Post-print version: Au-Yong, C. P., Ali, A. S., & Ahmad, F. (2014). Predictive Maintenance: Monitoring Tools and Equipment. *The Malaysian Surveyor, 49*(1), 6-11.
http://rism.org.my/ISMDoc/49.1/FlipPage/book.swf

Predictive Maintenance: Monitoring Tools and Equipment

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Abstract

Due to low service quality of maintenance management, high maintenance cost becomes a common issue in building industry of Malaysia. Lack of preventive measure is the problem that resulting poor maintenance performance. So, condition-based maintenance is introduced to improve the maintenance performance. Monitoring tools and equipment is seen as an important factor to ensure the efficiency of condition-based maintenance. So, this paper aims to determine the aspects of monitoring tools and equipment to be concerned in building maintenance, as well as to establish the relationship between the aspects and maintenance cost performance. A quantitative approach is adopted and performed through questionnaire survey. Furthermore, descriptive analysis and correlation analysis are used to analyse the research data. The literature review determines three aspects of monitoring tools and equipment to be considered in maintenance management. Furthermore, the research result demonstrates that the budget allocation for acquisition of monitoring tools and equipment, capability to operate the tools and equipment, as well as availability of the tools and equipment are significantly correlated to the maintenance cost variance. The research recommends the maintenance management to convince the clients or organisation to acquire advanced monitoring tools and equipment for implementation of condition-based maintenance. Besides that, provision of training is encouraged to ensure that the maintenance personnel are able to utilise the tools and equipment.

Keywords: Monitoring tools and equipment; availability; capability to operate; condition-based maintenance; cost performance

1. Introduction

High maintenance cost becomes a common issue in construction industry nowadays (El-Haram & Horner, 2002). The main reason of this issue is low service quality of maintenance management in Malaysia (Ruslan, 2007; Kamaruzzaman & Zawawi, 2010). In fact, lack of preventive measure is currently the problem that implicates poor maintenance performance. Thus, introduction and implementation of preventive maintenance is highly recommended to solve the issue high maintenance cost (Au-Yong et al., 2013a).

Condition-based maintenance, as one of the strategies of preventive maintenance, is noted as the most advantageous strategy compared to others (Ugechi et al., 2009). It is defined as the maintenance initiated as a result of knowledge of the condition or significant deterioration of an item or component through continuous monitoring and routine inspection to minimise the total cost of repairs (Kelly & Harris, 1978; Seeley, 1987; Horner et al., 1997; Ellis, 2008; Flores-Colen & De Brito, 2010).

Generally, condition-based maintenance involves continuous condition monitoring of system and components in order to detect the deterioration of the components and predict their lifetime (Mann et al., 1995; Tsang, 1995). It requires vigorous analysis on the data and information of systems condition and reliability, as well as financial maintenance data. Thus, available of monitoring tools and equipment are compulsory for implementing the maintenance strategy. Whereby, the tools and equipment assist the maintenance personnel in determining the condition of building systems and allow them to predict mechanical breakdown (Davies, 1995; Edward et al., 1998). This requires an adequate allocation of manpower and training on correct methods for the use of monitoring tools, data acquisition and processing, as well as data interpretation (Mann et al., 1995).

Through continuous conditions monitoring, the maintenance strategy attempts to reduce or even avoid unnecessary maintenance expenditures by performing maintenance tasks only when there is evidence of abnormal behaviours of a component or system (Jardine et al., 2006). Hence, the components will be used up to almost their full lifetimes (Hameed et al., 2010). The effectiveness of the maintenance

strategy is significantly affected by the use of tools and equipment for condition monitoring.

Taking into cognizance the significance of monitoring tools and equipment in implementation of condition-based maintenance, this paper aims to identify the aspects of monitoring tools and equipment to be concerned be the maintenance management, as well as to establish the relationship between the aspects and maintenance cost performance.

2. Monitoring Tools and Equipment

Condition monitoring technology has matured at an explosive rate in recent years (Mann et al., 1995). The technology involves the tools and technique to track and record the condition of building systems (Davies, 1995; Edward et al., 1998). Other than being used to monitor the performance of building and systems, the technology is able to initiate and record maintenance operations and to evaluate their effectiveness (Wood, 2005). One of the reasons that condition-based maintenance becomes well recognised is the rapid advancing of the monitoring technology.

