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A Review on Factors Affecting Maintenance Cost of Hospital Facilities

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Abstract: The researcher conducted a literature review on hospital maintenance cost to identify the factors affecting the cost of maintenance in order to maximize the safety, efficiency and state of good repair of hospital equipment and also decrease the total cost of the organization.

Key words: Maintenance, cost, factors, equipment, organization, efficiency

INTRODUCTION

Maintenance (BSI, 2001) is defined as the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in or restore it to a state in which it can perform the required function. Hence, now a day's maintenance management in different organizations become a very important issue which the top managements concentrate more on this topic. In most of the firms, maintenance was not focused as a strategic unit. Hence, maintenance planning was running as a midterm range. However, the strategic role of the maintenance function has recently attracted the researchers and practitioners with the increase in the competition at a global level with the increase of the maintenance cost relative to other costs in the organization.

Maintenance is becoming a critical functional area in most types of organizations and systems including servicing, manufacturing, transportation, etc. It is becoming a major function that effects and is affected by many other functional areas such as production, quality, inventory, marketing and human resources. In this between, healthcare organizations must ensure that their critical medical devices are safe, accurate, reliable and operating at the required level of performance and reliability.

According to increasing the number of population the rate of using the healthcare center's has been augmented also due to industrial development in courtiers, people's standards of living has been improved, subsequently their awareness about the quality and reliability of healthcare increased. Not only most of the governments allocate large amount of funds to construct the hospitals but also private sectors focus on this industry as a reliable business to invest and earn the profits.

In order to provide an incessant level of high quality and efficiency of services, hospitals need to be maintained. Generally, the operation and maintenance cost constitutes about 80% of the total life cycle cost of buildings (Kirk and Dell'Isola, 1995; Flanagan *et al*., 1989).

Focusing on identifying the main key performance indicators in the maintenance of hospital facilities, Shohet identified four key performance indicators to increase the efficiency of hospital maintenance.

These indicators include performance management, composition of labor, efficiency of maintenance and organizational effectiveness. The study concluded that these key performance indicators could be used in the maintenance of other types of buildings (Shohet *et al*., 2003).

In order to provide a continuous level of high quality services, hospitals need to be maintained. Generally, the operation and maintenance cost constitutes about 80% of the total life cycle cost of buildings (Kirk and Dell'Isola, 1995; Flanagan *et al*., 1989). Therefore, it is important to know the factors that affect the maintenance cost of hospitals so as to develop methods and strategies to control the ultimate cost of maintaining the hospitals and ultimately increase the intended benefits both to the public and private sectors.

Therefore, it is crucial to investigate the factors affecting the cost of equipment of hospital. Objective of this study is to address the factors affecting the cost of hospital facilities.

Literature review

Maintenance management models: According to literature, there are few types of maintenance strategies applied in organizations which can be categorized in the following manner.

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Corrective maintenance (Wang and Zhang, 2013): It is done on the network that are necessary to alleviate or remedy incidences that disrupts services if preventive activities are ineffective or technically unfeasible, corrective activities should be applied for certain failure modes. Possible corrective actions are:

Non-programmed maintenance activities: It is occurred when there is no preventive actions are done in lower costly compared with probable failure mode effects. It also assumed as the decision to wait for an act or failure in a helpful manner.

MATERIALS AND METHODS

Redesign: Are-design will be necessary for situations in which preventive actions cannot reduce the consequences of a failure mode to an acceptable level.

Preventive maintenance (Leflar, 2001; Umeh, 1995): A set of prearranged routines carried out on network elements in order to optimize their performance and reduce the reoccurrence of incidence. A time and state dependent PM policy for a multistage Markovian deteriorating system is proposed by El-Haram and Horner (2002). Besides, a PM policy with consequent checking process is suggested by Hassanain *et al.* (2013) for a Markov deteriorating system. A Bayesian theoretic approach has been considered by Shohet (2003) to provide the optimal adaptive PM policy with slight repair. Furthermore, a Bayesian theoretic approach is used by Ali (2009) and Flyvbjerg (2009) to provide an optimal adaptive PM policy with slight repair.

