Enhancing Building Maintenance Cost Performance with Proper Management of Spare Parts

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Abstract

Purpose: Scheduled building maintenance requires appropriate and adequate spare parts to replace existing parts on a regular basis. Management of spare parts is seen as an important criterion to ensure the efficiency of scheduled maintenance. Thus, this paper aims to identify the contributors of spare parts management and investigate the relationship between these contributors and maintenance cost performance.

Design/Methodology/Approach: This research adopted a quantitative approach, which utilised questionnaire surveys to study the relationship between the contributors of spare parts management and maintenance cost performance. The data was analysed through descriptive analysis, correlation, and regression analysis. Additionally, a case study was examined to validate the results obtained from the survey.

Findings: The results of this research demonstrated that the quality of spare parts, budget allocation for acquisition of spare parts, and level of stocks were significantly correlated to the maintenance cost variance. Moreover, the results of the regression analysis indicated that the quality of spare parts was the significant predictor of maintenance cost variance.

Originality/Value: This research highlights the importance of spare parts management in building maintenance. It recommends that maintenance management set up a spare parts management department for updating stocks frequently. Meanwhile, the management should avoid ad-hoc acquisition of spare parts, as this is always more expensive. The management should also select spare parts based on quality instead of lowest cost. In addition, building managers should also apply the developed regression model in practice to predict and improve maintenance performance.

Keywords: inventory; spare parts management; quality; maintenance; cost performance
1. Introduction

High building maintenance cost has become a common issue in construction industry nowadays (El-Haram & Horner, 2002). The main reason for this is the low service quality of maintenance management in Malaysia (Kamaruzzaman & Zawawi, 2010; Ruslan, 2007). This poor maintenance performance is primarily due to the lack of preventive maintenance measures. Thus, the introduction and implementation of preventive maintenance measures is highly recommended to solve the problem of high maintenance costs.

One preventive maintenance strategy that has been suggested for improving building maintenance costs is scheduled maintenance (Forster & Kayan, 2009). This is defined as preventive maintenance that is carried out in accordance with certain criteria, such as predetermined intervals of time, number of operations, and mileage, so as to ensure that building components remain in good condition (Flores-Colen & De Brito, 2010; Horner et al., 1997; Nilsson, 2007; Seeley, 1987).

Scheduled maintenance involves the regular replacement of parts to retain the functionality of the building and its components (Horner et al., 1997). Notably, the cost of spare parts, number of stocks, and lifespan of maintenance parts or items have been proven to be factors that influence maintenance performance (Groote, 1995). As a result, the effectiveness of scheduled maintenance can be greatly influenced by the quality of spare parts management.

For instance, inadequate stocking of spare parts may lead to extended system deterioration and failure, while maintaining excessive spare parts may lead to extensive carrying costs (Wang, 2012). In other words, the unavailability of spare parts affects scheduled maintenance operations and jeopardises the quality of systems. On the other hand, oversupply of spare parts requires more storage space, which is uneconomical.

Given this scenario, efficient spare parts management should aim to optimise spare parts provisioning costs in an environment that maintains the normal operation of the organisation or system (Kranenburg & van Houtum, 2008). Taking into cognizance the importance of spare parts management towards maintenance performance, this paper aims to identify the contributors of spare parts management that should be considered in maintenance management, and investigate the relationship between these contributors and maintenance cost performance.
2. Management of Spare Parts

Scheduled maintenance requires the availability of appropriate and adequate spare parts to replace existing parts on a regular basis (Au-Yong et al., 2013). Replacement tasks are meant to restore the conditions of buildings and systems to their original state of functionality by overcoming the effect of wear and tear (Bevilacqua & Braglia, 2000). Consequently, these tasks help in reducing the probability of a building or system breakdown (Hameed et al., 2010).

Spare parts are defined as all parts, equipment, and expandable assets that operate in a system for certain period of time (Assaf et al., 2011). Every part or component in a system has its own lifetime. It needs to be replaced when it reaches the end of its lifetime. It is important to have spare parts available for replacement to ensure a system operates consistently. For example, preventive maintenance requires several categories of spare parts, including exchange parts, lubricants, and other materials for maintenance such as rags and cleaning solvents (Salonen & Deleryd, 2011; Swanson, 2001).

Maintenance management is a process that allocates and coordinates resources such as spare parts, to enhance aspects of maintenance performance such as reliability, safety, function, cost, comfort, and convenience (Idrus et al., 2009). One important strategy to improve maintenance performance is the proper management of spare parts. In general, management of spare parts includes the study of spare part needs, efficient spare parts reordering, noting the level of stocks of spare parts, and storage of spare parts (Groote, 1995). Thus, proper management of spare parts is essential to improve maintenance performance.

