ESTABLISHING RELATIONSHIP BETWEEN CHARACTERISTICS OF PREVENTIVE MAINTENANCE AND COST PERFORMANCE

Au Yong Cheong Peng[1], Azlan Shah Ali[2] and Faizah Ahmad[3]

[1,2,3]Faculty of Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia

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, it is vital to identify the cost characteristics of preventive maintenance, includes scheduled maintenance and condition-based maintenance through literature review. The characteristics of preventive maintenance always affect the maintenance cost performance. Therefore, relationship between characteristics of preventive maintenance and maintenance cost performance must be established to understand and take into consideration in the maintenance planning stage. At the end, the significant relationship will be able to help the industry practitioners in selecting appropriate maintenance strategy with optimal maintenance expenditure, yet improving the maintenance outcome.

Keywords: condition-based maintenance, cost characteristics, maintenance cost performance, Malaysia, scheduled maintenance.

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).

[1] auyongcp@gmail.com

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 comparative study on the maintenance strategies is necessary to control the maintenance performance, especially the maintenance cost.

COST CHARACTERISTICS OF SCHEDULED MAINTENANCE

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:

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. 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.

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. 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.

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.

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.

COST CHARACTERISTICS OF CONDITION-BASED MAINTENANCE

Condition-based maintenance is aimed to minimise the total maintenance cost by collecting and gathering the condition data of the building systems, especially those critical components. However, the maintenance strategy might not be applicable to all building systems or assets in terms of the availability of such maintenance technology and cost effectiveness (Horner et al., 1997). The characteristics of condition-based maintenance toward maintenance performance are stated below:

Skilled Manager
This maintenance strategy requires vigorous analysis on the data and information of systems condition and reliability, as well as financial maintenance data. Meanwhile, building managers must have proper understanding on the failure modes and rates, asset criticality, and other significant factors while implementing condition-based maintenance (Ellis, 2008). Thus, a skilled manager is required to ensure the success of the maintenance strategy.

Monitoring Equipment and Technique
According to Edward et al. (1998), there is a wide range of techniques to examine the condition of specific items or assets, such as oil analysis, vibration monitoring, thermography and so on. Specific measuring and monitoring equipments are required by expertise to perform the maintenance tasks. The tools might be complicated and costly for an organisation (Carnero, 2006). Therefore, the availability of monitoring equipments and capability of the maintenance personnel to use the equipments should be taken into consideration for condition-based maintenance.

Acquisition of Data and Information
Bevilacqua and Braglia (2000) argued that the data and information acquisition systems are the necessary applications to perform condition-based maintenance. The documentation and record of information are essential to ensure the reliability of information about the conditions and remaining lifetime of system components. Ali (2009) further explained that the conditions of buildings and systems must be considered to allocate adequate maintenance cost. Thus, the maintenance personnel should acquire the data and information regarding the conditions of building system components.

Frequency of Monitoring and Inspection

Condition-based maintenance can only be implemented with proper system monitoring and inspection. Hameed et al. (2010) demonstrated that planning of appropriate maintenance activities prior to failure and maintenance cost is greatly influenced by the ability to monitor and inspect the condition of systems. Thus, it is necessary to identify the optimal frequency of monitoring and inspection, so that condition-based maintenance can improve the performance in term of cost-effectiveness.

RESEARCH METHODOLOGY

This research was conducted through literature review in early stage. The cost characteristics of scheduled and condition-based 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 strategies 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 results were produced by using SPSS to show the relationship between characteristics of maintenance strategies and maintenance cost performance.

FINDING

In this research, the number of valid return questionnaires was 120, which is 30 per cent of the total research population. Thus, the results were able to represent the research population.

Table 1: Job title of respondents

Job Title	**Frequency**	**Percentage (N=120)**
Building Manager	57	47
Building Executive/ Supervisor	43	36
Building Technician	12	10
Others	8	7
Total	**120**	**100.0**

Table 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.

