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LIFE CYCLE OPTIMIZATION OF FACILITY FINANCIAL MANAGEMENT FOR RESIDENTIAL COMMUNITIES

Saad, D.A.[1,3], and Osman, H.
[1,2] Structural Engineering Department, Cairo University, Egypt
[3] d.atef.saad@gmail.com (corresponding author email)

Abstract: The residential real estate market in Egypt has witnessed significant growth to meet the increasing demand for housing units. Accordingly, many residential communities have been developed. The performance and the quality of the provided housing facilities in most of these communities, however, have rapidly deteriorated. This is due to insufficiency of funds to cover the operating and capital expenses associated with the facilities' life cycle, and misalignment between the financial resources and the costs. This financial gap is due to missing predefined levels of services (LOS) which subsequently lead to improper allocation of funds, and incomprehensive study of the implications of the funding strategies on the facilities performance. Moreover, there is a lack of research efforts that have addressed this financial gap. Accordingly, this research paper presents a service-level based optimization model that maximizes the overall facilities' performance under the limited funds available, considering the life cycle costs over a predefined time horizon. Moreover, the model allows conducting sensitivity analysis to examine the facilities' performance under different funding strategies, and to determine the timing to introduce supporting financial resources. Using a real case study for a residential compound, the proposed model proved to be able to arrive at an optimum solution that determines the optimum combination of LOSs for each service without compromising the overall performance of the residential community under the limited funds available. This model, therefore, is a potential tool that can help provide cost-effectively quality facility management.

1 INTRODUCTION

With the ever-increase in population and urbanization all over the world, cities have become overcrowded. Cairo, Egypt's Capital, is no different. Moreover, the appreciation of house prices have directed investments towards the residential market. Accordingly, there has been an increasing demand for new housing units (Colliers, 2015). Thus, in the last couple of years, new gated communities (commonly known as compounds) were developed in the outskirts of Cairo. In spite of the significant investment in this sector, the performance and the quality of the provided housing facilities in the majority of these compounds have rapidly deteriorated over time due to lack of maintenance. This is partly due to misalignment between the funds available and the life cycle costs associated with the facilities' life cycle. This financial gap is due to missing service level agreements which subsequently lead to improper allocation of funds, high inflation rates, and incomprehensive study of the funding strategies' implication on the facilities performance. Therefore, cost-effective and quality facility management (FM) is needed to maintain the facilities provided in order to avoid the continual migration of residents to newer communities in search for better services. Facility asset management branches from the broader concept of infrastructure asset management (IAM), yet it is more focused on facilities or buildings. IAM comprises the following stages: condition assessment, asset deterioration modelling, life cycle cost analysis, and prioritization for funding (Hegazi & Elhakeem, 2011). Many research efforts have developed optimization models to address different stages of asset management for buildings or facilities. Tong et al. (2001), for example, developed an optimization model to determine the optimum funding scheme for a network of buildings. Elhakeem & Hegazy (2012) developed a building asset management system that determines the optimum repair type and repair timing for any organization with large pool of buildings. Saad & Hegazy (2015) developed a micro-economic optimization model to determine optimum fund-allocation decisions across large networks of facilities. Taillandier (2017) developed a multi-objective optimization model to arrive at a multiannual maintenance action plan for a pool of buildings.

However, it has been noticed that most of the existing efforts try to determine the optimum maintenance and renewal program for a network of facilities or facility components that maximizes the performance under a predefined limited budget, or that minimizes the costs while maintaining a predefined level of service. Few efforts tried to address the financing aspect in facility management of operating assets. Lai et al. (2008), for example, discussed the costs associated with running facilities along with the level of outsourcing, budgeting methods, and rental performance. Nutt (2000) discussed the importance of financial resources as a trail for FM functioning. Thus, there is a lack of research efforts that have addressed the alignment between the financial resources and the operating and maintenance expenses (Lai at al. 2008). Accordingly, overlooking the financial resources needed to sustain the serviceability of facilities, has led to property downsizing, cost-cutting, disinvestment and disposal (Nutt 2000). Hence, it is important to ensure that there is a proper amount of financial resources to cover life cycle costs at any point in time to provide quality level of service (Booty 2006). Moreover, these financial resources should be sufficient enough to cover any increase in costs due to economic fluctuations (Lai at al. 2008). Thus, it is quite challenging to determine the optimum allocation of funds to finance the operating and capital expenses associated with the facilities' life cycle to provide quality services.

This paper, therefore, presents an optimization model that determines the optimum level of service for each facility service that maximizes the overall facilities' performance under limited funds available, considering facility's life cycle costs and predefined service level agreement. The next section describes the framework of the developed optimization model.