In the manufacturing industry, McKone and Weiss (Horner *et al*., 1997) proposed some detailed guidelines presented in using predictive care. They believe that specialists should follow these guidelines in order to utilize scheduled maintenance with new technologies and try to account for traditional maintenance methods. Christian and Pandeya (1997) proposed a comprehensive predictive replacement model related to the dynamic programming.

On the other hand, Zhao (Horner *et al*., 1997) proposed the degradation ratio to show the imperfect effect that the system began a new failure process after PM action. The PM policy is suggested for a degradation system which have a suitable level of consistency. Christian and Pandeya (1997) indicated the effectiveness of an developed method through genetic algorithm and Monte Carlo simulation (with APLAB programming tool) for decreasing the PM cost of parallel systems sequences based on the time dependent Birnbaum key factor. Assaf *et al.* (1996) showed the development of a model through the choosing of a unique interval to minimize the cost per unit time of PM and inspection. Furthermore, Assaf *et al.* (2002) proposed a control policy anywhere the system was substituted as a factor that enters a PM suitability or low state. There are several steps that lifetime of each factor is explained such as doubtful, good and PM suitability or low state. A statistical decision and analysis approach is proposed by Shabha (2003) that uses consistency techniques to explain the PM best periodicity of power system protective transmits.

As per studies between 1997-2001, Salameh and Ghattas (Hammad *et al*., 1997) determined the level of Just-In-Time (JIT) buffer by balancing the cost per unit time against the lack of cost per unit time so their total is retained at a minimum which is showed for a production unit subjected to common PM. Mohammed and Hassanain (2010) proposed a recurring PM of a system with deteriorated factors. Therefore, an age decrease model corrupted the factors behavior as genetic algorithm was utilized to choose the best activity mixture at each PM.

Hua *et al.* (2005), Pintelon and Puyvelde (1997) proposed an easy-to-use state related PM policy which is reliable in the production setting. Their findings showed that PM activity improving could leads to lower the total estimated Work-In-Process (WIP) record exclusive for the lower unintended downtime accounting. Hastak and Baim (2001) develop optimal PM strategies in intermittently setting. Chan *et al.* (2004) reported the sequel method application to control when to carry out the optimal policy on PM action for an replace the engine.

Ben-Daya and Alghamdi (Colen and Lambrecht, 2012) presented two sequential PM models. In the first, the age reduction of the system is assumed to depend on the level of PM activities, while in the second, the PM intervals are defined in such a way that the hazard rate is similar for all. Hsu (El-Haram and Horner, 2002) addresses the joints effects of PM and the replacement policies on a queue-like production system with minimum repair at failures.

Gupta and Al-Turki (Hassanain *et al*., 2013) discussed adapting the JIT manufacturing systems to PM interruptions. Shohet (2003) presented an approach to generate an adaptive PM schedule which maximizes the net savings from the PM subject to workforce constraints.

Condition based maintenance actions: The most of preventive care activities are based on conditions of equipment, since the fact that it is incapable of changing

immediately when failure occurs. However, they track a particular constant weakening procedures regularly during a time period. Therefore, a potential failure can be a particular physical equipment condition shows a functional failure that is occurred in or during the procedures.

In order to predict the reliability of condition-based maintenance systems, Saranga and Knezevic (El-Haram and Horner, 2002) used the Reliability Condition Predictor (RCP). Markov models were used in this methodology to predict the reliability. A condition-based maintenance model with exponential failures and fixed inspection intervals for a two-unit system in series has been discussed by Umeh (1995). Leflar (2001) used Weibull Law as the best maintenance method through comparing CM, conditional PM and systematic PM.

