs of high-rise residential buildings at the early design stages.

Keywords: *Cost Components; High-rise Residential Apartments; Maintenance Costs; Maintenance Phase.*

1. INTRODUCTION

The traditional costing approach for building projects predominantly focuses on minimising initial capital cost at the expense of future costs (Kishk, et al., 2003). Despite the importance of initial capital costs, the running cost (RC) of most of the buildings exceeds 50% of the total Life Cycle Cost (LCC) (Alqahtani and Whyte, 2016). According to Alqahtani and Whyte (2016), the RC of commercial buildings account for 60-74% of LCC, whereas the RC of residential buildings accounts for 40-55% next to commercial buildings. On a slightly different note, Weerasighe, et al., (2016) indicated that the RC of Sri Lankan office buildings account for 75% and 25% of RC respectively. As Chua et al. (2018) stated, all buildings require maintenance for their continuous operation at a higher level through their extended life. The building maintenance can be considered as the

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combination of technical and administrative actions associated with ensuring the elements are in a position to perform and function in an acceptable and suitable standard (Chanter and Swallow, 2007; Pelzeter, 2007; Lateef, et al., 2010; Ali, et al., 2010). The quality of maintenance assures minimum interruption during the operation of the system (Lai and Yik, 2008). Due to higher Maintenance Costs (MC), the public ignores building maintenance value without focusing its effects on the operational phase (Lateef, et al., 2010). It is undeniable that routine maintenance plays an essential role in high-rise residential buildings (Au-Yong, et al., 2019).

During the last decade, Colombo's skyline has been dominated by a great number of high-rise apartment structures (Jayalath, 2016). In typical buildings, 80% of the RC are influenced by 20% of initial costs (as cited Weerasighe, et al., 2016). Therefore, early prediction of MC can assist in cost-related decisions and minimising subsequent future costs (Chan, et al., 2003). Masshender and Finch (1998) identified factors including building characteristics and political factors that affect MC. Subsequently, Ali et al., (2010) identified five factors influencing the MC, including the building characteristics, tenant, maintenance factors, political and other factors. Increased MC are a significant concern for the building industry (Lai and Yik, 2008). Besides every building having its unique characteristics, it requires a different degree of cost allocation and distribution for maintenance (Ali et al., 2010). Perera et al. (2016) believe that placing dominant factors influencing would assist the building managers in the budget allocation with optimum MC on each task from the early stage. Thus, this study aims to analyse the significance of MC in high-rise residential apartments in Sri Lanka.

2. LITERATURE REVIEW

2.1 FACTORS AFFECTING MAINTENANCE COSTS

MC contributes significantly to the total building cost (Boussabaine, et al., 1999). The quality of maintenance assures minimum interruption during the operation of the system (Lai and Yik, 2008). Futher to authors, 15% of the total number of elements of the Building MC Information System (BMCIS) account for 85% of total RC. Perera, et al. (2016) indicated that factors affecting MC should be recognised initially to reduce their impacts. Similarly, Ihsan and Alshibani (2018) stressed that factors should be identified to develop strategies and methods to regulate the cost, to increase its intended benefits, and enable maintenance managers to distribute limited resources efficiently. Maintenance strategy should be selected carefully considering the users' standard, budget, function, and building size (Elhag, et al., 2005).

Building characteristics are the essential operation and maintenance expense determinants (Perera, et al., 2016). The nature of the site refers to location, physical condition, services availability, resources availability and climate condition of the site affects the building MC (Cunningham, 2013). Technical factors also impact building MC (Nyayiemi, 2013). According to Nyayiemi (2009), poor workmanship leads to an increase in the cost of maintenance. Function of the building is another parameter that directly influences MC as factors including the design of the building and technology used vary depending on this (Bari, et al., 2012). A higher number of occupants will cost more to the client (Cunningham, 2013). Table 1 presents the factors affecting MC elements.