2 FM FINANCING SOLUTION

In order to provide quality FM services, the proposed optimization model includes four main aspects, as shown in Figure 1: financial resources, life cycle costs, service level agreement, and the performance of facilities. Life cycle costs include operating expenses (OPEX) and capital expenses (CAPEX) which are often function of the service level agreement (SLA); the higher the acquired level, the higher the expenses are. To confirm the sufficiency of funds to cover all expenses over the selected time horizon, cash flow analysis is incorporated in the model. Such that, the objective of the optimization model is to maximize the overall performance of facilities, considering the cash flow analysis of the financial resources and costs, while complying with the agreed-on overall level of service and the limited funds available. The next sub-sections describe the identified cost centers in the model and the recurring life cycle costs, and the resources of funding.

2.1 Cash flow Analysis

To provide quality FM services, sufficient funds are needed to cover all the recurring costs from OPEX and CAPEX. Accordingly, a cash flow analysis has been conducted to evaluate the sufficiency of funds. In Egypt, facility management (FM) services are usually funded by three strategies to secure financial resources: 1) upfront maintenance deposits collected at the time of purchase, 2) periodical maintenance fees, and 3) revenue-generating streams (e.g., endowment assets). The maintenance deposit is usually invested in a long-term investment at the prevailing interest rate. Typically the return of the investment will slowly become insufficient over time, leading to a shortfall in funding. In Egypt, periodical maintenance fees are often problematic as real estate developers or property associations may go through a lengthy legal process to force homeowners to pay their annual dues. Therefore, most compounds suffer from low collection rates (30-50%). Accordingly, an endowment asset is a novel solution to avoid the aforementioned problems whereby a portion of the development is set aside by the developer to be used to generate revenue to cover the cost of FM services. This is a relatively new and sparsely used practice in Egypt. In this research paper, the first financial strategy is employed in the optimization model. Therefore, the purpose of the model is to determine the optimum performance of facilities, over a specific time horizon, under a predefined upfront maintenance deposit. Also, it helps determine the appropriate time to introduce other sources of funding when the maintenance deposits are no longer sufficient to cover the recurring expenses.

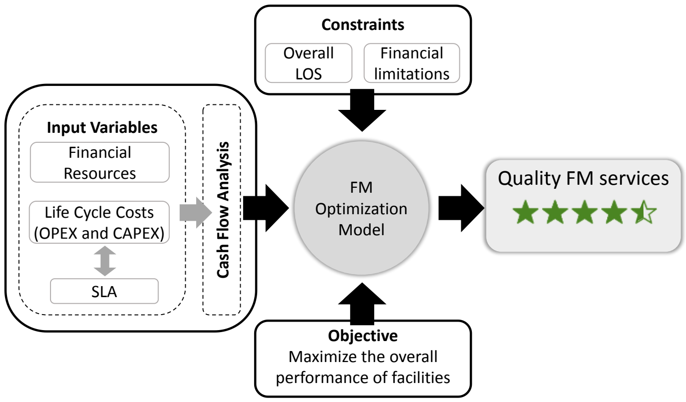


Figure 1: Framework of the FM optimization model

The maintenance deposit (MD) is a function of the agreed-on percentage deposit in the contract (D_{Per}), the average price of a given unit (U_{Price}), and the total number of residential units under study (N_{Units}), as follows:

[1] $MD = D_{Per} \times U_{Price} \times N_{Units}$

This maintenance deposit is often invested in a long-term investment and the return on this investment is spent on maintaining FM services. Accordingly, the income or revenue (R_t) at any given year(t), generated from selling units and investing maintenance deposits, is computed as follows:

[2] $R_t = MD \times RI_t \times PP_t$

Where, RI_t is the return on investment and PP_t is the percentage of units purchased at any given year (t).

In order to properly maintain FM services without incurring any losses over the selected time horizon, revenues should at least breakeven with the incurred costs. The NPV is computed as follows:

[3] $NPV_{t=0} = TC_0 - R_0$

[4] $R_0 = \sum_{t=1}^{T} \frac{R_t}{(1+i_r)^t}$

[5] $TC_0 = \sum_{t=1}^{T} \frac{TC_t}{(1+i_r)^t}$

[6] $TC_t = OC_t + CC_t$

Where, TC_0 and R_0 are the present value of the total costs and revenues, respectively. And, (i_r) is the interest rate used to discount any value to the present time, T is the selected time horizon (e.g., 15 years), OC_t is the sum of the operating costs at any given year t considering inflation, and CC_t is the sum of the capital costs associated with all assets at any given year t considering inflation.