Table 2: Correlation between characteristics of scheduled maintenance and maintenance cost performance

Characteristic	**Maintenance Expenditure Variance**
Skilled Labour-Skill and Knowledge	**-.417****

Skilled Labour-Number of Labours	-.182
Spare Part and Material-Level of Stock	**-.255***
Spare Part and Material-Quality	**-.327****
Predetermined Maintenance Interval-Length of Interval	**.301****
Failure and Maintenance Downtime-Amount of Downtime	**.207***

**. 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 2, 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 2). 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 2). Hence, the statement of De Silva and Ranasinghe (2010) was supported, 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 2). The correlation analysis result supported 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 2). The statement of Chareonsuk et al. (1997) was supported, 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.

Table 3: Correlation between characteristics of condition-based maintenance and maintenance performance

Characteristic	**Maintenance Expenditure Variance**
Skilled Manager-Skill and Knowledge	**-.276****
Equipment and Technique-Availability	**-.350****
Equipment and Technique-Capability to Adopt	**-.240***
Acquisition of Data-Reliability	**-.394****
Monitoring and Inspection-Frequency	-.138

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

In condition-based maintenance, skilful and knowledgeable maintenance manager is needed for allocating appropriate manpower, providing training, monitoring the system conditions, as well as supervising the execution of inspection and maintenance works. The analysis result as shown in Table 3 stated that the level of manager skill and knowledge was significantly correlated to the maintenance expenditure variance. Condition-based maintenance is meant to prevent system failure by monitoring the system condition and restoring the system to its required standard before failure occurs. When a manager does not have sufficient skill and knowledge to adopt the condition-based maintenance effectively, defects and failures are likely to occur. Thus, additional maintenance cost will be required for the repair works. As a result, the exact maintenance expenditure varies from the planned maintenance expenditure.

Additionally, the availability of condition monitoring technology may help to improve the maintenance outcome. It was found that the availability of equipment and technique significantly correlated to the maintenance expenditure variance (see Table 3). Since Tsang (1995) mentioned that the availability of reliable monitoring and inspection technology is one of the factors to be concerned in condition-based maintenance, the selection of monitoring equipment and technique must be suitable for the monitoring and inspection of building systems. Therefore, the probability of system failure is minimised. The maintenance expenditure variance is prevented as well because emergency repair cost is reduced.

Meanwhile, specific monitoring and inspection tools and equipment require the expertise to operate and use them in condition-based maintenance. The capability to

 ISBN: 978-1-84219-840-7 .

adopt equipment and technique was found to be significantly correlated to the maintenance expenditure variance (see Table 3). According to Carnero (2006), it is complicated and costly for an organisation to acquire the condition monitoring tools and technology. If yet, the maintenance personnel are not capable to utilise those tools and technology, more maintenance issues might be occurred. Additional maintenance cost will be needed to solve the problems. Therefore, the exact maintenance expenditure varies from the planned one.

Furthermore, system condition data and information is one of the most important aspects to be considered in condition-based maintenance. In this maintenance strategy, the maintenance tasks such as replacement works are implemented when the parts are almost end of their lifetime by referring to the condition data. The reliability of data and information was found to be significantly correlated to the maintenance expenditure variance (see Table 3). The primary aim of condition-based maintenance is to prevent failure occurs by monitoring the condition of building systems. Basically, emergency repair cost will not be allocated in planning stage of this maintenance strategy. However, when the obtained system condition data is not reliable and accurate, the occurrence of sudden breakdown may not able to be avoided. As a result, additional maintenance expenditure is required for the repair work and it varies from the planned maintenance expenditure.

