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Development of Maintenance Cost Prediction Model for Heritage Buildings

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Abstract

The lack of a simple and accurate method of estimating heritage buildings maintenance costs makes it difficult for custodians and owners of heritage building to make realistic maintenance budgets and to develop good financial plan for managing the maintenance works to heritage buildings. The purpose of this paper is to develop a model for predicting the maintenance costs of heritage buildings. To achieve the aforementioned objective, the paper combined a literature review, cost modeling, survey and case studies. The survey and case studies were adopted in order to validate the maintenance cost prediction model. The model validation results show that the maintenance cost prediction model has about 93% accuracy in predicting annual maintenance cost for heritage buildings based on the building age, gross floor area and building performance index. The model could help custodians and owners of heritage building to forecast maintenance costs easily and accurately, make realistic maintenance budgets and to develop good financial plan for managing the maintenance works of the buildings in their care.

Keywords: Building cost; heritage; Malaysia; maintenance; prediction model

Abstrak

Kekurangan satu kaedah yang mudah dan tepat menganggarkan bangunan warisan kos penyelenggaraan menyukarkan penjaga dan pemilik bangunan warisan untuk membuat belanjawan yang realistik dan untuk membangunkan rancangan kewangan yang baik untuk menguruskan penyelenggaraan kerja-kerja untuk bangunan warisan. Tujuan kertas ini adalah untuk membangunkan satu model untuk meramalkan kos penyelenggaraan bangunan warisan. Bagi mencapai matlamat di atas, kertas gabungan kajian literatur , pemodelan kos, kajian dan kajian kes. Kajian kajian dan kes telah diterima pakai bagi mengesahkan model ramalan kos penyelenggaraan. Keputusan pengesahan model menunjukkan bahawa model ramalan kos penyelenggaraan mempunyai ketepatan yang kira-kira 93% dalam meramalkan kos penyelenggaraan tahunan untuk bangunan warisan berdasarkan umur bangunan, kawasan lantai kasar dan indeks prestasi bangunan. Model ini dapat membantu penjaga dan pemilik bangunan warisan untuk meramal kos penyelenggaraan mudah dan tepat, membuat belanjawan yang realistik dan untuk membangunkan rancangan kewangan yang baik untuk menguruskan kerja-kerja penyelenggaraan bangunan dalam jagaan mereka.

Kata kunci: Bangunan kos; warisan; Malaysia; penyelenggaraan; ramalan model

■1.0 INTRODUCTION

Malaysia is blessed with distinctive multicultural and architectural heritage with strong Islamic, Chinese and Western influences which are evident in the heritage buildings. The architectural styles of heritage buildings in Malaysia can be traced back to the indigenous traditional Malay, Chinese, Indian, Middle East and European cultures that were brought into the country by traders and immigrants in the 16th century [1].

The over three centuries of colonial rule in Malaysia is still evident today by the presence of the unique colonial architectural styles left behind by colonial powers of the Portuguese, Dutch and British [2]. The Portuguese and Dutch architecture are found mostly in Malacca while British architecture are mostly found in George town, Kuala Lumpur, Ipoh, Taiping, Johor Bahru, Kuching and Seremban [3]. These unique heritage buildings can be seen in all major cities and were fundamental to the establishment of heritage cities in the country. With increasing awareness in the cultural significance of these heritage assets, many local authorities have earmarked heritage areas within their city limits in an effort to improve heritage tourism and generate revenue [4].

The growth of tourism in Malaysia has propelled the emergence of heritage tourism which is a potential form of alternative tourism to both local and foreign tourists [5]. Over the years, the global influx of tourists to Malaysia and the growing interest in heritage tourism have increased the number of heritage tourists visiting heritage cities of Malaysia especially Malacca and Penang [5]. In Malaysia today, heritage buildings are regarded as highly valuable assets due to their cultural significance and tourism potentials [6]. The buildings are regarded as essential products of promoting heritage tourism because of their strong influence in motivating cultural heritage tourists to visit the country. Cultural heritage tourists are attracted to these buildings due to their cultural uniqueness, high historical and architectural values, and the strong desire to see something different [7].