2.2 Life Cycle Costs

To properly maintain the service of a given facility, both operating and capital expenses associated with the facility's life cycle are incorporated in the proposed model. OPEX usually includes the expenses associated with operating and maintenance of the facilities/services provided; on the other hand, CAPEX includes the expenses associated with the replacement cost of the fixed short- and long-term capital assets (building facades, service roads, etc.). In the proposed model, the OPEX and CAPEX cost elements are categorized according to identified cost centers based on the type of service being provided, to facilitate tracking these costs, as shown in Figure 2. These cost centers were identified based on several interviews with FM practitioners in Greater Cairo. The OPEX and CAPEX expenses are formulated to be function of the required level of service (LOS). Such that, in the OPEX, the required LOS drives the number of resources assigned to each cost element and the caliber of resources, while in the CAPEX, the LOS drives the frequency of asset replacement. A detailed description of both OPEX and CAPEX costs is provided in the next subsections.

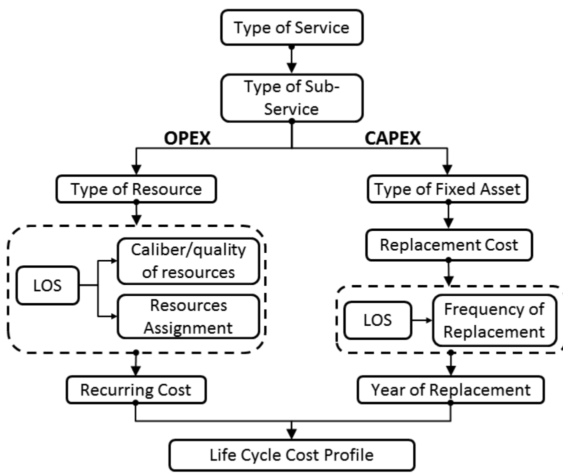


Figure 2: Modelling of OPEX and CAPEX in the life cycle cost profile

2.2.1 OPEX Cost Modelling

In the OPEX model, each cost center is classified by type of main service that it belongs to it (soft or hard services), followed by the sub-service (e.g., landscape, security). Each cost center comprises a number of cost elements that are classified by the type of resource, as illustrated in the hierarchy shown in Figure 3. The resource type shown in the figure is identified in terms of the salaries paid to the staff/labor, consumed materials (e.g., cleaning consumables, lubricants, pool chemicals), equipment (including tools, vehicles), and outsourced contracts (e.g., elevator maintenance).

To facilitate modelling the overall recurring OPEX costs, a spreadsheet has been constructed as shown in Figure 4; such that, it shows for each cost element in a separate row: the type of main service and sub-service that it belongs to it, the type of resource assigned, its existing status in the facility, the percentage allocation to show whether the resource is shared among multiple facilities, the selected LOS and the associated number of resources and unit cost, and finally the total periodical cost (monthly cost in this model). In this paper, the number of assigned resources and the cost of each item, as previously mentioned, is dependent on the selected LOS. In the current model, three LOSs are identified (A, B, and C), where A is the highest quality of service, and C is the least, yet they can be extended to any number of levels. Accordingly, a lookup table of the costs and resources associated with each level of service is developed for each cost element to facilitate computing the overall cost based on the selected LOS. Some items have constant cost and/or number of resources regardless of the LOS. For example, the pool cleaning staff may have a different number of resources with each LOS, yet the salary per worker remains constant. These lookup tables is built based on interviews with FM practitioners.