2.1 Previous Studies

Based on a review of the literature, the contributors of spare parts management are shown in Figure 1.

Figure 1 indicates that budget allocation is an important contributor in the management of spare parts. For example, Yik and Lai (2005) pointed out that the cost for spare parts required in scheduled maintenance is one of the major costs in building services maintenance. Accurate spare parts identification and stocking help to control and reduce operation and maintenance costs (Tsang, 1995). On the other hand, the
allocation of spare parts can be limited by budget constraints (Costantino et al., 2013). Thus, Hassan et al. (2014) argued that effective spare parts management requires an acceptable balance between budget allocation for spare parts and stock-out costs.

Figure 1: Contributors of spare parts management

Level of stocks (refer to Figure 1) is another significant contributor of spare parts management. Indeed, spare parts are much required for scheduled maintenance compared to other maintenance strategies (Horner et al., 1997). Some parts of building systems or services need to be replaced with new ones at a fixed interval depending on the maintenance program schedule, whether or not the items are damaged. Thus, the availability of spare parts is of high concern in scheduled maintenance as it can affect the maintenance performance (Parida & Kumar, 2006). Eti et al. (2006) noted that a good maintenance manager should be able to allocate adequate spare parts for maintenance programs at minimum cost without jeopardising the quality of systems. Nevertheless, maintaining appropriate levels of stocks for different spare parts requires reliable forecasting techniques over a specific time period to identify priorities in spare part storage (Hassan et al., 2014).

The quality of spare parts also has an impact on maintenance performance (Ali et al., 2010). Obviously, selection of good quality spare parts can reduce the maintenance budget and downtime loss (De Silva & Ranasinghe, 2010). On the other hand, poor quality spare parts have a shorter service lifespan compared to good spare parts, leading to more defects in a system (Zuashkiani et al., 2011). In some circumstances, poor quality items might be damaged before the predetermined replacement schedule and this would affect the whole system’s operation. As a result,
repair work would need to be carried out and additional maintenance costs would be incurred. The sourcing of spare parts is also critical as it involves risk of variations in quality Roda et al. (2014). Therefore, the quality of spare parts is another essential contributor to be taken into consideration, as the selection of spare parts and suppliers should not only be driven by cost saving. This way, the systems’ lifespans and their operations will be respectively prolonged and enhanced (Au-Yong et al., 2014).

3. Maintenance Cost Performance

In management, development of performance measurement is usually conducted to improve quality and service, as well as to meet cost parameters (Amaratunga & Baldry, 2002). The aspect of cost or expenditure for building maintenance is mostly used in measuring the performance of buildings. Commonly, maintenance cost performance is calculated using variance of actual expenditure and planned cost for building maintenance activities (Ali, 2009). A comparison between actual and planned cost is usually made to identify the level of maintenance performance. For instance, the 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, a high performance level is achieved when the total expenditure is less than the planned cost of the maintenance works. Since rising maintenance costs are of major concern to the industry and public, this research is concerned with improving cost performance.

4. Research Methodology

This research investigated the relationship between management of spare parts and maintenance cost performance. A quantitative approach using a survey questionnaire was utilised with reference to research undertaken by Ali (2009), who used questionnaire surveys to study the relationship between uncertainties in refurbishment design processes and project performance. Additionally, this research carried out a case study to validate the results obtained from the survey questionnaire.

The questionnaire survey used in this research was targeted at collecting data on the contributors of spare parts management and the cost performance of maintenance management in office buildings. In order to obtain a high response rate, the questionnaire was constructed in a short and simple manner so that it would not
take up too much of the respondents’ time. The questionnaire was constructed using close-ended questions in 5-point Likert scales and multiple choices. Simple random sampling was adopted to identify relevant respondents who were previously or currently involved in building maintenance management in the area of Klang Valley, Malaysia. Furthermore, respondents were required to answer questions based on their experience or involvement in maintenance management for high-rise office buildings. Meanwhile, the criteria for buildings were that they must have a minimum of seven storeys and be at least two years old.

Questionnaire surveys require a minimum response rate of 30% to produce reliable and convincing results (Hoxley, 2008). In this research, a total of 300 questionnaires were distributed to building managers, building executives, supervisors, technicians, and other maintenance personnel within the Klang Valley. Out of 113 responses, 101 were found to be useful and valid for analysis. The remaining 12 questionnaires were incomplete or invalid for some reasons. Therefore, a response rate of 38% was achieved. The demographic profile of respondents is shown in Table 1. 83% of the respondents were building managers, executives, and supervisors. They had considerable expertise in the planning and implementation of maintenance strategies. 10% of the respondents were building technicians, while the remaining 7% were categorised as “others” (which referred to mechanical and electrical engineers).

