Abstract
The building maintenance costs are rising rapidly from time to time due to poor maintenance in the past. In UK, total spending on building maintenance had a dramatically increase of 66% in the past 10 years. In Malaysia, the development plan allocation for repair and maintenance works in building sector increased from RM296 million during the Eighth Malaysian Plan to RM1,079 million during the Ninth Malaysian Plan. However, the development plan allocation for repair and maintenance works in the Tenth Malaysian Plan has decreased to RM500 million. The decrease of resource allocation for building maintenance activities urges the professions to develop solutions on reducing the maintenance costs. Thus, this research seeks to identify the characteristics of preventive maintenance, which is the scheduled maintenance through literature review. It is found that the characteristics of scheduled maintenance always affect the maintenance cost performance. Therefore, this research is aimed to establish relationship between characteristics of scheduled maintenance and cost performance. Then, regression model is produced for the purpose of maintenance prediction. At the end, the research outcomes will be able to help the industry practitioners in considering the significant characteristics with optimal maintenance expenditure and maintenance performance.

Keywords: Characteristics, Scheduled maintenance, Cost performance, Office building, Malaysia
1. Introduction

Building maintenance is the combination of technical and administrative actions to ensure the items and elements of a building in an acceptable standard to perform its required function. In order to implement or perform the tasks of building maintenance efficiently, a proper building maintenance management is a necessary tool for it.

Generally, building maintenance is subdivided into two main categories, which are planned maintenance and unplanned maintenance under BS3811 (Seeley, 1987). Planned maintenance is the predetermined tasks that are well organised and performed in advance. The maintenance actions reduce or prevent any damage of the components or items. On the other hand, unplanned maintenance is carried out in the event of emergency or contingency maintenance without any predetermined plan. The maintenance actions are carried out after failure or damage detected.

In fact, planned maintenance is supposed to be the major activity in building maintenance instead of unplanned maintenance. Otherwise, frequent breakdown or downtime could be occurred and high maintenance cost is required by unplanned maintenance for repair and replacement works (Chareonsuk et al., 1997). Thus, unplanned maintenance should be minimised to achieve optimal maintenance expenditure.

Since Horner et al. (1997) noted that there are several strategic options available to management and many alternative decisions to be considered for maintaining a building in proper aspect, the study on the maintenance strategies is necessary to control the maintenance performance, especially the maintenance cost. In this research, the characteristics of scheduled maintenance were studied and reviewed. Then, the relationship between characteristics of scheduled maintenance and cost performance was examined.

1.1 High-Rise Office Building

In Malaysia, DBKL (1986) defined high-rise building as the building that is more than 7 floors (or the top floor of building is more than 60 feet). This definition is in accordance to the Uniform Building By-Laws 1984. The maintenance of buildings in Malaysia is more concerned lately, there were a few researches discussing about the facilities and maintenance management of high rise office building.

According to Zawawi and Kamaruzzaman (2009), office buildings always have their own maintenance management team to take care the conditions of buildings, which are managed by maintenance or building managers. Basically, the services provided by building managers in office buildings are cleaning, landscaping, general maintenance, lightings, heating, ventilating and air conditioning (HVAC), lift or escalators, mechanical and electrical, sanitary and plumbing, access, signage, parking and others (Myeda et al., 2011). These services are the significant systems of office buildings to be concerned by maintenance management, as they provide function, safety, health and comfort to the building users in daily working activities.

Unfortunately, Zawawi and Kamaruzzaman (2009) demonstrated that most of the building users were not satisfied with the services provided through building satisfaction survey. This was mainly due to the issues such as lack of maintenance staff, lack of expertise, lack of tools and technology, insufficient budget allocated, inappropriate maintenance strategies and so on. Those issues often occur in high-rise office building as it is a medium-sized building, which is equipped with more sophisticated systems such as fire detection and protection systems, central heating, ventilating and air conditioning system, escalators and others (Halim et al., 2011).
Therefore, this research focused about the issue that causing building users’ dissatisfaction in high-rise office buildings. In other words, the characteristics of maintenance strategy (scheduled maintenance) toward maintenance performance were examined.