The increasing consciousness in the cultural significance of the buildings has helped in conserving these assets to promote heritage tourism as well as boost revenue generation in the country. In the year 2010, the country attracted 24.6 million foreign tourists and generated MYR56.5billion to the tourism sector [8]. Therefore, it is necessary to conserve heritage buildings in Malaysia considering their high tourism potentials and the fact that the buildings serve as fundamental cultural heritage elements that strengthen Malaysia's national identity and sovereignty as well as capture its soul and spirit.

Conservation of heritage is essential for a society to pass onto future generations what is currently identified as being of cultural significance today [9]. It is natural that as buildings aged, they will be exposed to serious building defects and deterioration. Every building whether heritage or new, requires care and protection to limit deterioration [4]. The need for regular maintenance of built assets, both in terms of its potential investment worth and as a productive resource, is mostly accepted by most organizations [10]. Besides, various authors have described regular maintenance as the most important, pragmatic, sustainable and philosophically appropriate method of conserving heritage buildings. Thus, heritage buildings require efficient maintenance management practices in order to extend the life of the buildings and avoid the need for potentially expensive and disruptive repair works, which may damage the heritage values of the buildings [11].

The maintenance strategy for heritage buildings is different from normal buildings because the fabric of heritage building has cultural significance, which should be retained maximally. Besides, maintenance of heritage building involves repairing the building fabric very close to the original using traditional techniques and traditional matching materials and being sensitive to the original structure. However, the lack of a simple and accurate method of estimating heritage buildings maintenance costs makes it difficult for custodians and owners of heritage building to make realistic maintenance budgets and to develop good financial plan for managing the maintenance works to heritage buildings. Thus, the development of maintenance cost prediction model for heritage buildings is considered useful in order to assist in making realistic budgets for managing the maintenance of heritage buildings. Considering the significance of regular maintenance to heritage building conservation, our focus now shifts to the Malaysian government. The government being the leading financier of heritage building conservation in the country may stand to benefit from this basic, simplified and realistic method of estimating heritage buildings maintenance costs. Thus, this makes it difficult to make realistic budgets and have an effective financial plan and control for heritage building maintenance. Therefore, there is the need to come up with a model that predicts heritage buildings maintenance cost to the nearest accuracy.

■2.0 SIGNIFICANCE OF PREDICTING MAINTENANCE COSTS FOR HERITAGE BUILDINGS

As key resource, heritage buildings have become a driver for development, which when properly managed can enhance the livability of their surrounding areas and sustain productivity in a changing global environment [12]. For maintenance management of heritage buildings to be efficient, financial planning and budgeting should take a central stage. Estimates of repair and maintenance costs for heritage buildings are important for maintenance management decisions and for general budgeting. Custodians of heritage buildings often consider maintenance costs as uncontrollable costs. Contrary to this view, maintenance costs for heritage buildings are highly controllable when an accurate strategy for estimating maintenance cost is established.

When an element of heritage building collapses or is about to collapse, many decisions have to be taken on the appropriate conservation approaches. Making the right decision about the conservation approaches to adopt can save money but retaining the original building materials is the most important factor to be considered. Maintenance costs incurred on heritage building differs. The difference can be as results of the age, building fabric, history and architecture of the building, types, functions, size, complexity and methods of construction of the building. Building structure also compose of distinct but interrelated components, materials and elements. This is contributing to the difficulty in maintenance allocations for building maintenance. Generally, these complexities have discouraged the use of quantitative maintenance model. Researchers like [13]-[15] have developed mathematical model for prioritizing building maintenance and various variables were used in the development of the models. These variables include age of the building, condition of the building, degree of building failure and intensity of use. The main purpose of a model or any maintenance decision support system is to help in ranking maintenance needs and eventually the maintenance cost [16]. This will permit the maintenance unit to identify which element should be included in the successive maintenance programmes [13]. This is crucial because maintenance needs for heritage buildings are always on the increase and many maintenance works are often being deferred due to inadequate maintenance costs [17].