Scheduled restoration actions: Scheduled restoration actions are regular activities for restoring an amount of an item such as part, system and equipment to its original situation. The time interval between two consecutive scheduled actions are shorter than the operative life limit of the item part should be restored. To avoid the probable failure modes, some actions happen throughout preventive maintenance action. Items will be put aside after being taken out of service and being unarmed. Afterwards, they will be generally inspected. Then, if necessary, they will be corrected and replaced. Scheduled restoration tasks are usually identified as "overhauls" in large systems or equipment cases and they are mutual in equipment includes engines, compressors, turbines, broiler and furnaces. Restoration contains of distinctive actions includes restoration, adjustment, inspection, cleaning, improvement and even replacement.

Scheduled replacement actions: Scheduled replacement actions concern more on replacing a used item part with a new one. The operative life limit of the item part that should be replaced is longer than the time interval between two consecutive replacement actions. Generally, simple items are replaced (discarded) while more complicated ones are restored.

Revisions searching for hidden faults: Under normal operation conditions, the hidden fault modes will not be obvious. For reducing the possibility of hidden faults, periodical checks are required so that it can show if hidden tasks are working properly which are called as revision tasks for hidden faults.

Predictive maintenance: Based on condition (Colen and Lambrecht, 2012). A set of analysis aimed at estimating the occurrences and behaviors of incidences.

Proactive maintenance (Fernandez and Marquez, 2012; Rausand, 1998): A set of activities that are designed to detect as well as correct, an incidence prior to its occurrence and also avoid its effects within the network and services.

Perfective maintenance: In order to continue the incessant enhancement (Christian and Pandeya, 1997) this type of activities are included within a set of projects that are normally designed after the start of the operational phase of a distribution network. Their scope is to enhance network performance and/or maintainability as well as the provided services. Other researchers refer to these activities as "design-out maintenance" (BSI, 2001).

Braglia and Bevilacqua (Flanagan *et al*., 1989), unlike Shohet *et al*. (2003) consider maintenance strategy as a combination of elements such as backup equipment, maintenance policies and equipment upgrades. They also consider each maintenance policy as a separate strategy. Flanagan *et al*. (1989) provided examples of maintenance strategies as improving responsiveness, maximizing asset utilization and focus on developing core competencies. Furthermore, Wireman (2005) identified four strategic dimensions of maintenance:

- Organization and work structuring
- Support systems
- Service-delivery options
- Maintenance methodology

Review of maintenance costs: There is very few literature focused on factors affecting the maintenance cost of hospitals. However, Umeh (Herbaty, 1990) presented a method for closer integration and coordination between various governmental agencies involved in funding of hospital facilities. The financing scheme includes the operation and maintenance of hospitals. El-Haram and Horner identified 24 factors affecting housing maintenance cost (Fernandez and Marquez, 2012). To distinguish the most important factors he has conducted a survey among 50 local authority and housing association. The study concluded that "high tenant expectations", "budget constraints", "improper use of property" and "right-to-buy policy" plays the most important factors. Al-Khatam conducted a literature review on the factors affecting the cost of maintenance in constructions (Rausand, 1998). He has classified the 34 factors in to seven major groups as "engineering services", "labor", "building materials", "environment", "management and administration," "budget and finance" and "building user behavior (Fig. 1)".

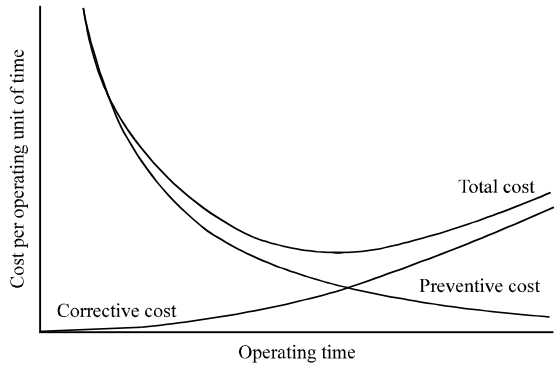

Fig. 1: Cost operating unit per operating time

According to the literature review, it was concluded that the crucial factors affecting the maintenance cost are: absence of local material standards and specifications, concern about the initial cost by owners, poor supervision and management of maintenance projects, poor scheduling, absence of standardized maintenance contracts and faulty design and construction. According to Shohet (Moore, 1998) has determined performance management, composition of labor, efficiency of maintenance and organizational effectiveness are the four key performance indicators to increase the efficiency of hospital maintenance. Ali (Vagliasindi, 1989) conducted a survey of 200 building managers on the factors affecting the cost of building maintenance.