Table 1: Factors affecting MC elements

	Factors	Maintenance Management	Services Management	Repairs and replacement	Cleaning	External works	Fabric cost	Decorations & Finishes
Design of the building	Life time	✓	✓	✓	✓	✓	✓	✓
	Plan shape	✓	✓	✓		✓	✓	✓
	Size of the building (GFA)	✓	✓	✓		✓		✓
	Wall to floor ratio	✓	✓	✓				✓
	Degree of circulation space		✓			✓		✓
	Storey heights		✓			✓	✓	✓
	Total height of the building		✓			✓		✓
	Grouping of buildings	✓		✓				✓
	Ecstatically appearance				✓	✓	✓	✓
Nature of the site	Location							✓
	Physical condition							
	Services availability							
	Resources availability				✓			✓
	Climate condition	✓	✓	✓		✓	✓	✓
Technical factors	Technology used	✓	✓	✓	✓	✓		✓
	Workmanship	✓	✓	✓	✓	✓		✓
	Quality of materials & equipment used	✓	✓	✓				
	The durability of materials & equipment used	✓	✓	✓				✓
Tenant factors	Expectation of tenant	✓		✓	✓	✓	✓	✓
	Use of the property							
	Vandalism by the tenants							
	Delay and failure in reporting problem	✓	✓	✓			✓	✓
	Accessibility to the property							
Other factors	The function of the building	✓	✓	✓	✓	✓	✓	✓
	Number of Occupants	✓	✓	✓				
	Legislative constraints							

Adapted from: (Meng, et al., 2009; Bari, et al., 2012; Krstić and Marenjak, 2012; Nyayiemi, 2013; Cunningham, 2013; Islam, et al., 2015; Che-Ghani, et al., 2016; Shabniya, 2017).

During the early stage of the construction projects, the initial cost estimates are highly focused on the early decision-making process (Ji and Ahn, 2019). At the design stage, critical activity forecasts cost for services elements and evaluate alternative designs proposals (Aibinu, et al., 2015). It has been reported that between 70-85 % of the building

which is a significant part of the total building life cycle costs, can be influenced during the design stage (Krstic and Marenjak, 2012).

3. RESEARCH METHODOLOGY

Initially, a questionnaire survey was conducted using a Likert scale to assess the impacts of factors on the MC elements. Respondents were asked to weigh the factors identified through literature review on a 5-point scale representing 1-Not at all affected, 2-Slightly affected, 3-Neutral, 4-Affected and 5-Highly affected. Then a case study approach was adopted to analyse the MC of the high-rise residential apartments in detail. Three high-rise residential apartments of above 30 floors located in Colombo were selected for the study considering different factors impacting the MC of residential apartments. Documents such as annual budget estimates, maintenance budgets, utility bills, drawings, manuals, and other cost documents were reviewed to obtain the MC details of the selected apartments. Along with this, semi-structured interviews were conducted to obtain other cost-related details and building characteristics. The interviewees included professionals who were involved in the maintenance of the selected apartments including the Project Manager, Facilities Engineer and Facilities Manager. The unique characteristics and features of the buildings were also noted. Details of MC elements were derived from New Rules of Measurement (NRM) 1 and Building Cost Information Service (BCIS) standards. The obtained data were tabulated in Microsoft excel and manually analysed in terms of cost per GIFA (m^2), cost per person, cost per unit and cost of maintenance elements as a percentage of total MC. Further, cross-case analysis was carried out considering the MC of the apartments. Weighted Mean Rate (WMR) was calculated to evaluate the factors affecting the MC. The WMR was calculated according to the formula given in Eq. 01.

$$WMR = \frac{\sum_{i=1}^{5}(x_i \times f_i)}{\sum R} \qquad \textit{(Eq. 01)}$$

Where: WMR= Mean Rating for an attribute; f_i = Frequency of responses for an attribute, x_i= Likert scale for an attribute (ranging 1 to five), $\sum R$= Total number of respondents.

In addition, Pareto analysis was selected because it reflects on potential issues and attempts to recognize areas of improvement (Tembo Silungwe and Khatleli, 2020). Typically, the results of a Pareto analysis are represented by a Pareto chart, and in ranked order, the chart represents the different variables under consideration (Talib, et al., 2010). The theory of Pareto is a mathematical approach based on the Pareto Theory that approximately 80% of the consequences arise from 20% of the reasons for certain cases (Tembo Silungwe and Khatleli, 2020). In this study, Pareto analysis identifies the significant elements that contribute to 80% of the MC in the residential apartments.

4. RESEARCH FINDINGS

4.1 QUESTIONNAIRE ANALYSIS

The questionnaire survey was administered to a sample of 37 professionals who involved in the maintenance of high-rise residential apartments and were aware of MC. Table 3 provides the basic characteristics of the respondents. As seen from Table, a total of 34 professionals with a fair distribution of professional category of Architects, Facilities Managers, Engineers, Quantity Surveyors and Project Managers responded to the survey.

Further, 50% of the sample respondents have over 10 years of experience, while remaining 50% was with less than 50%.