CONCLUSION

The significance in selecting appropriate maintenance strategies to improve maintenance performance should be emphasised in maintenance management. Through examination of literature, the characteristics of scheduled maintenance and condition-based maintenance were found to be directly influencing the maintenance cost performance. Therefore, it is important to understand the influences of the characteristics in whole maintenance process, which is from planning to outcome of maintenance. In this research, the Spearman's rank correlation coefficient detected significant correlation between characteristics of maintenance strategies and maintenance cost performance. Thus, those significant characteristics as stated below should be taken into consideration in planning and execution of maintenance program:

Characteristics of scheduled maintenance:

(a) Level of skill and knowledge of labour
(b) Level of stock of spare part and material
(c) Quality of spare part and material
(d) Length of predetermined maintenance interval
(e) Amount of maintenance and failure downtime

Characteristics of condition-based maintenance:

(a) Level of skill and knowledge of manager
(b) Availability of equipment and technique
(c) Capability to adopt the equipment and technique
(d) Reliability of system condition and maintenance data

As a conclusion, the research result would allow the practitioners, such as maintenance personnel or organisation to be clear on which aspect of maintenance strategies they should concern in maintenance activities to improve the maintenance cost performance.

REFERENCES

Ali, A. S. (2009). Cost Decision Making in Building Maintenance Practice in Malaysia. *Journal of Facilities Management,* 7**,** 298-306.

Ali, A. S., Kamaruzzaman, S. N., Sulaiman, R. & Au Yong, C. P. (2010). Factors Affecting Housing Maintenance Cost in Malaysia. *Journal of Facilities Management,* 8**,** 285-298.

Bevilacqua, M. & Braglia, M. (2000). The Analytic Hierarchy Process Applied to Maintenance Strategy Selection. *Reliability Engineering and System Safety,* 70**,** 71-83.

Carnero, M. C. (2006). An Evaluation System of the Setting up of Predictive Maintenance Programmes. *Reliability Engineering and System Safety,* 91**,** 945-963.

Chareonsuk, C., Nagarur, N. & Tabycanon, M. T. (1997). A Multicriteria Approach to the Selection of Preventive Maintenance Intervals. *International Journal of Production Economics,* 49**,** 55-64.

De Silva, N. & Ranasinghe, M. (2010). Maintainability Risks of Condominiums in Sri Lanka. *Journal of Financial Management of Property and Construction,* 15**,** 41-60.

Edward, D. J., Holt, G. D. & Harris, F. C. (1998). Predictive Maintenance Techniques and Their Relevance to Construction Plant. *Journal of Quality in Maintenance Engineering* 4**,** 25-37.

Ellis, B. A. (2008). Condition Based Maintenance. *The Jethro Project***,** 1-5.

Groote, P. D. (1995). Maintenance Performance Analysis: A Practical Approach. *Journal of Quality in Maintenance Engineering,* 1**,** 4-24.

Hameed, Z., Ahn, S. H. & Cho, Y. M. (2010). Practical Aspects of a Condition Monitoring System for a Wind Turbine with Emphasis on its Design, System Architecture, Testing and Installation. *Renewable Energy,* 35**,** 879-894.

Horner, R. M., El-Haram, M. A. & Munns, A. (1997). Building Maintenance Strategy: A New Management Approach. *International Journal of Quality in Maintenance,* 3**,** 273-280.

Moghaddam, K. S. & Usher, J. S. (2010). Optimal Preventive Maintenance and Replacement Schedules with Variable Improvement Factor. *Journal of Quality in Maintenance Engineering,* 16**,** 271-287.

Narayan, V. (2003). *Effective Maintenance Management: Risk and Reliability Strategies for Optimizing Performance,* New York, Industrial Press Inc.

Seeley, I. H. (1987). *Building Maintenance,* New York, Palgrave.

Tsang, A. H. C. (1995). Condition-Based Maintenance: Tools and Decision Making *Journal of Quality in Maintenance Engineering,* 1**,** 3-17.

Yang, S. K. (2004). A Condition-Based Preventive Maintenance Arrangement for Thermal Power Plants. *Electric Power Systems Research,* 72**,** 49-62.

Zuashkiani, A., Rahmandad, H. & Jardine, A. K. S. (2011). Mapping the Dynamics of Overall Equipment Effectiveness to Enhance Asset Management Practices. *Journal of Quality in Maintenance Engineering,* 17**,** 74-92.