Cost modelling is used to forecast costs [18]. Building maintenance costs are the cost required in keeping the building and engineering services beneficially functionally and they include, labour, materials, parts, statutory fees and profits [19]. Mathematical models for maintenance works are used in order to determine variables that best describe cost and provide better forecast for maintenance service.

■3.0 DEVELOPMENT OF MAINTENANCE COST PREDICTION MODEL

This paper is aimed at developing maintenance cost prediction model for heritage buildings. In other words, mathematical relationship between heritage building maintenance costs and its major determinants will be established. The maintenance cost model is based on Regression analysis. Four determinants were used to develop the model. The determinants are annual maintenance cost, age of buildings, gross floor area and building performance index. The determinants were used because they are considered the primary components of building maintenance expenditure. Annual maintenance cost are used as the dependent variable while the remaining three determinants are used as independents variables. This means that maintenance costs for heritage buildings can be predicted based on the three determinants. The multiple regression analysis is performed using:

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + \ldots + b_nx_n \text{ or } a + \sum_{i=1}^{n} b_i x_i$$

Y=annual maintenance cost (dependent variable to be predicted)
a=constant (annual maintenance cost when the independent variables are zero)
x= independent variables used to predict annual maintenance cost (x_1, x_2, x_3)
b= multipliers that describe the size of the effect the independent variables are having on the dependent variable (b_1, b_2, b_3)

The model seeks to identify the contribution of each of the determinants and components to the maintenance costs, which could help the government and custodians of heritage buildings to make major financial decisions with respect to managing the maintenance works for conservation of the buildings. The following basic assumptions were made: age of building has a linear effect on maintenance cost; building performance index has a linear effect on maintenance cost; gross floor area has a linear on maintenance cost; the summation of all the predictors are feasible and all the variables are interactive.

In order to develop the maintenance cost prediction model, information on gazetted national heritage buildings in Malaysia was obtained. The information was obtained through case studies, visual observations and interviews while some were obtained from heritage organizations and trusts in the country. The obtained information includes the buildings' average annual maintenance costs in the last five years, age of the buildings, gross floor area, building performance indices and present physical conditions of the buildings (whether 'good', 'fair' or 'poor'). Reliability test was carried out to check the internal consistencies of the variables. The reliabilities of the variables are shown Table 1.

Table 1 Cronbach's reliability test

Maintenance criteria	Cronbach's Alpha
Annual maintenance cost	0.83
Age of buildings	0.78
Gross Floor Area	0.72
Buildings performance index	0.80

The results indicate strong internal consistency among the four items. Reference [20] pointed out that Cronbach's coefficient alpha of 0.7 is mostly considered as being the minimum level acceptable. If the coefficient is less than 0.7, it signifies that the items are unlikely to be reliably measuring the same thing. A generally accepted rule of thumb for explaining internal consistency using Cronbach's coefficient alpha was provided by [21] as: Greater than 0.9 = Excellent; Greater than 0.8 = Good; Greater than 0.7 = Acceptable; Greater than 0.6 = Questionable; Greater than 0.5 = Poor; Less than 0.5 Unacceptable. The results of the reliability test were satisfactory, thus the data was used for further analysis.

Table 2 Correlation matrix of the dependent and independents variables

Maintenance Criteria	Annual maintenance cost	Age	Gross Floor Area	Building Performance Index
Annual maintenance cost	1.000	.783	.551	.063
	.	.066	.257	.906
Age	.783	1.000	.086	-.278
	.066	.	.872	.594
Gross Floor Area	.551	.086	1.000	.772
	.257	.872	.	.072
Building Performance Index	.063	-.278	.772	1.000
	.906	.594	.072	.