Table 2: Basic characteristics of respondents

Professionals	No. of Participants	Years of experience	No. of Participants
Architect	4	Less than 5 years	8
Facilities Manager	7	5 – 10 years	9
Engineer	9	10 - 15 years	5
Quantity Surveyor	10	15 - 20 years	8
Project Manager	4	20 - 25 years	4

The questionnaire responses were tabulated and WMR was calculated. The WMRs were further categorised using another scale to decide the degree of affected level. Table 3 provides the scale used to represent the affected level.

Table 3: Affected criteria based on weighted mean

Mean Value	Degree of Affected Level
$4.75 \leq x \leq 5.00$	Highly Affected factor (HA)
$3.50 \leq x < 4.75$	Affected factor (A)
$2.00 \leq x < 3.50$	Slightly Affected factor (SA)
$1.00 \leq x < 2.00$	Not Affected factor (NA)

Respondents were asked to scale the factor based on its impacts on the respective building MC elements. Factors were scaled based on a Likert scale from 1-5. The weighted mean value of each factor was used to determine its rank. The weighted mean of each factor is used to decide the affected type based on Table 3. Table 4 shows the link between the selected parameters and the MC aspects gleaned from the questionnaire survey.

Table 4: The relationship between the selected factors and the MC elements

	Factors	Maintenance Management	Service Management	Repairs and Replacement	Cleaning	External Works	Fabric Cost	Decoration Cost
Design of the building	Life time	HA	HA	HA	SA	A	A	A
	Plan shape	SA	HA	A	HA	A	HA	HA
	Size of the building (GFA)	HA	HA	A	HA	NA	A	SA
	Wall to floor ratio	HA	A	A	NA	NA	NA	NA
	Degree of circulation space	HA	HA	A	A	A	HA	HA
	Storey heights	HA	HA	HA	SA	A	NA	A
	Total height of the building	HA	HA	SA	A	A	A	A
	Grouping of buildings	A	NA	SA	SA	A	SA	A
	Aesthetical appearance	A	SA	A	HA	A	HA	HA

	Factors	Maintenance Management	Service Management	Repairs and Replacement	Cleaning	External Works	Fabric Cost	Decoration Cost
Nature of the site	Location	A	A	NA	NA	A	SA	A
	Physical Condition	SA	A	SA	NA	NA	NA	SA
	Services availability	HA	A	A	SA	A	A	A
	Resources availability	HA	SA	NA	NA	SA	A	NA
	Climate condition	SA	HA	A	A	HA	HA	HA
Technical factors	Technology used	SA	HA	HA	A	SA	SA	NA
	Workmanship	A	HA	HA	HA	A	A	NA
	Quality of material and equipment used	HA	HA	HA	A	A	A	SA
	Durability of material and equipment used	HA	HA	HA	A	NA	NA	NA
Tenant factors	Expectation of tenant	A	SA	A	A	HA	A	A
	Use of the property	HA	HA	SA	NA	SA	HA	NA
	Delay and failure in reporting problem	HA	A	HA	A	SA	NA	NA
Other factors	Number of occupants	HA	SA	HA	HA	A	NA	A
	Function of the building	HA	HA	HA	HA	HA	NA	NA
	Legislative constraints	SA	NA	A	A	NA	NA	NA

As observed from the table, most of the design variants affect MC of the building. In particular, building lifetime and plan shape were identified as highly affecting the MC while wall to floor ratio has the least impact. Similarly, nature of the site has less impact on MC compared to other factors. All the technical factors including technology used, workmanship, quality of material and equipment used and durability of material and equipment used have a high impact on services management, and repairs and replacement. Tenant factors affect most of the MC elements. Number of occupants and functionality of the building highly affect most of the MC elements. However, they have less influence on the fabric and decoration costs. Compared to other factors, legislative constraints have the least influence on MC elements. The maintenance management cost was mostly affected by most of the factors as stated in the table. The services management is highly affected by building design factors and technical factors. The repairs and replacement costs are highly affected by the total height of the building, technical factors, delay and failure in reporting problems, number of occupants and function of the building. Cleaning cost, external works, fabric cost and decoration cost were impacted by a few factors. Fabric cost and decoration cost were impacted by plan shape, degree of circulation space and aesthetic appearance.

4.2 CASE STUDY ANALYSIS

The high-rise buildings selected for the study were named AP1, AP2 and AP3 and the RC data were obtained for one year period of April 2019 to March 2020 to analyse the significance of MC elements. Table 5 presents the profile of the selected three buildings.