2. Characteristics of Scheduled Maintenance

Scheduled maintenance is defined as the preventive maintenance carried out in accordance with predetermined interval of time, number of operations, mileage and others to ensure such components perform in good condition (Seeley, 1987; Horner et al., 1997; Nilsson, 2007; Flores-Colen and de Brito, 2010). Hameed et al. (2010) pointed out that maintenance activities performed at fixed time interval are mean to reduce the probability of failures and breakdowns. However, some researchers argued that scheduled maintenance is not cost effective, which the replacement of components is often performed regardless of the condition. Literature indicated that the maintenance performance of scheduled maintenance relies on the criteria as stated below:

2.1 Skilled Labour

Since scheduled maintenance is carried out in a fixed time interval, it does require permanent maintenance personnel or technicians to perform the tasks. Commonly, the organisation allocates different amount of salary for the maintenance personnel based on their level of competency. Groote (1995) pointed out that the qualification of the maintenance labour force is an important factor that affecting the maintenance outcome. For instance, some of the scheduled maintenance works are determined by experienced and skilled technician, who observes the wear and tear of the parts or components. Thus, the technicians should not only limit their capability in replacing and overhauling system components, but they must be capable to identify the need of scheduled maintenance. Furthermore, Horner et al. (1997) claimed that the labour is highly demanded for scheduled maintenance activities. Thus, skilled labour is one of the main characteristics to be considered for implementation of scheduled maintenance, which includes:

- Skill and knowledge of labour.
- Number of labour.

2.2 Spare Part and Material

According to Horner et al. (1997), spare part and material is much required for scheduled maintenance compared to other maintenance strategies. Some parts of building systems or services need to be replaced with a new one in fixed interval as determined in the schedule maintenance program, no matter such items are damaged or not. Thus, Tsang (1995) stated that accurate spare parts identification and stocking help to control and reduce the operation and maintenance costs. In addition, the quality of spare part and material always has an impact towards maintenance performance (Ali et al., 2010). Thus, the selection of spare part and material should not only concern about cost saving, the quality of spare part and material is another essential aspect to be taken into consideration. In this research, the spare part and material cover:

- Level of stock of spare part and material
- Quality of spare part

2.3 Predetermined Interval for Maintenance

The interval of maintenance activities is critically influencing the maintenance outcome. Narayan (2003) proven that unavailable or delay to perform maintenance task at the right time may cause further damages to the system components. Meanwhile, Yang (2004) argued that the scheduled maintenance programs might not be able to avoid the risk of failure occurred on system components before the fixed replacement time. This problem occurs due to unknown condition of the system components. Hence, an adequate maintenance interval must be identified and performed to enhance the effectiveness of
scheduled maintenance. Therefore, the criterion of predetermined interval for maintenance includes the length of predetermined maintenance interval.

2.4 Maintenance and Failure Downtime

Since Yang (2004) had mentioned that the scheduled maintenance is not able to prevent the risk of failure, the downtime and cost allocation for maintenance and failure should be considered when planning the maintenance approach. According to Zuashkiani et al. (2011), breakdown may cause collateral damage in a particular system. Relatively, additional downtime and cost will be incurred for the failures occurred before the predetermined maintenance time. Hence, the amount of downtime for maintenance and failure must be taken into consideration for the planning and execution of scheduled maintenance activities.

3. Maintenance Performance

Amaratunga & Baldry (2002) stated that the development of performance measurement in management is to improve quality and service, as well as meeting cost parameters. Measurement of maintenance performance is an assessment that helps to identify the strengths and weaknesses of the maintenance activities. In addition, the result of performance measurement indicates the effectiveness of existing strategy. Consequently, the management team is able to plan and make appropriate decision for future maintenance strategy.

The measurement of performance can be obtained through the level of success or failure in terms of schedule, cost and functionality (Sidwell 1990; Johnson 1995). Since the rising maintenance cost is one of the major issues concerned by the industry and public, the cost performance is focused in this research as the dependent variable.

The aspect of cost or expenditure for building maintenance is mostly used in measuring the performance of buildings. Ali (2009) noted that maintenance performance is calculated using variance of actual expenditure and planned cost for building maintenance activities. Comparison between actual and planned cost is made to identify the level of maintenance performance. For instance, maintenance performance of a building system is deemed below expectation when the actual spending for maintenance tasks is more than the planned cost. In contrast, high performance level is achieved when the total expenditure is less than the planned cost for the maintenance works.

4. Research Methodology

This research was conducted through literature review in early stage. The characteristics of scheduled maintenance were identified by reviewing the journal articles and other reliable reference sources. Then, quantitative approach was adapted to study on the relationship between characteristics of maintenance strategy and maintenance cost performance. Questionnaires were sent out to the relevant expertise in Klang Valley, Malaysia to obtain the factual data for analysis, such as building or maintenance manager, building executive or supervisor, and other maintenance personnel. At the end of the research, Spearman’s rank correlation analysis result was produced by using SPSS to show the relationship between characteristics of maintenance strategies and maintenance cost performance. Furthermore, regression models were produced to identify the significant predictors of cost performance. A correlation test was used to measure the relationship between characteristics of maintenance strategy and performance. In this study, the Spearman rank-order correlation was employed for analysis. Generally, a correlation of -1.00 or +1.00 is a perfect negative or positive relationship respectively. A correlation of zero means that no linear relationship exists. The correlation test calculated using the following formula:
The findings of relationships between characteristics of scheduled maintenance and cost performance were referred to provide information for the prediction of maintenance performance. The prediction of the value of a dependent variable from the value of an independent variable is called regression. In this study, there was more than 1 significant independent variable identified. Thus, multiple regression was used as it is a method of analysing collective and separate contributions of two or more independent variables to the variation of a dependent variable. The multiple linear regression is formulated as:

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \epsilon \]

Where,
- \( Y \) is dependent variable (\( Y = \) compatibility of design to existing site)
- \( X_1, X_2, ..., X_k \) are independent variables (\( X_1 = \) knowledge on assessing the condition of a building; \( X_2 = \) enthusiasm in refurbishment design work; \( X_3 = \) coordination skill)
- \( Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k \) is the deterministic portions of the model
- \( \beta_i \) determines the contribution of the independent variable \( X_i \)
- \( \epsilon \) is random error

5. Finding

In this research, the number of valid return questionnaires was 101, which is 30 per cent of the total research population. Thus, the results were able to represent the research population.

![Job Title (N = 101) Pie Chart]

Figure 1: Job title of respondents

Figure 1 indicated that the respondents of the questionnaire survey comprised building managers, building executives or supervisors, building technicians, and others. Based on the data obtained through
the survey, some of the respondents, who selected the category of “others”, were either managing directors of a property management firm or mechanical and electrical engineers.

5.1 Relationship between Characteristics of Scheduled Maintenance and Cost Performance

The relationship between characteristics of scheduled maintenance and cost performance was identified as shown in Table 1. The cost performance was the dependent variable of this study, which was determined by maintenance expenditure variance. Then, there were total of six independent variables in this study. Among six of them, five were detected to be significantly correlated to the maintenance expenditure variance, include:

- Skill and knowledge of labour
- Level of spare part and material stock
- Quality of spare part and material
- Length of predetermined maintenance interval
- Amount of maintenance and failure downtime

Table 1: Correlation between characteristics of scheduled maintenance and maintenance cost performance

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Maintenance Expenditure Variance</th>
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<tbody>
<tr>
<td>Skilled Labour-Skill and Knowledge</td>
<td>-0.417**</td>
</tr>
<tr>
<td>Skilled Labour-Number of Labours</td>
<td>-0.182</td>
</tr>
<tr>
<td>Spare Part and Material-Level of Stock</td>
<td>-0.255*</td>
</tr>
<tr>
<td>Spare Part and Material-Quality</td>
<td>-0.327**</td>
</tr>
<tr>
<td>Predetermined Maintenance Interval-Length of Interval</td>
<td>0.301**</td>
</tr>
<tr>
<td>Failure and Maintenance Downtime-Amount of Downtime</td>
<td>0.207*</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed)

In schedule maintenance, the quality of work provided by the maintenance labour directly influences the maintenance performance outcomes (Groote, 1995). The statement was proven by the analysis result. According to the correlation analysis result obtained as shown in Table 1, the skill and knowledge of maintenance labour was found to be significantly correlated to the maintenance expenditure variance. The labour without proper skill and knowledge are more likely to misjudge and misinterpret the condition or problem of a system. The repair and replacement works done by such labour might not be appropriate. As a result, further damages will be occurred and additional repair works will be required. As such, the task spends additional maintenance cost and leads to the issue of over-budget.

Then, level of spare part and material stock is another aspect highly concerned in scheduled maintenance. Greater amount of spare parts are needed to replace the existing parts compared to other maintenance strategies. In this research, the level of spare part and material stock was found to be significantly correlated to the maintenance expenditure variance (see Table 1). The analysis result supported the statement of Tsang (1995) that accurate spare parts identification and stocking help to control and reduce the operation and maintenance cost. For example, the maintenance personnel will be urged to order small amount of spare parts to execute the maintenance works when there are no adequate spare part stock. It usually costs higher to order small amount of spare part instead of large amount. As a result, the variance of maintenance expenditure occurs.
Furthermore, the analysis result supported the statement of Ali et al. (2010) that the quality of spare part and material always has an impact towards maintenance performance. The result indicated that the quality of spare part and maintenance expenditure variance were significantly correlated (see Table 1). Hence, the statement of De Silva and Ranasinghe (2010) was verified, which revealed that good quality spare part and material can optimise the maintenance expenditure. Poor quality spare part and material is likely to damage and cause unwanted failure to the building systems. Thus, additional repair and replacement works are required. Extra maintenance expenditure is needed and variance of maintenance expenditure is happened.