These factors include "existing building condition", "building age", "complaints received regarding building performance", "client's request", "availability of funding", "safety and health requirements". Eventually the study has summarized that "condition of building" and "complaints received about building performance" are the most critical factors affecting the maintenance cost. Flyvbjerg (2009) indicated that planning of major infrastructure projects usually carries out some faults in it. Projects are usually completed with time and cost overruns and benefits shortfalls. Wang and Zhang (2013). The main reasons for this situation are honest mistakes, unexpected events, forecasting errors and deception.

RESULTS AND DISCUSSION

Factors affecting maintenance cost of hospital facilities: In this study, it is aimed to review the factors affecting maintenance cost of hospital facilities. According to different literatures, 17 factors identified which has been categorized in seven main groups as follow: design phase, construction phase, managerial phase and financial phase and maintenance staff (Fig. 2).

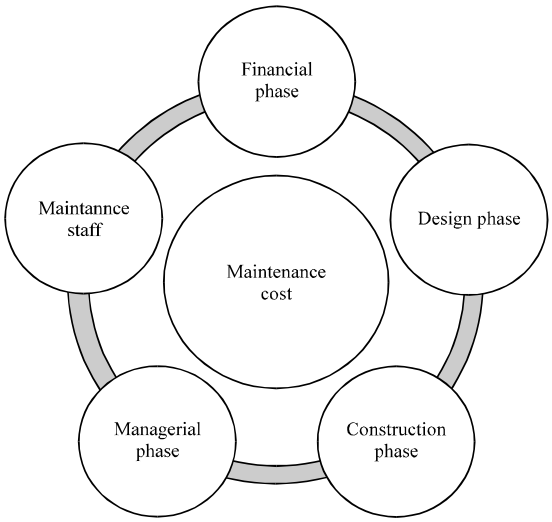

Fig. 2: Maintenance cost groups

Financial phase

Delay in payment: Delay in payment of maintenance has absolutely negative impact to worker and suppliers for material. Moreover, it may cause some problems for contactors to borrow funds from lending institutions at high interest rate.

Insufficient credit and finance allocated: For maintenance activities. The amount of credit and finance which should be allocated to do the maintenance job should be based on the condition and sufficient. According to Horner the maintenance manager usually complain about lack of good policy on this matter (Leflar, 2001).

Lack of failure forecast the maintenance expense: According to Christian, since maintenance expenses will carry out in future, the approximate cost of maintenance should be calculated to understand how much benefit it has for doing maintenance. However, the estimation might be inaccurate due to different unpredictable factors (Umeh, 1995).

Inflation of maintenance cost: Inflation is one of the facts of markets which cannot be eliminated and it is not under control of facility managers. Since, maintenance have some effects on the cost of labor and equipment, it might have direct effect on the cost of maintenance (El-Haram and Horner, 2002).

Design phase:

Lack of main maintainability analysis: Maintainability analysis during the design phase has direct effect on the prevention of future building defects (Hassanain *et al*., 2013).

Failure to consider life cycle costing analysis: Life cycle cost analysis usually not consider at design phase which might have results in ignoring the future cost of operation and maintenance of the facility (Shohet, 2003).

Quality of materials: The selection of the quality of the materials which would be used in the organization is important that not to be damage soon (Ali, 2009).

Errors conducted during the design phase: The effects of errors which would be conducted during the design phase cannot ignore which may have effects on construction and operation and maintenance of the facilities ultimately it may cause some reworks (Flyvbjerg, 2009).