Before proceeding with the development of the regression model, a correlation matrix of the variables was performed using;

$$r = \frac{\sum_{i=1}^{n}(x_1 - \bar{x})(y_1 - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_1 - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_1 - \bar{y})^2}} \text{ OR}$$

$$r = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{\sqrt{n\left(\sum x^2\right) - \left(\sum x\right)^2}\sqrt{n\left(\sum y^2\right) - \left(\sum y\right)^2}}$$

where, n is four (determinants), x or y is any of the determinant of maintenance cost. The results of the correlation are listed in Table 2. It could be seen that there are relationships among the variables. However, an important requirement to perform regression analysis is that the independent variables should not be highly correlated. According to Reference [22], the correlation among the independents variables should not exceed 0.80; otherwise problem associated with multi-collinearity issue will emerge. From Table 2, this rule has not been violated indicating the data are suitable for regression model.

The regression output has three main components: Regression statistics table (model summary for maintenance cost forecast); ANOVA table (Analysis of variance of maintenance cost forecast) and Regression coefficients table (coefficients of maintenance costs prediction for the model building). Table 3 shows the model summary for maintenance costs prediction while Table 4 shows Analysis of variance of maintenance costs prediction.

Table 3 Model summary for maintenance costs prediction

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.966	0.933	0.923	1907.06358

Table 4 ANOVA maintenance costs prediction

	Model	Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1.076E9	3	3.587E8	98.62	0.010
	Residual	7273783.02	2	3636891.51		
	Total	1.083E9	5			

Table 5 Coefficients of maintenance costs forecast for the Model building

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
	(Constant)	59989.78	24962.29		2.40	0.14
	Age (*years*)	485.59	90.201	0.468	5.38	0.03
	Gross Floor Area (m^2)	50.24	6.913	1.352	7.27	0.02
1	Building Performance Index	-1759.75	345.160	-0.976	-5.09	0.04

Table 5 shows the results of co-efficient of the maintenance cost forecast. The mathematical relationship between annual maintenance cost on the one hand and the other variables on the other hand is:

Maintenance cost (MYR) = 59989.78 + 485.59* age of building (years) + 50.24* gross floor area of building (m^2) – 1759.75* building performance index

The mathematical model indicates that if the age of a building increases by 1 year, it is predicted that annual maintenance cost will increase by approximately MYR485.59. Similarly, if the gross floor area of a building increases by 1m^2, it is predicted that annual maintenance cost will increase by approximately MYR50.24. However, if the building performance index increases by 1%, it is predicted that annual maintenance cost will decrease by MYR1,759.75. The results which are based on 95% confidence level show that the largest influence on maintenance cost is from 'building age' while the least is from gross floor area of the building. The building performance index was found to have negative relationship with the maintenance cost. This is expected because the higher the building performance index, the less the maintenance demands, everything being the same.

The R^2 value of 0.933 in Table 3 indicates that about 93% of variation in the annual maintenance cost that can be explained by the linear relationship between the annual maintenance cost and independent variables (i.e. age, gross floor area and building performance index). This very high proportion (93%) shows the accuracy of the regression model in predicting annual maintenance cost based on the three aforementioned determinants. Therefore, the model fits the data well. Table 3 further indicates that the three maintenance criteria are responsible for about 92% (0.923 Adjusted R^2) of the annual building maintenance costs. Therefore, they could be used to forecast maintenance costs more reliably.

The Analysis of variance (ANOVA) can also be used to check the accuracy of the regression model in predicting annual maintenance cost based on the three aforementioned determinants. The results in Table 4 indicate that the significance value of the F statistics (0.010) is smaller than 0.05 meaning that age of the building, gross floor area and building performance index did a good job in explaining the variation in the annual maintenance cost and the null hypothesis that all the population values for the regression coefficients are 0 is not accepted. In essence, the regression is significant and when the independent variables are combined together; they can be used to determine building annual maintenance costs accurately.