Table 1: Demographic profile of the respondents

<table>
<thead>
<tr>
<th>Position</th>
<th>Percentage (N = 101)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building manager</td>
<td>50</td>
</tr>
<tr>
<td>Building executive/supervisor</td>
<td>33</td>
</tr>
<tr>
<td>Building technician</td>
<td>10</td>
</tr>
<tr>
<td>Others</td>
<td>7</td>
</tr>
</tbody>
</table>

In order to validate the questionnaire’s results, a case study was carried out on a 32-storey office building located in Kuala Lumpur. The building was seven years old, with a total floor area of 493,000 square feet, and privately owned and managed under the in-house maintenance and management team. The purpose of the case study was also to test the applicability of the developed regression model. Relevant information about the significant predictor was collected. The data was applied into the regression model for calculation of the maintenance cost variance ratio. Consequently, the ratio was compared to the exact scenario of the office building.
5. Findings and Discussion

5.1 Ranking Analysis

Ranking analysis is commonly used to determine the relative importance of variables in research. The mean score (with 1 – not important at all, to 5 – very important) indicates the different levels of importance of the various spare parts management contributors in maintenance management (refer to Table 2).

Table 2: Importance level of the contributors of spare parts management

<table>
<thead>
<tr>
<th>Rank</th>
<th>Variable</th>
<th>Mean (N=101)</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Quality</td>
<td>3.53</td>
<td>0.944</td>
</tr>
<tr>
<td>2</td>
<td>Budget allocation</td>
<td>3.19</td>
<td>0.880</td>
</tr>
<tr>
<td>3</td>
<td>Level of stocks</td>
<td>2.83</td>
<td>0.861</td>
</tr>
</tbody>
</table>

It was found that ‘quality of spare parts’ achieved the highest ranking, with a mean score of 3.53. Meanwhile, the standard deviation value was 0.944, indicating that the data was widespread and not biased. Essentially, the quality of spare parts was identified as the most important characteristic in executing scheduled maintenance. This finding supports the statement of Ali et al. (2010) that the quality of spare parts is crucial, as it always has an impact on maintenance performance. By having good quality spare parts, building systems can operate effectively with minimal breakdowns or failure. Additionally, the replacement interval of the parts can be extended, as quality parts usually have a longer lifetime. In order to acquire good quality spare parts, selection of reliable suppliers is significant (Roda et al., 2014).

The results also showed that the ‘budget allocation to acquire spare parts’ ranked second, with a mean score of 3.19 and standard deviation value of 0.880. Indeed, adequate budget allocation is vital, as it ensures that resources are available to acquire parts needed to perform replacement tasks on time. Additionally, a sufficient budget allows for a bulk order of spare parts that is usually sold at cheaper cost. On the other hand, insufficient funds may lead to acquisition of poor quality parts that cause more maintenance issues in the future. Hence, optimal budget allocation ensures the availability of spare parts, efficient spare parts reordering, adequate stocks of spare parts, and good quality spare parts (Groote, 1995). In addition, the balance
between budget allocation for purchasing spare parts and the consequences of stock-
out cannot be ignored (Hassan et al., 2014).

The variable found to rank lowest in this analysis was stock levels of spare parts, with a mean score of 2.83, which is below 3.00. Data is normally distributed with a standard deviation value of 0.861. This result indicates that excessive stocks of spare parts may jeopardise effective maintenance management. This is because extra storage space is required to keep and store these spare parts. Meanwhile, extensive care is required to ensure the upkeep of the spare parts, especially fragile parts like fluorescent tubes and light bulbs. Thus, this result confirms that accurate spare parts identification and stocking help to control and improve the effectiveness of maintenance management (Tsang, 1995). As suggested by Hassan et al. (2014), decision making in prioritising the level of stocks for different spare parts is critical.

5.2 Reliability Analysis

The reliability of data for the various contributors of spare parts management was then examined through Cronbach’s alpha analysis. The Cronbach’s alpha coefficient for the contributors was 0.756. A coefficient number above 0.70 indicates acceptable reliability (Leech et al., 2011). Therefore, the scale and data obtained in this research was confirmed to be reliable.