Lack of feedback from the maintenance group to the design team: According to Mohammed and Hassanain Communication between design group and maintenance is an important issue to solve the problems before running the system and decrease the maintenance cost (Mohammed and Hassanain, 2010; Hua *et al*., 2005).

Construction phase

Lack of quality control measures during the installation of systems: Quality control is one of the important phases of the installation of the system which should be done properlywith the experts. In fact if this stage of work will not check deeply, the cost of maintenanceafter running the system would be increase (El-Haram and Horner, 2002; Pintelon and Puyvelde, 1997).

Lack of coordination between the construction and maintenance groups: Coordination between design phase, construction phase and operation and maintenance groups would be diminish the cost of maintenance (Assaf *et al*., 1996).

Faulty construction: Utilizing poor material and low quality would have direct effect on maintenance and increasing the rework job of organization (Hastak and Baim, 2001). In addition due to lack of quality control and monitoring by experts, after implementing and installing the equipment will increase the costs of maintenance (Chan *et al*., 2004).

Managerial phase

Duration of the maintenance contract: Duration of contract between the organization and the maintenance group could be effect on performance, quality and cost of agreement. According to Hassanain believes, since long-term contractors usually would be involved in different projects therefore, it may reduce the costs and increase the quality of maintenance (Hassanain *et al*., 2013). Beside this short duration of maintenance contract would have negative effect on willingness of people in working in maintenance departments.

Poor administration of maintenance management: According to Horner Administration of maintenance department and decisions taken by this department is playing the most important in reducing the costs of maintenance (Horner *et al*., 1997).

Lack of documentation on the maintenance work: Maintenance history of equipment and their documentation will help the expert to make better decision and reduce the future costs (Mohammed and Hassanain, 2010).

Maintenance staff

Shortage of properly trained maintenance personnel: Poorly trained staff of maintenance groups would negative result in performance of defective work (Colen and Lambrecht, 2012).

Lack of awareness about the importance the maintenance: Flyvbjerg described that it is an important that the management of organization highlight the importance of maintenance for the staff whom working in the organization. As much the staff realize the importance of the maintenance and its cost, it could have high effect on correct using of facilities and maintain the equipment (Flyvbjerg, 2009).

Failure to recognize the correct problem: Once the failure has not been identified properly, the defect would be occurring nonstop. Hence, employing the expert technicians for an organization is a critical phase to eliminate the source of problem. Performing the wrong maintenance would have direct result in increasing the maintenance cost (Horner *et al*., 1997).

Reliability centered management: Founded in 1960's, reliability-centered approach was first meant for aircraft maintenance. Since, a decade ago this concept has found its way into industries. It leads maintenance at those parts and units that reliability is a main concern. In sum, 5 studies were conducted on the subject. A developed RCM is administered as integrated CMMS as specified by Christian and Pandeya (1997). The main modules of the improved RCM procedure are recognized and a prototype is used as integrated with the several adopted CMMS modules. A cost enhancing scheduled maintenance interval using computer technology to implement costs as

a lack affects quantitative difficulty (Assaf *et al*., 1996). This gap permits an organization to apply a widespread RCM program efficiently.

Rakowsky and Eisinger (Assaf *et al*., 2002) proposed a probabilistic approach in modeling doubts in RCM. They said that these uncertainties in the RCM process of decision making might be improper in various applications since they will result to non-optimum maintenance approaches. However, Cock and Hipkin (Shabha, 2003) discussed the employment of TPM and RCM in consider to TQM and Business Process Re-engineering (BPR) and indicated how maintenance employment keep on the path of other involvements. Ultimately, Rausand (Hammad *et al*., 1997) proposed structured approach to RCM where its various steps were detailed.