Meanwhile, length of predetermined maintenance interval is vital aspect to be considered in scheduled maintenance. The length of fixed maintenance interval was significantly correlated to the maintenance expenditure variance (see Table 1). The correlation analysis result was in accordance to the statement of Narayan (2003), which proved that delay or unavailable to perform maintenance work at the right time may implicate further damages or defects to the system components. Thus, additional repair and replacement costs are required to restore the system back to its acceptable operation standard. Nevertheless, optimal maintenance interval must be achieved. Although frequent maintenance is able to enhance the quality of a system, it is costly at the same time (Moghaddam and Usher, 2010).

Besides that, proper planning for the downtimes is necessary to retain and improve the maintenance performance. The amount of failure and maintenance downtimes was significantly correlated to the maintenance expenditure variance (see Table 1). The statement of Chareonsuk et al. (1997) was confirmed, which stated that the downtime might be very costly. The maintenance expenditure is likely to be varied as more downtimes occur in a building system. Therefore, the downtime for maintenance must be well managed to avoid unnecessary cost. Minimal failure and maintenance downtimes should be obtained in building maintenance.

### 5.2 Regression Model of Maintenance Cost Performance

Since there were five characteristics found to be significantly correlated to the cost performance, the predictors of maintenance expenditure variance (MEV) included skill and knowledge of labour (SKL), level of spare part and material stock (LSP), quality of spare part and material (QSP), length of predetermined maintenance interval (LMI), as well as amount of maintenance and failure downtime (AMD). The regression model for the research was produced as follows:

**Model 1 (Enter Method)**

\[
\text{MEV} = 4.846 - 0.563 \text{SKL} - 0.072 \text{LSP} - 0.097 \text{QSP} + 0.427 \text{LMI} + 0.062 \text{AMD}
\]

Coefficient of multiple regression, \(R^2 = 0.260\) (26.0%)

However, the analysis results determined that three predictors were not significant with p-value of more than 0.05. So, another regression model to eliminate the non-significant predictors was produced as follows:

**Model 2 (Stepwise Method)**

\[
\text{MEV} = 4.811 - 0.677 \text{SKL} + 0.441 \text{LMI}
\]

Coefficient of multiple regression, \(R^2 = 0.255\) (25.5%)

In order to ensure that the regression models were not violated, the validity of the regression models was checked. Data tabulated in Table 2 and Table 3 had proven that there was no problem of multicollinearity for Model 1 and Model 2 respectively. Whereby, the tolerance value should not be less than 0.1 and variance inflation factor, VIF should not be greater than 10.
Table 2: Checking assumption of Model 1 (Enter Method)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Collinearity Tolerance (&gt; 0.100)</th>
<th>VIF (&lt; 10.000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill and knowledge of labour</td>
<td>0.475</td>
<td>2.105</td>
</tr>
<tr>
<td>Level of spare part and material stock</td>
<td>0.688</td>
<td>1.453</td>
</tr>
<tr>
<td>Quality of spare part and material</td>
<td>0.455</td>
<td>2.199</td>
</tr>
<tr>
<td>Length of predetermined maintenance interval</td>
<td>0.939</td>
<td>1.065</td>
</tr>
<tr>
<td>Amount of maintenance and failure downtime</td>
<td>0.867</td>
<td>1.153</td>
</tr>
</tbody>
</table>

Table 3: Checking assumption of Model 2 (Stepwise Method)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Collinearity Tolerance (&gt; 0.100)</th>
<th>VIF (&lt; 10.000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill and knowledge of labour</td>
<td>0.991</td>
<td>1.009</td>
</tr>
<tr>
<td>Length of predetermined maintenance interval</td>
<td>0.991</td>
<td>1.009</td>
</tr>
</tbody>
</table>

6. Conclusion

This paper emphasised the significance in planning and executing appropriate maintenance strategy to improve maintenance performance. Through examination of literature, the characteristics of scheduled maintenance were found to be directly influencing the cost performance. Therefore, it is important to understand the influences of characteristics in whole maintenance process, which is from planning to outcome of maintenance. From a review of literature, six characteristics of scheduled maintenance were found dominant and important in influencing the maintenance performance. Among the six characteristics, five were detected to be significantly correlated to the maintenance expenditure variance. They were skill and knowledge of labour, level of spare part and material stock, quality of spare part and material, length of predetermined maintenance interval, as well as amount of maintenance and failure downtime. In addition, there were two prediction models generated using SPSS. Three of the independent variables of Model 1 were determined to be insignificant predictors. Thus, another model was produced by using the Stepwise method. As a result, only two independent variables were selected by SPSS in Model 2, which was more significant compared to Model 1. The significant predictors included skill and knowledge of labour as well as length of predetermined maintenance interval. This article is able to assist the practitioners in considering and concerning the significant characteristics while planning and executing the scheduled maintenance with optimal maintenance cost performance.

References