A useful conclusion that can be drawn from the results of the model is that irrespective of age of building and the building performance index, annual maintenance cost for heritage building increases with the gross floor area. In other words, as gross floor area increases, maintenance cost increases sequentially because there is a uniform increase in maintenance cost irrespective of the values of other determinants. Moreover, maintenance cost decreases with improvement in the physical condition of the building (building performance index) irrespective of age of building and gross floor area of building. In other words, as building condition improves, maintenance cost decreases sequentially because there is a uniform decrease in annual maintenance cost irrespective of the age and gross floor area of the building.

■4.0 STRATEGY FOR VALIDATING THE COST PREDICTION MODEL

From the results of the multiple regression analysis, the maintenance cost prediction model for heritage buildings was developed. After developing the model, it was set for validation to ensure its accuracy in predicting maintenance cost for heritage buildings. As pointed out by [22], a pilot survey is considered a requirement to the collection of any significant data with which to test a model. Thus, three national heritage buildings were chosen for the validations. During interviews with the maintenance managers of these buildings, data on annual maintenance costs, age of building, gross floor area and building performance indices of the three buildings were obtained. These data were used to validate the model. In order to obtain the predicted annual maintenance cost, each of the three buildings was treated separately. For each building, the numerical value of the determinants' obtained during the interview would be substituted with the corresponding determinants in the model and then multiplied with the determinant's coefficients to obtain the predicted maintenance cost. For instance, Building A has a gross floor area of 1600m^2, building performance index of 82 and is 103 years old. Substituting these values into the prediction model, we will have;

Predicted Maintenance Cost (MYR)
= 59989.78+ 485.59 x 103(years) + 50.24 x 1600(m^2) – 1759.75 x 82
= MYR46, 091.98

In order to validate the model, the percentage accuracy of the model was obtained. For each building, the percentage difference between predicted maintenance cost and the observed maintenance cost (disclosed by the maintenance managers during the interview) would be obtained and used to determine the percentage accuracy of the model in predicting the maintenance cost of that particular building.

■5.0 MODEL VALIDATION

Results of the model validation are presented in Table 6. The results show the accuracy of the regression model in predicting annual maintenance cost based on the building age, gross floor area and building performance index. For instance, the observed maintenance cost of Building A was MYR50, 000 while the estimated annual cost based on the model is around MYR46, 000. From Table 6, it could be seen that the percentage accuracy of the model in predicting annual maintenance costs for heritage buildings is approximately 93%. This is an indication that the model could be used reliably to predict annual maintenance cost of heritage buildings using the building age, gross floor area and building performance index as main determinants.

The various amounts of money spent annually on maintenance by custodians and owners of some heritage buildings in conserving heritage buildings in Malaysia have been shown in Table 7. Thus, there is a further need to ascertain the minimum, average and maximum amounts of money that might likely be spent by custodians and owners in order to efficiently manage the maintenance of their buildings and to improve the buildings' physical conditions. To do so, maintenance costs of buildings in the 'good physical condition' category in Table 7 were adopted.

Table 8 shows the maintenance costs indicator for improving physical conditions of heritage buildings. In order to efficiently manage the maintenance of heritage buildings in Malaysia and to improve the buildings' physical conditions; the minimum, average and maximum amount custodians and owners of the buildings might likely spend are approximately MYR28.57/m^2, MYR34.05/m^2 and MYR40.00/m^2 respectively. This means that spending an amount less than MYR28.57/m^2 could be considered inadequate in order to efficiently manage the maintenance of heritage buildings in Malaysia and to improve the buildings' physical conditions. On the other hand, spending an amount in excess of MYR40.00/m^2 could be considered excessive. Furthermore, there is a need to ascertain the effect of annual maintenance costs and maintenance approach on heritage buildings.