Table 5: Profile of the selected buildings

Details	AP1	AP2		AP3
		Tower - I	Tower - II	
Size (GIFA - m^2)	44,528	25,620	28,698	42,300
Circulation space (m^2)	3,670	2,760	3,090	4,243
Number of floors	47	33	37	45
Number of units	152	48	56	115
Total height (m)	160.9	142	131	146
Number of occupants (Nr)	600	180	220	448
Operated years	03	11		10
Orientation	North	North		South
Grouping of buildings	Detached	Attached		Detached
Type of structure	Tubular structure	Tubular structure		Tubular structure
Location	Colombo	Colombo		Colombo
Specific feature	Green certified	Twin tower		-

As all three buildings were situated in a given location, Colombo where the political, social, and environmental set-up are similar, hence, it is expected the effects of those factors; political, social, and environmental are minimal. Similarly, the impact of tenant characteristics on the cost is considered to be minimal when considering the tenants' income and affordability in luxury apartments. The operational phase maintenance management of three apartments was outsourced to specialised facilities management companies. Two of the apartments are managed by the same company while the third apartment is managed by a similar type of organisation. Therefore, almost similar maintenance procedures and standards are followed in all three apartments. Further, the impact of design and construction defects can be considered a minimum based on fewer operating years and the construction uniqueness of the apartments. The AP1 residential apartment tower consists of 152 units. AP2 has only two apartment units on each floor. AP3 includes one to four-bedroom apartment units and penthouses. Each floor includes only four apartments. All three apartments have incorporated amenities with unique features for comfortable residence in high-rise apartments.

As evidenced in Table 6, the average operating costs of apartments is 70% of the RC, while MC accounts for 30%. Table 6 presents the distribution of major MC elements as a percentage of RC in all three residential apartments. In terms of major elements of MC, services and maintenance management are the significant contributors with 14% and 5% contribution respectively. Further, the annual MC per GFA is about Rs. 350.00.

Table 6: Distribution of major MC elements as a percentage of running cost in all three residential

Cost Elements	AP1		AP2		AP3	
	(Rs.)	%	(Rs.)	%	(Rs.)	%
Running costs	49,693,684.00		60,019,320.00		53,820,659.34	
Operational costs	32,906,119.00	66.22%	41,898,279.00	69.81%	39,677,153.91	73.72%
Maintenance costs	16,787,565.00	33.78%	18,121,041.00	30.19%	14,143,505.43	26.28%
Services maintenance	6,587,837.00	13.26%	9,690,581.00	16.15%	6,872,505.43	12.77%
Maintenance management	2,883,000.00	5.80%	2,950,000.00	4.92%	2,571,000.00	4.78%
External works	5,047,288.00	10.16%	1,216,460.00	2.03%	1,130,000.00	2.10%
Fabric	1,119,440.00	2.25%	1,544,000.00	2.58%	1,675,000.00	3.11%
Repairs & replacement	500,000.00	1.01%	1,870,000.00	3.12%	1,000,000.00	1.86%
Cleaning	480,000.00	0.97%	680,000.00	1.13%	750,000.00	1.39%
Decoration	170,000.00	0.34%	170,000.00	0.28%	145,000.00	0.27%
Cost per m^2 of GFA		377.01	333.61		334.36	
Cost per occupant (per month)		2,331.61	3791.74		2,630.86	

4.3 PARETO ANALYSIS

The Pareto analysis was conducted on the major and sub-elements of MC represented in Table 7. According to Pareto analysis, 11 of 21 sub-elements contribute to 80% of MC. Of them, lifts and escalators account for 30% of MC while maintenance management accounts for 17% of MC. The remaining elements (9 out of 11) contribute 2% to 7% as seen from Table 7. The remaining individual elements which contribute less than 2% on average were merged and represented as other elements in the table. The other elements include other structural items, heating and ventilation, windows, plumbing and internal drainage, external finishes, fittings and fixtures, internal decoration, telecommunication and data, gas installations and external decorations. The average cost of the elements of landscaping and repairs and decoration was derived ignoring AP1 as the contribution of the respective elements is abnormally higher than in other two buildings.

According to Table 7, services maintenance accounts for approximately 47% of MC. The lifts and escalators are the primary cost accounting sub-element in-service maintenance. More than 55% of services MC is spent on lifts and escalators. The regenerative drive technology utilised in apartment AP1 generates its electricity in elevators and uses the least amount of power from the main grid. Elevators in AP1 are more cost-effective to run than conventional elevators. The intelligent sorting system incorporated into the lift programming also increases its efficiency. The regenerative drive technology and PORT have helped to reduce the building's total energy use and contribute to achieving the building's sustainability targets. AP2 includes two elevators and one service elevator in each tower. The lift access control service is outsourced to a specialised organisation. AP3 includes two elevators and one service elevator. All three elevators have been equipped with the group controller system to reduce energy consumption and waiting time.