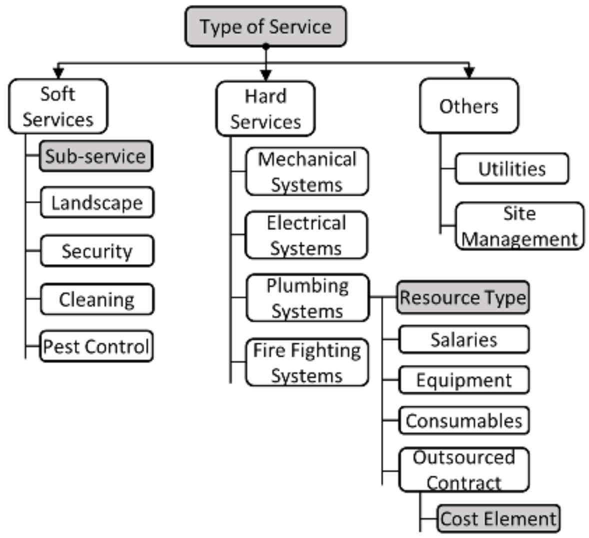


Figure 3: OPEX Cost structure

1	Main Service Category: Soft, Hard, Others	Sub-service	Cost Items	Type	P/NP	% Allocation	LOS	Unit Cost Per (X) Period	Unit Cost	No of resources or units	Total Cost /month	No of Resources or units			Unit Cost		
												LOS (A)	LOS (B)	LOS (C)	LOS (A)	LOS (B)	LOS (C)
2	Soft Services	Security	Staff	Contract	1	100%	LOS (A)	Per month	2000	11	22,000	11	9	7	2000	1600	1400
4	Soft Services	Landscape	Irrigation workers	Salaries	1	100%	LOS (B)	Per month	1500	1	1,500	2	1	1	1600	1500	1400
5	Soft Services	Landscape	Landscape Workers	Salaries	1	100%	LOS (B)	Per month	2500	1	2,500	2	1	1	3000	2500	2000
6	Soft Services	Landscape	Landscaping equipment	Equipment	1	100%	LOS (B)	Per month	4000	2	8,000	1	1	1	5000	4000	3000
7	Soft Services	Landscape	Landscaping consumables (pesticides, fertilizers, etc…)	Consumables	1	100%	LOS (B)	Per month	4000	1	4,000	1	1	1	5000	4000	3000
9	Soft Services	Cleaning	Cleaning staff	Salaries	1	100%	LOS (A)	Per month	1600	10	16,000	10	8	6	1600	1400	1200
10	Soft Services	Cleaning	Cleaning supervisor	Salaries	1	100%	LOS (A)	Per month	3000	2	6,000	2	1	1	3000	2500	2000
11	Soft Services	Cleaning	Garbage Collection	Contract	0	100%	LOS (A)	Per month	12000	1	0	1	1	1	12000	12000	12000
12	Soft Services	Cleaning	Water Tanks Cleaning	Contract	0	100%	LOS (A)	Per month	0	0	0	0	0	0	0	0	0
13	Soft Services	Cleaning	Cleaning material & consumables (sweepers)	Consumables	1	100%	LOS (A)	Per month	2000	1	2,000	1	1	1	2000	2000	2000
14	Soft Services	Pest Control	Pest Control Spraying Motor	Equipment	1	100%	LOS (B)	Per month	20000	1	20,000	1	1	1	25000	20000	15000
15	Soft Services	Community Management Services	Pool cleaning staff	Salaries	1	100%	LOS (B)	Per month	1500	2	3,000	3	2	1	1500	1500	1500
18	Hard Services	Mechanical Systems	Mechanical Systems Staff	Salaries	1	100%	LOS (B)	Per month	1200	1	1,200	2	1	1	1200	1200	1200
19	Hard Services	Electrical Systems	Electrical Systems Staff	Salaries	1	100%	LOS (B)	Per month	3000	4	12,000	6	4	2	3000	3000	3000

Provided or not in the facility under study

% allocation of resource to a certain facility

Lookup table of resources and costs for each LOS

Figure 4: Sample of the OPEX cost model

2.2.2 CAPEX Cost Modelling

Similarly to the OPEX model, a CAPEX cost model has been developed to compute the capital replacement cost of a given fixed asset and to identify its replacement frequency over the selected time horizon. Each cost element in the CAPEX model is classified according to the main service/cost center that it belongs to it, followed by the type of the related fixed asset existing in the facility. Figure 5 shows the cost structure that has been adopted in the model to develop the CAPEX cost model, it shows the main services' categories, and the asset categories utilized in the model. These two dimensions allow for cost analysis to be reported across various cost categories of services being delivered (e.g. security, cleaning, landscaping, etc.) and asset types (e.g. water network, electrical systems, etc.). To facilitate cost modelling, a spreadsheet has been constructed, as shown in Figure 6, such that it shows for each cost element: the type of main service/cost center, sub-service, and asset type that it belongs to it, the measuring unit, the status of the asset whether it exists or not in the facility under study, replacement cost, selected LOS, replacement frequency, and the total annual cost at the time of occurrence. The frequency of replacement is dependent on the selected LOS. Such that, the replacement frequency is expected to be shorter for higher LOS. In this model, three levels of services are identified as well (A, B, and C), where A is the highest quality of service, and C is the least. Accordingly, a lookup table of the replacement frequency associated with each level of service is developed for each cost element, as illustrated in the figure. The frequency of replacement is function of the required level of service, which is driven either by the aesthetics of the asset (e.g., façade, footpaths, light poles), physical condition (e.g., pipelines, tanks), or service reliability in terms of the number of service interruptions (e.g., elevators, transformers, water pumps). The replacement costs and the lookup tables are identified based on interviews with FM practitioners as well.