5.3 Correlation Analysis

Following this, an associative test using Spearman rank correlation coefficient analysis was conducted to establish the relationship between the contributors of spare parts management and maintenance cost performance (refer to Table 3). Higher concern for the contributors is likely to reduce the cost variance. Therefore, a negative correlation between the contributors and cost variance was expected in the analysis outcome.

Table 3: Correlation matrix between the contributors of spare parts management and maintenance cost variance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cost Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>-0.327**</td>
</tr>
<tr>
<td>Budget allocation</td>
<td>-0.232*</td>
</tr>
<tr>
<td>Level of stocks</td>
<td>-0.255*</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level
*. Correlation is significant at the 0.05 level
In an associative test, the null hypothesis is rejected at a significance level of 0.05. In other words, the probability of error in rejecting the null hypothesis is 5%. The null ($H_0$) and alternative ($H_1$) hypotheses of this study are stated as follows:

$H_0$ – There is no significant correlation between the contributors of spare parts management and maintenance cost performance.

$H_1$ – There is a significant correlation between the contributors of spare parts management and maintenance cost performance.

The correlation analysis results (Table 3) indicated that the quality of spare parts was significantly correlated to the cost variance with a correlation coefficient of -0.327 (p-value less than 0.01). This indicates that good quality spare parts optimise maintenance expenses by minimising defects and failures. Poor quality spare parts and materials are likely to become damaged and cause unwanted failure to building systems. Thus, additional repair and replacement work would be needed, which incurs extra maintenance cost.

The results also found that budget allocation for acquisition of spare parts was significantly correlated to the cost variance, with a correlation coefficient of -0.232 (p-value less than 0.05). Budget allocation for spare parts allows for the storing of spare parts at an adequate level. Furthermore, better quality spare parts are obtained when there is less budget limitation. In some circumstances, organisations refuse to allocate an adequate budget for acquiring spare parts. As a result, maintenance personnel face issues of poor stock management and reduced quality of spare parts, which are factors that lead to delayed maintenance tasks and unwanted damages. This is especially pertinent because extra maintenance incurs cost.

The level of stocks was significantly correlated to the maintenance cost variance with a correlation coefficient of -0.255 (p-value less than 0.05). This indicates that proper management of spare parts ensures the availability of adequate spare parts for maintenance tasks. The maintenance expenditure also increases under inefficient management of spare parts. For example, the maintenance staff will be urged to order a small number of spare parts to carry out maintenance tasks when there are no spare part stocks available. It usually costs more to order a small number of spare parts instead of a large number. Consequently, maintenance expenses will increase.
Based on these results, the null hypothesis was rejected and the alternative hypothesis was accepted. These findings confirm that the higher the concern towards the quality, budget, and stock of spare parts, the lower the variation of maintenance cost. In other words, building managements can optimise maintenance costs if they are able to effectively manage the quality, budget, and stock of the spare parts.

5.4 Regression Analysis

Subsequently, a regression analysis was performed to produce a prediction model of the strength of the relationship between the variance of maintenance cost and the contributors of spare parts management. According to the correlation analysis result, the predictors of maintenance cost variance (MCV) included quality of spare parts (QSP), budget allocation for management of spare parts (BSP), and stocking of spare parts (SSP). The regression model for this research is produced below:

Model 1 (Enter Method)

\[
MCV = 6.308 - 0.490 \text{QSP} - 0.184 \text{BSP} - 0.031 \text{SSP}
\]

Coefficient of multiple regression, \(R^2 = 0.126\) (12.6%)

Nevertheless, the results of the analysis identified that two predictors were not significant with a p-value of more than 0.05 (see Table 4). Therefore, another regression model was produced to eliminate the non-significant predictors, as follows (see Table 5):

Model 2 (Stepwise Method)

\[
MCV = 5.949 - 0.580 \text{QSP}
\]

Coefficient of multiple regression, \(R^2 = 0.116\) (11.6%)

Table 4: Coefficient of Model 1 (Enter Method)

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>95.0% Confidence Interval for B</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td>t</td>
</tr>
<tr>
<td>1</td>
<td>(Constant)</td>
<td>6.308</td>
<td>.686</td>
<td>9.194</td>
</tr>
<tr>
<td></td>
<td>QSP</td>
<td>-.490</td>
<td>.195</td>
<td>-.289</td>
</tr>
<tr>
<td></td>
<td>BSP</td>
<td>-.184</td>
<td>.212</td>
<td>-.101</td>
</tr>
<tr>
<td></td>
<td>SSP</td>
<td>-.031</td>
<td>.233</td>
<td>-.017</td>
</tr>
</tbody>
</table>

Dependent Variable: Maintenance Cost Variance
The assumptions of the multiple regression analysis were then examined. It was found that no multicollinearity problem occurred, where all the tolerance and VIF values of the predictors were more than 0.1 and less than 5 respectively.