Computerized maintenance management: Now a days this systems are very common in industries that leads to a huge amount of benefits such as reducing costs, increasing productivity and effective use of the labor force (Mohammed and Hassanain, 2010). Primarily these computerized maintenance management systems were utilized on mainframe computers but was moved to micro-computers later (Hua *et al*., 2005). Much different type of such systems now exists commercially to increase the management of maintenance works. However, a list of 60 such software was reported in a survey in 1985 (Pintelon and Puyvelde, 1997) and during the last few years this list has continuously grown. The basic functions of a computerized maintenance management system have been shown in Fig. 3.

Computerized maintenance management systems are common in today's industries. Their use has brought about a large number of benefits that include increased productivity, reduced costs and effective utilization of the labor force (Umeh, 1995). These computerized maintenance management systems were initially used on mainframe computers but this was shifted later to micro-computers (El-Haram and Horner, 2002). A large variety of such systems is now commercially available. A survey conducted in 1985 reported a list of 60 such software (Hassanain *et al*., 2013) and this list has grown very rapidly during the last few years. These systems were installed mainly to improve the management of maintenance works. Figure 3 shows the basic functions of a computerized maintenance management system.

A maintenance maturity grid was proposed by Shohet, 2003 to support the implementation of CMMS. Movel and Leger (Ali, 2009) regards to computer-aided combination of maintenance in enterprises. Prior studies such as Singer (Flyvbjerg, 2009) where in order to

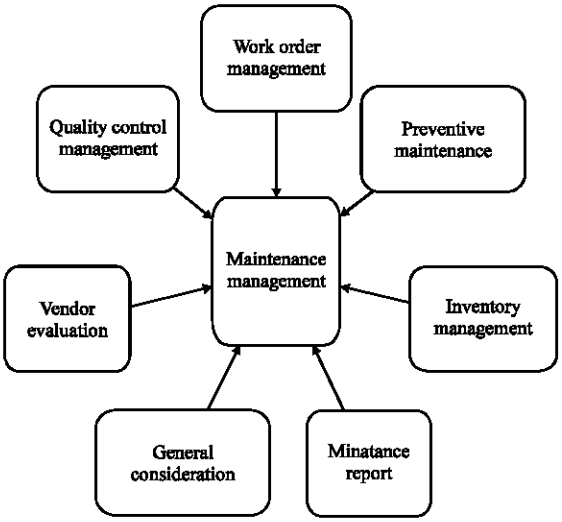

Fig. 3: Basic information of computerized maintenance management system

make use of all the CMMS package features, he proposed a seven-step plan. A formalized decision analysis approach was introduced by Labib based on rule-based and multiple criteria system for determining the poorest machines. Therefore, it can be concluded that the best strategy is the one that enhance the life-cycle benefit. The characteristics and use of CMMS as well as its literature review were detailed by Swanson (Horner *et al*., 1997). Collis and Jones (Christian and Pandeya, 1997) studied the computers assisted in maintenance management and they believe that computers are not used optimally which means that there is considerable potential for future improvement. Wickers (Assaf *et al*., 1996) proposed "front end maintenance analysis" method that has widely been used in industry and efficient in identifying parameters for monitoring situations and obviously indicated the link between maintenance management system and these parameters.

CONCLUSION

A consolidated summary highlighting various factors affecting maintenance cost of hospital facilities. According to the literature reviewed, depending on the hospital either private or public one, impact of the maintenance factors and their effects on whole organization would be changed. The researcher concludes that main reason for difference between facility managers of public and private hospitals on the impact of the so-called factors on maintenance cost include the following.

Private hospitals managers are always focusing on maximizing the total profit of the organization. Hence, they

concern about the performance of the organization as well as reducing the total cost. Moreover, selection the type and duration of contract and agreement between organization and contractors are basically much easier rather than in public sectors. In addition in public sectors, the budget allocated for maintenance is decided by ministry while this can be allocated easily by facility managers in private sectors. Since, the efficiency and effectiveness is an important aim of each organization this could be reach by employee the experts and talented technicians and focusing on maintenance and reduce the rework jobs by control and monitoring the system.

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