Building inspection or condition monitoring is categorised into two methods, which are intrusive test and non-destructive test. Intrusive test is carried out with sample of materials that are obtained from the building or building systems. However, the test may affect the performance of building systems by disturbing the components, structures, or materials of buildings. Thus, non-destructive test is recommended in building inspection nowadays. Non-destructive test is performed to evaluate the properties of materials and performance of systems without causing damage. There is a wide range of techniques used and applied in non-destructive test. By implementing condition-based maintenance, the system and components can be monitored via non-destructive testing (Mann et al., 1995). This can significantly eliminate the system downtime.

Basically, there are several factors to be concerned in selecting the parameters to be monitored (Tsang, 1995). The factors are type of services and facilities to be covered, availability of reliable monitoring and inspection technology, budget allocation in instrumentation and training, manpower requirement and operating costs. According

to Edward et al. (1998), there is a wide range of techniques to examine the condition of specific items or assets. Infrared thermography, vibration monitoring, tribology are some examples of technologies and techniques adopted in condition-based maintenance.

However, some specific measuring and monitoring equipments such as scanning equipment, are required by expertise to perform such technologies and techniques. This might be complicated and costly for an organisation (Carnero, 2006). Knowledgeable maintenance personnel are required to perform the maintenance tasks by adopting condition monitoring techniques (Ellis, 2008). Due to the increase in the technical complexity of building systems and the level of sophistication of monitoring tools, the need for training to use and operate the monitoring tools also increases (Veldman et al., 2011). Moreover, Hassanain et al. (2011) demonstrated that an organisation should gain new skills and technical knowledge in maintenance management, so that the maintenance personnel will be able to develop themselves for adaptation of advanced and new monitoring techniques.

In fact, high effort for condition monitoring tools, hardware and software are required for different monitoring techniques (Hameed et al., 2010). It is expensive to implement condition-based maintenance at the inception stage, especially to acquire the advanced monitoring tools and equipment. In order to enhance the effectiveness of condition-based maintenance and to improve the maintenance performance, there are several aspects of monitoring tools and equipment that should be taken into consideration for condition-based maintenance as shown in Figure 1.

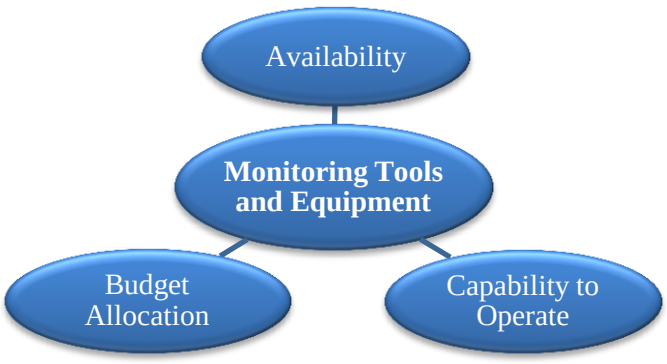

Figure 1: Aspects of monitoring tools and equipment

3. Maintenance Performance

Development of performance measurement in management is to improve quality and service, as well as meeting 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 performance is calculated using variance of actual expenditure and planned cost for building maintenance activities (Ali, 2009). 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. Since the rising maintenance cost is one of the major issues concerned by the industry and public, the cost performance is concerned in this research.

4. Research Methodology

This research adopted quantitative approach with reference to the research undertaken by (Ali, 2009). In order to get a high response rate, the questionnaire should be short and simple. It would not take much time for the respondents to answer too. So, close-ended questions were drafted in 5-point Likert scale and multiple choices. Simple random sampling was adopted to identify relevant respondents who have been or are currently involved in building maintenance management in Klang Valley, Malaysia. Furthermore, the respondents were required to answer questions based on their experience or involvement in maintenance management for high-rise office buildings. Meanwhile, the buildings must have a minimum of seven storeys and at least two years old. Questionnaire survey requires a minimum response rate of 30 percent to produce reliable and convincing results (Hoxley, 2008). In this research, a total of 300 questionnaires were distributed to the building manager, building executive and supervisor, technician and other maintenance personnel within Klang Valley. Out of 107 responses, 100 were found to be useful and valid for the analysis. The remaining seven questionnaires were incomplete or invalid for some reasons. Therefore, a response rate of 33 percent was achieved. The demographic profile of respondents is shown in Table 1. 85 percent of the respondents were building managers, executives,

and supervisors. They have considerable expertise in the planning and implementation of the maintenance strategy.

Table 1: Demographic profile of the respondents

Position	Percentage (N = 100)
Building manager	47
Building executive/ supervisor	38
Building technician	9
Others	6

5. Findings and Discussion

Ranking analysis determines the importance of the variables in the research. The mean score (with 1 – not important at all to 5 – very important) indicates the level of importance among the aspects of monitoring tools and equipment in condition-based maintenance as shown in Table 2.