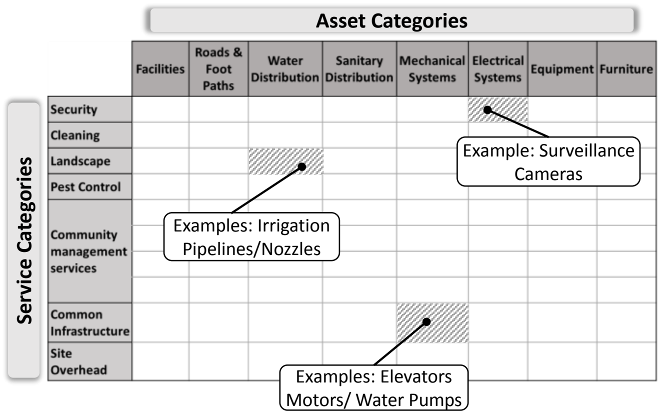
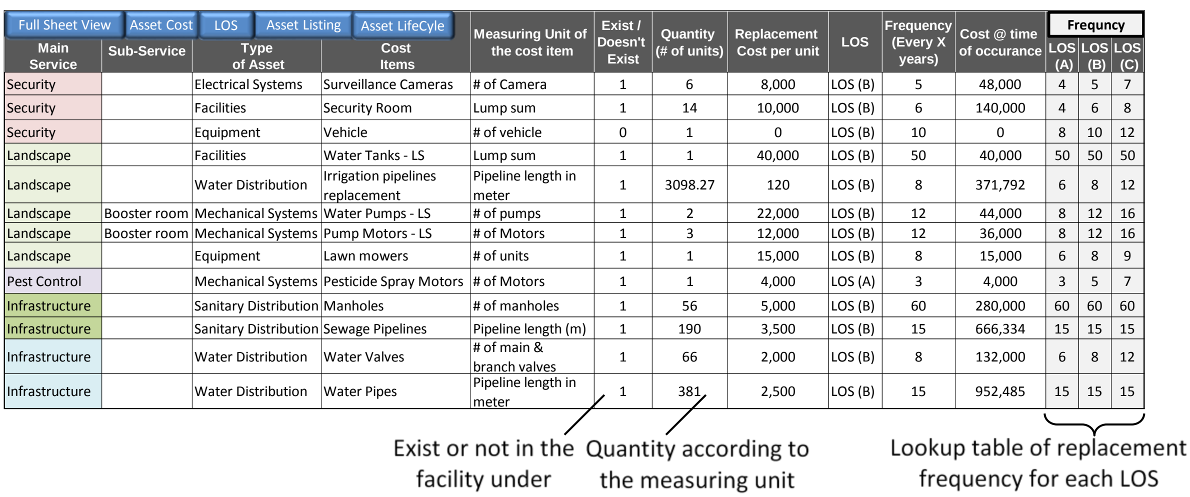


Figure 5: CAPEX Cost Structure



Main Service	Sub-Service	Type of Asset	Cost Items	Measuring Unit of the cost item	Exist / Doesn't Exist	Quantity (# of units)	Replacement Cost per unit	LOS	Frequency (Every X years)	Cost @ time of occurance	Frequncy LOS (A)	LOS (B)	LOS (C)
Security		Electrical Systems	Surveillance Cameras	# of Camera	1	6	8,000	LOS (B)	5	48,000	4	5	7
Security		Facilities	Security Room	Lump sum	1	14	10,000	LOS (B)	6	140,000	4	6	8
Security		Equipment	Vehicle	# of vehicle	0	1	0	LOS (B)	10	0	8	10	12
Landscape		Facilities	Water Tanks - LS	Lump sum	1	1	40,000	LOS (B)	50	40,000	50	50	50
Landscape		Water Distribution	Irrigation pipelines replacement	Pipeline length in meter	1	3098.27	120	LOS (B)	8	371,792	6	8	12
Landscape	Booster room	Mechanical Systems	Water Pumps - LS	# of pumps	1	2	22,000	LOS (B)	12	44,000	8	12	16
Landscape	Booster room	Mechanical Systems	Pump Motors - LS	# of Motors	1	3	12,000	LOS (B)	12	36,000	8	12	16
Landscape		Equipment	Lawn mowers	# of units	1	1	15,000	LOS (B)	8	15,000	6	8	9
Pest Control		Mechanical Systems	Pesticide Spray Motors	# of Motors	1	1	4,000	LOS (A)	3	4,000	3	5	7
Infrastructure		Sanitary Distribution	Manholes	# of manholes	1	56	5,000	LOS (B)	60	280,000	60	60	60
Infrastructure		Sanitary Distribution	Sewage Pipelines	Pipeline length (m)	1	190	3,500	LOS (B)	15	666,334	15	15	15
Infrastructure		Water Distribution	Water Valves	# of main & branch valves	1	66	2,000	LOS (B)	8	132,000	6	8	12
Infrastructure		Water Distribution	Water Pipes	Pipeline length in meter	1	381	2,500	LOS (B)	15	952,485	15	15	15

Figure 6: Sample of the CAPEX cost model

3 MATHEMATICAL FORMULATION OF FM OPTIMIZATION MODEL

To optimally maintain the performance of a facility while running it without incurring any losses, there is a need to determine the optimum LOS for each service that makes the NPV greater than or equal to zero without compromising the overall performance of the facility. Accordingly, an integer decision variable $\mathrm{LS_i}$ is used to represent the level of service selected for each service (i) in the model; such that, $\mathrm{LS_i}$ of 1 stands for LOS A, 2 stands for LOS B, and so forth. Accordingly, the model's variables, constraints, and objective function are as follows:

Decision Variables:

[7] LS_i $\quad$ for $i = 1, 2, 3, \ldots.N$ services

Objective function: is set to maximize the overall performance index (PI) of the facility considering the relative importance of each service, as follows:

[8] Maximize $$PI = \left(RIF_{OP} \times \left(\frac{\sum_{i=1}^{N} PI_i[LS_i] \times W_i}{N}\right)_{OPEX} + RIF_{CA} \times \left(\frac{\sum_{i=1}^{N} PI_i[LS_i] \times W_i}{N}\right)_{CAPEX} \right)$$

Where $PI_i[LS_i]$ is the performance index associated with each level of service LS_i selected for each service i. Each performance index has a score out of 100. While, W_i is the weight of importance of each service. N is the number of services in each of the OPEX and CAPEX, and RIF_{OP} is the relative importance of the OPEX spending, and RIF_{CA} is the relative importance of the CAPEX spending.

Constraint(s): The net present value, computed using Equation 3, should be greater than or equal to zero as shown in Equation 9. The overall performance index of the facility should be greater than or equal to a specified score (S) out of 100 (e.g., 90 out of 100), as shown in Equation 10. The selected level of service LS_i should be an integer number lying between 1 and the number of levels identified in the model (n_L), as shown in Equation 11.

[9] $NPV_{t=0} \geq 0$

[10] $PI \geq S$

[11] $1 \leq LS_i \leq n_L$

The NPV, as previously shown in Equation 3, is the difference between the total costs and revenues discounted to the present time. The total costs, as shown in Equation 6, is the sum of the operating costs OC_t and capital costs CC_t. Since the operating and capital costs are associated with the selected LS_i and the replacement cost of capital assets is cyclic, they are formulated as follows:

[12] $$OC_t = \sum_{i=1}^{N} \sum_{j=1}^{J} C_{ij}[LS_i] \times m_{ij}[LS_i] \qquad \text{for } j = 1, 2, 3, \ldots.J \text{ Cost elements}$$

[13] $$CC_t = \begin{cases} \sum_{i=1}^{N} \sum_{j=1}^{J} RC_{ij} & t = k \times RF_{ij}[LS_i] \\ 0 & \text{otherwise} \end{cases} \qquad \text{for } k = 1, 2, \ldots.T/RF_{ij}[LS_i]$$

Where, $C_{ij}[LS_i]$ is the cost of the element (j) associated with selected LS_i for service (i), $m_{ij}[LS_i]$ is the number of resources assigned to element (j) according to the selected LS_i. RC_{ij} is the replacement cost of the cost element (j), and $RF_{ij}[LS_i]$ is the replacement frequency according to the selected LS_i.

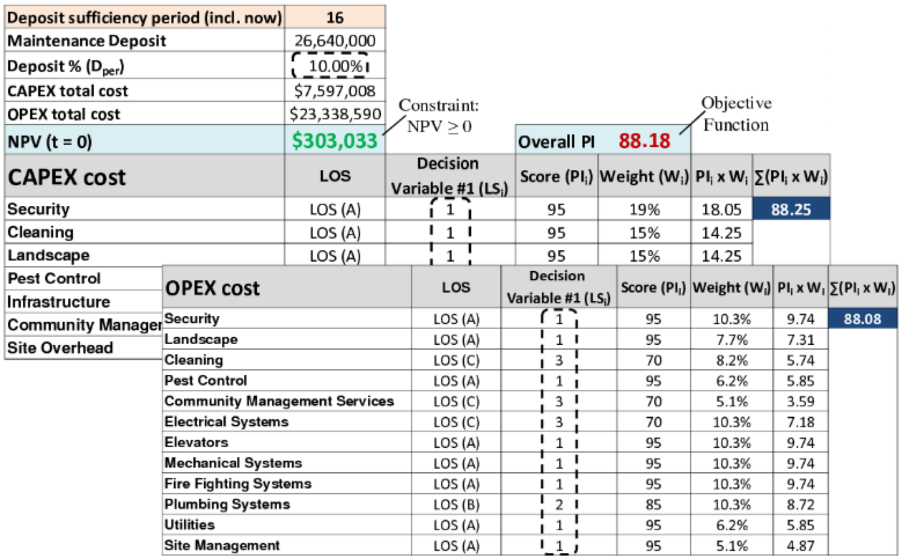
To validate the model and prove its applicability, it has been implemented on a real case study of a high-end residential gated compound. Afterwards, a sensitivity analysis has been conducted to evaluate the performance of the facilities in the compound under different maintenance deposit scenarios, as discussed in the next section.