Table 7: Distribution of MC elements

No	Cost components (Rs.)	AP1		AP2		AP3		Average cost	As % of MC	Cumulative %
		(Rs.)	%	(Rs.)	%	(Rs.)	%	(Rs.)		
	Maintenance Cost	16,787,565.00		18,121,041.00		14,143,505.43		16,350,703.81		
1	Lifts and escalators	4,016,318.00	23.92%	6,738,056.00	37.18%	3,795,500.00	26.84%	4,849,958.00	29.66%	29.66%
2	Maintenance management	2,883,000.00	17.17%	2,950,000.00	16.28%	2,571,000.00	18.18%	2,801,333.33	17.13%	46.79%
3	Repairs and replacement	500,000.00	2.98%	1,870,000.00	10.32%	1,000,000.00	7.07%	1,123,333.33	6.87%	53.67%
4	Electric power and lighting	833,126.00	4.96%	967,590.00	5.34%	1,059,500.00	7.49%	953,405.33	5.83%	59.50%
5	Repairs and decoration	1,547,288.00	9.22%	736,460.00	4.06%	630,000.00	4.45%	683,230.00	4.18%	63.67%
6	Fire detection and protection system	565,440.00	3.37%	720,200.00	3.97%	650,000.00	4.60%	645,213.33	3.95%	67.62%
7	Landscaping	3,500,000.00	20.85%	480,000.00	2.65%	500,000.00	3.54%	490,000.00	3.00%	70.62%
8	Other M&E services	415,484.00	2.47%	490,000.00	2.70%	490,505.43	3.47%	465,329.81	2.85%	73.46%
9	Internal finishes	325,000.00	1.94%	504,500.00	2.78%	540,000.00	3.82%	456,500.00	2.79%	76.26%
10	Roof structures	318,440.00	1.90%	450,000.00	2.48%	480,000.00	3.39%	416,146.67	2.55%	78.80%
11	Internal/external surfaces	250,000.00	1.49%	400,000.00	2.21%	500,000.00	3.54%	383,333.33	2.34%	81.15%
12	Other elements	1,433,469.00	8.54%	1,605,500.00	8.86%	1,677,000.00	11.86%	1,571,989.67	9.61%	

The maintenance management of all three apartments accounts for nearly 16-18% of MC and 5-6% of RC. Repairs and replacement are another critical element that contributes significantly to MC. Repairs and replacement cost in AP1 account for 3% whereas an average cost of 9% in the other two apartments. Compared to AP1, increased spending is observed in AP2 and AP3. Apartments AP2 and AP3 have nearly ten years of operational period, whereas AP1 has three years of operation. With the increased operational period, the spending on repairs and replacement works has increased. Also, from Table 4, it is noted lifetime is a highly affecting factor for repairs and replacement. Electric power and lighting cost approximately 5-8% of MC while fire detection and protection system cost 3-5% of MC. All three apartments have integrated smoke, heat and gas detector, and fire safety systems, including an automated fire sprinkler device, a firefighting hose reel wet riser system, and fire extinguishers on each floor.

As evidenced in the profile of the selected buildings, AP1 is a green-certified building. Compared to other two apartments, a significant increase is observed in the MC of external works of AP1. External works contribute approximately 10% to RC in AP1 while an average of 2% in the other two apartments. The increased percentage is observed as the result of increased expenditure for landscaping and repairs and decoration. The landscaping costs of apartments AP2 and AP3 are 3-4% whereas AP1 accounts for 21%. Repairs and decoration in AP1 account for 9% whereas the other two apartments have only 4% of the MC. Repairs and decoration consist pest control services, drains and road pavements. As the AP1 is a green-certified residential vertical garden, more cost is spent on maintaining the garden and drip irrigation system and pest control. The management has assigned a specialist landscape architect to carry out the ongoing maintenance of the green terraces of the apartments.