Table 9 shows the effect of annual maintenance costs and maintenance approach on heritage buildings in Malaysia. From the table, we could see that where a custodian or owner of heritage building adopts a planned preventive maintenance approach and spends MYR28.57/m^2, it is likely that the severity of the building's defects will be low. Similarly, a heritage building may very low defects severity in case the custodian or owner adopts a planned preventive maintenance approach and spends MYR34.05/m^2. Where a custodian or owner of heritage building adopts a planned preventive maintenance approach and spends MYR40.00/m^2, it is likely that the severity of the building's defects will be extremely low. However, Table 10 shows the effect of annual maintenance costs and unplanned maintenance approach on heritage buildings in Malaysia.

From the Table 10, we could see that where a custodian or owner of heritage building adopts unplanned maintenance approach and spends MYR28.57/m^2, it is likely that the severity of the building's defects will be extremely high and a possible loss of fabric and authenticity of the heritage building. Similarly, a heritage building may likely have very high defects severity, and a possible loss of fabric and authenticity of the heritage building in case the custodian or owner adopts unplanned maintenance approach and spends MYR34.05/^{m2}. On the other hand, where a custodian or owner of heritage building adopts an unplanned maintenance approach and spends MYR40.00/m^2, it is likely that the building will have high defects severity, and a possible loss of fabric and authenticity of the heritage building.

In Table 6, it was shown that Buildings 'A', 'B' and 'C' spend an observed amount of MYR31.25/m^2, MYR27.27/m^2 and MYR21.05/m^2 respectively. Relating these costs to the annual maintenance costs in Table 10, it could be seen that 'Building A' spends above the minimum cost (MYR28.57/m^2). Even though the building is in good condition, serious physical defects with very high degree of severity were observed. Besides, there is a possibility of loss of original fabric and genuineness of the building. Similarly, 'Building B' and 'C' spend below the minimum cost (MYR28.57/m^2); the buildings are not in very good conditions, with high severity of defects threatening the existence of the buildings.

Besides, some of the building elements have deteriorated resulting to serious loss of fabric and originality of the buildings. Considering the amount of money that might likely be spent on maintenance in Table 9, one could argue that had the custodians of the three buildings (A, B and C) adopted planned preventive maintenance approach; the conditions of the buildings would have been in 'good', 'very good' and 'extremely good' respectively. However, that was not the case. It is obvious that the maintenance costs for Buildings A is more than the suggested minimum costs while Building B's maintenance cost is not far from it. Even though Building C's maintenance cost (MYR21.05/m^2) is less than the suggested minimum costs, nonetheless, the owners can turn things around by adopting planned preventive maintenance.

Table 6 Model validation

	b-value	**Building "A"**	**Maintenance cost (MYR)**	**Building "B"**	**Maintenance cost (MYR)**	**Building "C"**	**Maintenance cost (MYR)**
Constant	59989.781	1	59989.781	1	59989.781	1	59989.781
Age of building (years)	485.59	103	50015.77	104	50501.36	86	41760.74
Gross floor area (sq meters)	50.241	1600	80385.6	1100	55265.1	475	23864.475
Building performance index	-1759.746	82	-144299.172	76	-133740.696	66	-116143.236
Estimated (predicted) annual maintenance cost (MYR)			46,091.98		32,015.55		9,471.76
Observed	average annual maintenance expenditure		50,000		30,000		10,000
	Cost per square meter		31.25		27.27		21.05
Estimated (Predicted)	average annual maintenance expenditure		46,091.98		32,015.55		9,471.76
	Cost per square meter		28.81		29.11		19.94
Accuracy (%)			92.41%		93.28%		94.39%
Accuracy of maintenance cost prediction model (%)			93.36%				

*Maintenance cost = b-value x independent variables

Despite the fact that money spent on maintenance by custodians of these building are not very low, yet the buildings keep manifesting defects with high severity and the originality of the fabric of the buildings is seriously waning. Although we may not rule out the possibility of old age catching up with buildings, the problems with these heritage buildings could be strongly attributed to poor maintenance management practices by the custodians of the buildings. Poor maintenance strategy will only cause heritage buildings to degrade and make future maintenance works more difficult and expensive. Failure to adopt planned preventive maintenance strategy will cause the building fabric and structure to keep deteriorating. This is because lack of proper maintenance leads to further deterioration, decay and failure.