These results indicate that only one contributor of spare parts management was a significant predictor in Model 2, namely, quality of spare parts ($\beta = -0.341$, $p < 0.05$). Meanwhile, it was found that 11.6% of the maintenance cost variation could be predicted by the quality of spare parts. The regression analysis results therefore prove that the quality of spare parts is the most influential contributor in maintenance cost performance. Consequently, the selection of good quality spare parts must be emphasised in the maintenance and repair of buildings and services. Building managers are recommended to apply the regression model in planning maintenance strategies. This is because the regression model is able to predict the maintenance cost performance before the implementation of maintenance strategies.

### 5.5 Testing the Applicability of the Regression Model in Practical Life

Since Model 2 was identified as an appropriate model for estimating the cost performance, a case study on a selected office building was conducted to collect data on the quality of spare parts and maintenance cost variance. The respondents’ level of concern towards the quality of spare parts was reflected by the criteria of acquiring spare parts as shown in Table 6; while the maintenance cost variance was reflected by the ratio of actual maintenance cost to planned maintenance cost, as shown in Table 7.

In this case study, the management team of the building had a very high degree of concern regarding the quality of spare parts. The management spent 50% of total maintenance costs on acquiring spare parts with a lifespan of at least two years, achieving a measurement unit score of 4 (refer to Table 6). Meanwhile, the actual and
planned annual maintenance costs of the building were 175,000 and 160,000 Malaysian Ringgit respectively. Therefore, the ratio of the maintenance cost variance was 1.09, with a measurement unit score of 4 (refer to Table 7).

<table>
<thead>
<tr>
<th>Criteria of Acquiring Spare Parts</th>
<th>Level of Concern towards Quality of Spare Parts</th>
<th>Measurement Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest acquisition cost without considering lifespan of spare parts</td>
<td>Very low degree</td>
<td>1</td>
</tr>
<tr>
<td>Lower acquisition cost with little concern on lifespan of spare parts</td>
<td>Low degree</td>
<td>2</td>
</tr>
<tr>
<td>Lower acquisition cost with moderate concern on lifespan of spare parts</td>
<td>Average</td>
<td>3</td>
</tr>
<tr>
<td>Optimal acquisition cost with high concern on lifespan of spare parts</td>
<td>High degree</td>
<td>4</td>
</tr>
<tr>
<td>Longest lifespan without considering acquisition cost</td>
<td>Very high degree</td>
<td>5</td>
</tr>
</tbody>
</table>

The measurement unit score of the predictor was inserted into the regression model for calculation as follows:

\[
\text{MCV} = 5.949 - 0.580 \times \text{QSP} \\
= 5.949 - 0.580 (4) \\
= 3.629 \approx 4
\]

The results showed that the prediction of maintenance cost variance calculated through the regression model exactly matches the scenario in the case study. Therefore, the applicability of this regression model in practical life is validated and confirmed. This result also indicates that a very high degree of concern towards the quality of spare parts is essential in eliminating the issue of over-budgeting.
6. Conclusion

The significance of spare parts management in improving maintenance cost performance was the focus of this paper. The literature review revealed three important contributors of spare parts management in building maintenance, namely, quality of spare parts, budget allocations for the acquisition of spare parts, and level of stocks. However, the ranking analysis showed a lack of concern towards level of stocks by building practitioners. The result of the associative test demonstrated a significant correlation of the three contributors with cost variance. Meanwhile, the regression analysis result emphasised the significance of the quality of spare parts. These results highlight the fact that improper management of spare parts must be avoided to achieve better maintenance performance. In order to avoid unavailability of spare parts, this study recommends that maintenance management set up a spare parts management department for updating stocks frequently. Additionally, management should avoid ad-hoc acquisition of spare parts - as this is always more expensive - and focus on the quality of spare parts instead of selecting spare parts based on lowest cost. In conclusion, the findings and discussion of this research emphasise that selection of good quality spare parts is the most important principle to be practised by practitioners of building maintenance. As mentioned before, in order to ensure the acquisition of good quality spare parts, selection of reliable suppliers is of utmost concern. Finally, this paper proves that effective management of spare parts tends to improve maintenance cost performance. Furthermore, the effective management of spare parts does not only enhance maintenance performance, but also aids organisations in achieving their organisational objectives. This is because positive maintenance performance ensures that buildings and systems operate effectively to support the organisations’ activities.

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