The maintenance of other M&E services costs nearly 2-3% of MC. All three apartments do not have records related to the expenditure of refrigeration equipment and loose appliances. Internal finishes account for 2-4% of MC. The internal finishes include three major sub-elements including wall finishes, floor finishes and ceilings. Roof structures are considered as one of the critical elements of fabric maintenance. It includes three further sub-elements covering flat, covering pitched and gutters and rainwater pipes accounting for 2-4% of MC. The cleaning cost maintenance for internal and external surfaces are more significant than the cleaning cost for windows accounting for 2-4% of MC. Figure 1 illustrates the Pareto analysis for the MC elements derived from Table 7.

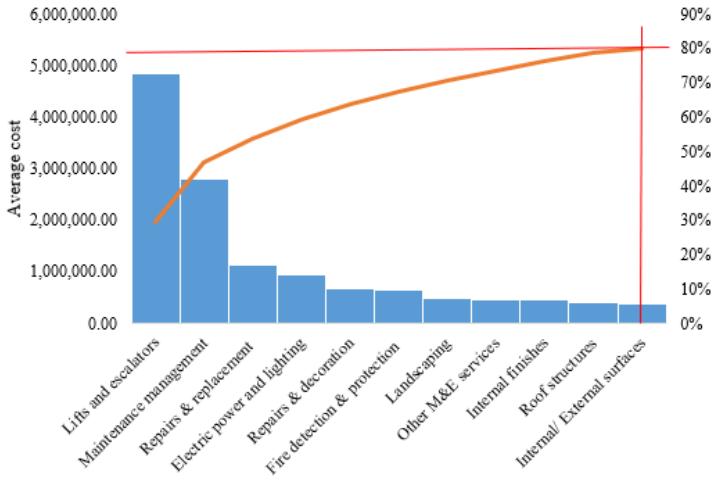

Figure 1: Pareto analysis for the MC elements

According to Figure 1, the first five elements of lifts and escalators (30%), maintenance management (17%), repairs and replacement (7%), electric power and lighting (6%) and other elements including repairs and decoration, fire detection and protection system, landscaping, other M&E services, internal finishes, roof structures and internal/external surfaces contribute to 80% of the MC.

5. DISCUSSIONS

The operating costs range from 65% to 70% of RC in the selected apartments, while MC accounts for between 30%-35% of the RC. The operational costs include insurance, utilities, administrative costs, and taxes. The service MC accounts for approximately 47% of MC and this is highly affected by the design of the building except the grouping of elements, technical factors, climatic condition, use of property and function of the building. The legislative constraints and grouping of buildings do not seem to influence the service maintenance. Maintenance management is another critical element that accounts for approximately 16-18% of RC. The factors such as plan shape, degree of circulation shape, climatic condition and lifetime of the building highly affect the MC, whereas physical condition, legislative constraints, resource availability and wall to floor ratio seem to have a slight impact. The external work is an item that has a minimal impact on the MC with nearly 7-8% contribution in a typical building whereas, the same in a green building account for about 30% of the MC. The external works are highly affected by climate conditions, expectation of tenants and function of the building. Size of the building, wall to floor ratio, physical condition, the durability of material and equipment used and legislative constraints have least or no impact on external works. The MC of repairs and replacement accounts for 7-10% in buildings with more than 10 years of occupancy and just 3% in building with 3 years of occupancy. Also, it is noted that lifetime is a highly affecting factor of repairs and replacement. Cleaning and fabric also take a small share of nearly 3-7% of MC. Further, the cost of these elements is highly dependent on plan shape and aesthetical appearance of the building.

6. CONCLUSIONS AND RECOMMENDATIONS

Maintenance is one of the significant concerns in buildings throughout the life cycle, thus the cost of it is not to be oversighted. Thus, this research has analysed the MC of high-rise residential apartments in Sri Lanka and concluded that the annual MC per GFA is about Rs. 350.00. According to the analysis, this is account for 30-35% of the RC. Services maintenance, maintenance management, external works and repairs and replacement are the critical major elements contributing over 80% of the MC in these high-rise buildings. Over 55% of services maintenance is spent on lifts and escalators. It is noted repairs and replacement costs have increased with the building lifetime. Similarly, the maintenance cost of external works is significantly higher in the green building with the increased cost for landscaping and repairs and decoration. Of the factors influencing the maintenance cost of elements, building design factors and technical factors are significant.

Service management and maintenance management are highly affected by the design of the building. Similarly, technical factors critically affect services management and repairs and replacement. In addition, climatic condition, use of the property, number of occupants and function of the building highly affects most of the MC elements. Thus, a careful focus on these factors would enable designers and investors and occupants to optimise the

maintenance costs of high-rise residential buildings in the early design stages as well as during the operational stage.

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