4 CASE STUDY

This case study investigates facility management services for a high-end residential compound located in Egypt, in East of Cairo over a total gross area of 18.5 Acre. The compound consists of 74 residential buildings, green areas, footpaths, service roads, etc. The total number of units (incl. villas and apartments) is 255 units with an average area of 150 square meter. The units' sale started three years before the beginning of operation in the compound (i.e., delivery of units to owners). Accordingly, it is assumed that 30% of the units are sold in the 1st year, 50% in the 2nd year, and 75% in the 3rd year. The units will be completely sold with the beginning of operation in the compound. The developer is responsible for running the facility management services in the compound, including soft and hard services. In this study, the maintenance deposit is set to be 10%, and three LOSs have been identified for each type of service (A, B, and C) along with their corresponding performance index and recurring OPEX and CAPEX costs. The developer, therefore, needs to determine the optimum combination of LOS for each service under the predefined maintenance deposit that maintains the overall performance of the compound at an acceptable level, over a time horizon of 15 years. In this study, expected values for both annual inflation rates and return on investment are used, yet future work will consider the uncertainty associated with these values in the model formulations.

Using the case study data, all the OPEX and CAPEX costs have been identified, classified as previously shown in Figures 4 and 6, and revised with the developer to capture their preferences. The formulations of the generic optimization model have been updated to account for the given information. Such that, the value of $\mathrm{n_L}$ is set equal to 3 in Equation 11 to account for the three levels of services. The performance index $\mathrm{PI_i[LS_i]}$ associated with each level of service is assigned a numerical score out of 100; such that, the higher the score, the better is the performance of the service. Thus the performance index associated with LOS A, $\mathrm{PI_i[LS_i = 1]}$, is assigned a score of 95, $\mathrm{PI_i[LS_i = 2]}$ is given a score of 85, and $\mathrm{PI_i[LS_i = 3]}$ is assigned a score of 70. The objective function of the model is to maintain the overall performance of the compound at a PI of 85. Therefore, the value of S is set equal to 85 in Equation 10. The time horizon (T) is set to 15 years in Equations 4, 5, and13. In this research paper, the values of $\mathrm{RIF_{OP}}$ and $\mathrm{RIF_{CA}}$ of the OPEX and CAPEX are set to 0.4 and 0.6, respectively. These values are flexible to be changed according to the decision makers' preferences. The optimization model has been implemented in Excel, and solved using Evolutionary solver which utilizes Genetic Algorithms to find the optimum solution. The setup of the optimization model is shown below in Figure 7. It shows the main services for the CAPEX and OPEX, the LOS selected for each service which is triggered by the value of the decision variable $\mathrm{LS_i}$, the performance index $\mathrm{PI_i[LS_i]}$ of each service associated with the selected LOS, weight of importance of each service $\mathrm{W_i}$, weighted performance index for each service, and the overall weighted performance index of both CAPEX and OPEX services, separately. Moreover, it shows the present value of the total CAPEX and OPEX spending along with the NPV, the total maintenance deposit computed using Equation 1; and the overall performance index (PI) computed using Equation 8.

After running the optimization model considering all the constraints, the model was able to arrive at an optimum solution that achieved an overall PI of 88.18 for 16 years (including the current year), under the imposed percentage deposit of 10%. It can be noticed from Figure 7 that a compromise has been made across the services in order to arrive at the optimum overall performance of the facilities in the compound under study. To facilitate examining the performance of the compound's facilities under different percentage maintenance deposits, the developed model provides an extra feature that determines the deposit sufficiency period for the selected deposit percentage. This feature identifies the time when costs and revenues breakeven, and thus it helps determine the appropriate timing to introduce other supporting financial resources, as previously discussed. Accordingly, in order to achieve a higher *PI*, the deposit sufficiency period will decrease as a compromise due to the financial constraints. For instance, to increase the overall *PI* achieved from 88.18 to 90.78, the deposit sufficiency period decreased to 11 years instead of 16 years. In this case, there would be budget deficit and supporting financial resources would be needed at the beginning of the 12th year to cover the whole time horizon. Accordingly, to further examine the facility performance under different deposit scenarios, a sensitivity analysis has been conducted, as discussed in the next subsection.