Table 2: Importance level of the aspects of monitoring tools and equipment

Rank	Variable	Mean (N=100)	Std. Deviation
1	Budget allocation	3.28	0.900
2	Capability to operate	3.25	0.796
3	Availability	3.09	0.911

It is found that the budget allocation for acquisition of monitoring tools and equipment is at the highest rank, with a mean score of 3.28. Meanwhile, the standard deviation value of 0.900 indicates the widespread of data and eliminates the issue of biased data. In fact, it is important to have sufficient budget in obtaining required tools and equipment to run condition-based maintenance smoothly. The budget should cover the cost to buy the tools and equipment, as well as the cost to train the maintenance personnel in adopting the condition monitoring technique. Thus, willingness to spend on the tools and equipment required for implementation of the maintenance strategy ensures the success of maintenance process. Eventually, maintenance issues can be reduced and minimised, cost and time for maintenance work are optimised as well. The result supports that the acquisition of monitoring tools is expensive and hence, adequate budget allocation plays an important role in the effectiveness of the maintenance strategy (Carnero, 2006).

Next, the capability to operate the monitoring tools and equipment is ranked second with the mean score of 3.25, and standard deviation value of 0.796. Whereby, capability in using the monitoring tools correctly can improve the quality of maintenance works. It minimises maintenance cost and time, as well as prevents system failure. On the other hand, if the staffs are not capable to utilise the tools, the monitoring system will not be able to indicate the exact condition of system. This will implicate poor outcomes, such as system failure, waste of resources, increase of downtime, and dissatisfaction of clients and users. As a result, the finding confirms that the need of training is highly demanded to ensure the capability of the maintenance personnel in operating the tools and equipment (Veldman et al., 2011).

In addition, the availability of monitoring tools and equipment is at the lowest rank with mean score of 3.09, which is still above 3.00. The data are normally distributed with a standard deviation value of 0.911. In condition-based maintenance, monitoring tools and equipment are necessary to track the system conditions. With the monitoring tools, the maintenance personnel are able to detect the abnormal condition of system. Thus, they will only perform remedial work when defect is detected. This can reduce the maintenance downtime and save cost as the parts are fully utilised until the end of their lifespan. The result further explains the statement of Ugechi et al. (2009) that the condition monitoring is not reliable when the judgement and decisions made by the maintenance personnel only rely on their senses of hearing and sight without proper tools and equipment.

Then, an associative test using Spearman rank correlation coefficient analysis establishes the relationship between the aspects of monitoring tools and equipment and maintenance cost performance as shown in Table 3. In fact, higher concern towards the aspects is likely to reduce the cost variance. Therefore, negative correlation between the aspects and cost variance is expected in the analysis outcome.

Table 3: Correlation matrix between the aspects of monitoring tools & equipment and maintenance cost variance

Variable	**Cost Variance**
Budget allocation	-0.249*
Capability to operate	-0.240*
Availability	-0.350*

*. Correlation is significant at the 0.05 level

In the associative test, null hypothesis is rejected at significance level of 0.05. In other words, the probability of error in rejecting the null hypothesis is 5 percent. The null (H_0) and alternative (H_1) hypothesis are stated as follow:

H_0 – There is no significant correlation between the aspects of monitoring tools and equipment and maintenance cost performance.

H_1 – There is significant correlation between the aspects of monitoring tools and equipment and maintenance cost performance.

The correlation analysis result indicates that the budget allocation for acquisition of monitoring tools and equipment, capability to operate the tools and equipment, as well as availability of the tools and equipment are significantly correlated to maintenance cost variance. Therefore, it rejects the null hypothesis and accepts the alternative hypothesis.

6. Conclusion

The literature review identified three important aspects of monitoring tools and equipment in condition-based maintenance. The result of associative test demonstrates significant correlation of the budget allocation for acquisition of monitoring tools and equipment, capability to operate the tools and equipment, as well as availability of the tools and equipment towards cost variance. The monitoring tools and equipment assist the maintenance personnel in tracking the conditions of building systems and to prevent failure occurs by executing maintenance tasks when necessary. As a conclusion, the use of monitoring tools and equipment helps to improve the maintenance outcome. Lastly, the research recommends the maintenance management to convince the clients or organisation to acquire advanced monitoring tools and equipment for implementation of condition-based maintenance. Besides that, provision of training is encouraged to ensure that the maintenance personnel are able to utilise the tools and equipment.

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