Hence, for a heritage building to retain its functions, values, integrity and cultural significance, it is vital that adequate maintenance funding is provided and planned preventive maintenance strategy should take a leading role in conserving heritage buildings.

Table 7 Annual maintenance costs for conserving heritage buildings in Malaysia

Physical condition of the buildings	Average Annual Maintenance Expenditure (MYR)	Building Area (m^2)	Cost per square meter (MYR/m^2)
Good	50000	1600	31.25
	50000	1750	28.57
	20000	580	34.48
	30000	900	33.33
	30000	1000	30.00
	20000	600	33.33
	50000	1300	38.46
	20000	580	34.48
	50000	1500	33.33
	30000	805	37.27
	50000	1250	40.00
Fair	30000	1220	24.59
	50000	2000	25.00
	30000	1100	27.27
	50000	2300	21.74
	50000	2250	22.22
	70000	2770	25.27
	20000	800	25.00
	20000	805	24.84
	30000	1100	27.27
	50000	2300	21.74
	50000	1950	25.64
Poor	50000	2800	17.86
	50000	2920	17.12
	30000	2200	13.64
	10000	520	19.23
	10000	600	16.67
	10000	475	21.05
	50000	2600	19.23
	30000	1890	15.87
	20000	1030	19.42
	30000	1600	18.75
	50000	2440	20.49

Table 8 Maintenance costs indicator for improving physical conditions of heritage buildings

Maintenance cost per square foot (MYR/m^2)		
Minimum	*Average*	*Maximum*
28.57	34.05	40.00

Table 9 Effect of annual maintenance costs and planned maintenance approach on heritage buildings

Annual maintenance Cost		Maintenance Approach	Effect on the buildings
Minimum	$MYR28.57/m^2$	Planned Preventive	Manifestation of defects; severity is low
Average	$MYR34.05/m^2$	Planned Preventive	Manifestation of defects; severity is very low
Maximum	$MYR40.00/m^2$	Planned Preventive	Manifestation of defects; severity is extremely low

Table 10: Effect of annual maintenance costs and unplanned maintenance approach on heritage buildings

Annual maintenance Cost		Maintenance Approach	Effect on the building
Minimum	$MYR28.57/m^2$	Unplanned	Defects severity is extremely high; possible loss of fabric & authenticity of the building
Average	$MYR34.05/m^2$	Unplanned	Defects severity is very high; loss of fabric & authenticity of the building
Maximum	$MYR40.00/m^2$	Unplanned	Defects severity is high; loss of fabric & authenticity of the building

■6.0 CONCLUSION

In this paper, the maintenance cost prediction model for heritage buildings was developed. The model was developed to assist custodians and owners of heritage in estimating and forecasting maintenance cost of heritage buildings in their care. Multiple regression analysis was performed to develop maintenance cost prediction model. Four determinants were used to develop the model. The determinants are annual maintenance cost, age of buildings, gross floor area and building performance index. The results of the developed model which are based on 95% confidence level show that the largest influence on maintenance cost is from building age while the least is from gross floor area of the building. The building performance index was found to have negative relationship with the maintenance cost. A useful conclusion that can be drawn from the results of the model is that irrespective of age of building and the building performance index, annual maintenance cost for heritage building increases with the gross floor area. Moreover, maintenance cost decreases with improvement in the physical condition of the building (building performance index) irrespective of age of building and gross floor area of building. Thus, as building condition improves, maintenance cost decreases sequentially because there is a uniform decrease in annual maintenance cost irrespective of the age and gross floor area of the building. The model validation results show that the maintenance cost prediction model has about 93% accuracy in predicting annual maintenance cost for heritage buildings based on the building age, gross floor area and building performance index.

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