Deposit sufficiency period (incl. now)	16
Maintenance Deposit	26,640,000
Deposit % (D_{per})	10.00%
CAPEX total cost	$7,597,008
OPEX total cost	$23,338,590
NPV (t = 0)	$303,033

Constraint: NPV ≥ 0

Overall PI 88.18

Objective Function

CAPEX cost	LOS	Decision Variable #1 (LS_i)	Score (PI_i)	Weight (W_i)	$PI_i \times W_i$	$\Sigma(PI_i \times W_i)$
Security	LOS (A)	1	95	19%	18.05	88.25
Cleaning	LOS (A)	1	95	15%	14.25	
Landscape	LOS (A)	1	95	15%	14.25	
Pest Control						
Infrastructure						
Community Manager						
Site Overhead						

OPEX cost	LOS	Decision Variable #1 (LS_i)	Score (PI_i)	Weight (W_i)	$PI_i \times W_i$	$\Sigma(PI_i \times W_i)$
Security	LOS (A)	1	95	10.3%	9.74	88.08
Landscape	LOS (A)	1	95	7.7%	7.31	
Cleaning	LOS (C)	3	70	8.2%	5.74	
Pest Control	LOS (A)	1	95	6.2%	5.85	
Community Management Services	LOS (C)	3	70	5.1%	3.59	
Electrical Systems	LOS (C)	3	70	10.3%	7.18	
Elevators	LOS (A)	1	95	10.3%	9.74	
Mechanical Systems	LOS (A)	1	95	10.3%	9.74	
Fire Fighting Systems	LOS (A)	1	95	10.3%	9.74	
Plumbing Systems	LOS (B)	2	85	10.3%	8.72	
Utilities	LOS (A)	1	95	6.2%	5.85	
Site Management	LOS (A)	1	95	5.1%	4.87	

Figure 7: Setup of the LOS-based optimization model

4.1 Sensitivity Analysis

To compete in the real estate market, developers often tend to lower the percentage maintenance deposit to attract new buyers. Accordingly, it is beneficial to examine the sufficiency period under different deposit scenarios along with the expected budget deficit to identify the timing of the needed supporting financial resources. Figure 8 shows the results of running different deposit scenarios from 5% up to 10%; such that, it shows the sufficiency period and the budget deficit (in terms of negative NPV) corresponding to each scenario. From the experiments, it has been noticed that the overall performance index was maintained at an approximate value of 90 in all of the scenarios. Also, it has been noticed that for maintenance deposit of 6% to 8%, the sufficiency period was fixed at 6 years, yet the budget deficit kept decreasing. Accordingly, it can be concluded from this analysis that the higher the value of the maintenance deposit, the longer would be the sufficiency period and the less would be the budget deficit.

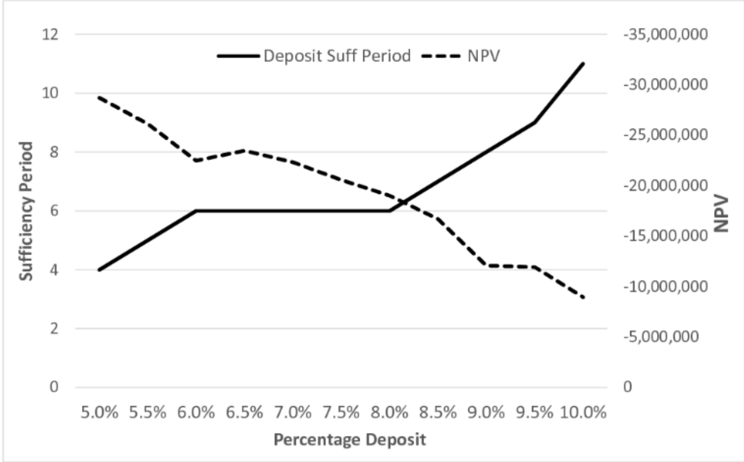


Figure 8. Maintenance Deposit Sensitivity Analysis

5 SUMMARY AND CONCLUSIONS

This paper presented a generic optimization model that determines the optimum financing scheme along with level of service for each facility service without compromising the overall performance of the facility. The model incorporates all the recurring operating and capital expenses at different levels of services, and the financial resources to cover these expenses. To capture all the expenses associated with any given facility, cost structures followed by cost models have been developed for both OPEX and CAPEX. In the OPEX cost model, the number of resources assigned to each service and the cost of each element varies according to the level of service; while in the CAPEX model, the frequency of replacement varies according to the level of service. Using maintenance deposit as one type of financial resource or income, cash flow analysis, over a certain time horizon, has been conducted to compute net present value. To validate the applicability of the optimization model, a real case study for a residential community in Egypt that comprises multiple facilities, has been used. The proposed model proved to be able to arrive at optimum financing scheme, in terms of optimum alignment between the imposed maintenance deposit percentage, and the levels of services assigned to each service and subsequently cost element without compromising the overall performance of the compound. Currently, there is ongoing research on enhancing the model to incorporate: key performance indicators for each cost element to better formulate the level of service, uncertainty associated with the costs and revenues, and other financial resources. In essence, the proposed optimization model can be used as a useful tool by facility managers or facility owners to improve the economics of facility management while maintaining quality of facility services.

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