STRATEGIC MANAGEMENT FOR OPERATION AND MAINTENANCE COST OF UNIVERSITY OFFICE BUILDING COOLING SYSTEM

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ABSTRACT

The building cooling system is served as important function providing a comfortable environment for building occupants. Indeed, the building cooling system is a demand-oriented with sustainable building management strategy which is desirable for balancing between both building usage and energy demand. At present, the management of the cooling energy building demand often raised concerns on potential reduction of building Operational and Maintenance (O&M) cost. The integration between O&M cost involved was used as a benchmark strategy for building energy-saving potential with regard to high system performance. To address these issues, this study focused at the medium size office building Universiti Teknologi Malaysia (UTM). The present work integrates centralised building cooling system, Heating, Ventilating and Air Conditioning (HVAC) equipment and cooling energy demand loads. The cooling energy data is based on site-measured data collected and engineering-cost analysis. Engineering-cost analysis results demonstrated that the operation and maintenance cost of cooling tower system increased by 3 % per year due to the annual inflation rate. It is considered that method in this study can be applied to provide the guideline for building energy consumption and strategic management cost.

Keywords: Strategic Management, Operation Cost, Maintenance Cost, Cooling System.

INTRODUCTION

Recent world development on industrial-technology economy contributes substantial significant increase in energy consumption. Hence, other factors such as rapid urbanisation and population also become a major factor driving growth for global electrical energy consumption. Aside from rising issues of energy consumption, the environmental concerns on energy usage and the frequent increase of energy consumption costs has become an important and challenging issue in many countries. In this regard, buildings contribute significantly to the overall energy consumption. Current research revealed that energy consumption of buildings account for approximately 40% of the total electrical energy consumption (Gruber et al., 2015). Quantitative studies on building energy consumption showed that projected energy consumption will continually increase for the period of 2010 to 2040 (Li et al., 2018).

The present research raises another contribution to address building energy management issues related with energy efficiency, minimize total building energy consumption and optimised building system with lowest energy consumption. Typically, Building Energy Management (BEM) involved monitoring and controls the energy consumption in buildings. According to

Gruber et al. (2015) the implementation of BEM during building operation time is important to reduce energy consumption and improve energy efficiency. They also stated that by understanding building energy consumption patterns and prediction of BEM creates an opportunity to resolve other issues related building energy consumption issues such as security of supply, environmental and economic. Throughout the BEM strategies, such practices like energy refurbishment and retrofitting have largely become a standard practice due to basic energy and economic efficiency in order to reduce energy dependency and greenhouse gas emissions. The building energy refurbishment and retrofitting are important factors for reducing energy and emissions but do not reward or promote efforts to improve other process improvements (Khairi et al., 2017).

In addition, BEM is an important issue related to operation of Heating Ventilating and Air Conditioning (HVAC) systems due to the growing energy costs and environmental concerns. In building sector, HVAC systems is predicted as the largest energy consumption in building which represent 45% from total building energy consumed. The effective of HVAC system Operation and Maintenance (O&M) procedure involved systematic task and requirements for occupants comfort, HVAC components reliability, efficient HVAC system operation, energy and cost saving potentials. Bory et al. (2007) found that adaptation of HVAC system O&M procedure can enhance operating efficiency of overall HVAC system and can reduce 5 to 20 % of the capital investment and O&M costs.

With this realization, this study conducted on one medium size of university office building with the centralized HVAC system. This scope of study is limited to one study area in order to develop a conceptual framework for evaluating O&M cost from collecting the building specific information, gather information of the centralized HVAC system and evaluate O&M cost within the system. This study primarily addressed the issues related to building energy management with respect to identify a potential of primary cost savings under the O&M cost of centralised HVAC system for Administration office building at Universiti Teknologi Malaysia (UTM). This building were specifically chosen for the important reason that this building will provide the best option for pioneering the implementation of HVAC systems management for university that currently exist. On the other hand, this case study was particularly selected to provide a benchmark for centralised HVAC system performance measurements as representatives under real-working conditions and evaluate the potential energy savings. The results of this study will provide important insights of the O&M cost management of the centralized HVAC system impacts and in assisting forward strategies opportunities to manage HVAC system facilities of other university office buildings with similar specification.

LITERATURE REVIEW

Several studies have accentuated that the exponential increase of building energy consumption reflected on changes in building energy management in terms of energy saving, cost reduction, system efficiency operation and sustainable building management (Soares et al., 2017; Min et al., 2016; Shoubi et al., 2015). Buildings energy consumption is expected to frequent changes in the way how they are used, maintained and refurbished that may affect their energy consumption and supply costs (Gruber et al., 2015).In addition, energy consumption for building cooling system accounts for 57% from total energy consumed in buildings (Rismanchi et al., 2012). Specifically, some studies in Malaysia showed that the average rate of building cooling energy consumption increased by 1.4 % per year (Kubota et al., 2011). The extent of this cooling energy consumption is 60% outpaced from total building energy consumption in Malaysia (Chong et al., 2015; Saidur et al., 2009). This factor, in turns highlighted the key strategy for managing building cooling energy system and addresses the opportunities for energy saving consumptions and cost.

At present, the lack of comprehensive university building energy consumption and the encountered problem have been identified due to the insufficient budget and lack experienced of energy management team. Thus, it is recommended for a series of building energy management is to ensure in direction with a target for university energy-cost saving, hence, enhancement procedure to prevent energy wastage by providing the means to reduce university energy consumption. Building energy consumption management is considered one of the most important aspects that should be conducted in parallel with sustainability university campus. Within this context, the implementation of building energy evaluation will enhance knowledge and awareness for energy and non-energy benefits.

In recent year, numerous studies have highlighted the increasing of Malaysia energy consumption that represents significant impact either cost or management for diverse buildings and specific group such as university. Considering the constant increase of Malaysia energy consumption with predicted annual average of 2,533 Ghw (Muhammad, 2017) there is growing interest for improving energy efficiency at university level. Accordingly, the university buildings energy consumption will gradually increase every year due to its variety building usage and population (Muhammad, 2017). In practice, it is essential to identify main influencing factors such as management and monitoring university energy consumption for university sustainability requirement and reduced building operation and maintenance budget while maintaining occupant comfort. This parallel with the requirement under Ministry of Education (MOE) of Malaysia framework to assure higher educational institution implement energy security and energy saving programs.

The specific context of BEM for university will significantly help energy manager to understand actual energy consumption supported with energy consumption pattern from other electrical equipment and building facilities. At first sight, university building energy cost management might be evaluated based on its demand and consumption cost. This would be laudable but most building facilities such as cooling system should be subjected to driving trend changes in terms of cost for building management in order to facilitate the operations, maintenance and monitoring of building systems. The most important functions of cooling system in office buildings are evidence to increase occupants comfort so that they can work at their optimum performance level. Instead of providing a comfortable environment, building cooling system is a demand-oriented with sustainable building management strategy which is desirable for balancing between both building usage and energy consumption.

In particular, the implications role of building and HVAC system (as building cooling system) energy efficiency strategy is to bridging the gap between the efforts to lowest the energy consumption, reduce energy cost and optimised the cooling system operation. In consequence, it has been identified that one of the main problem of the centralized HVAC system is the cost to run the cooling process and system maintenance cost which opposed to the performance of the system (Gang et al., 2015; Al-Bassam & Maheshwari, 2000). Therefore, the intend to study the centralized HVAC system O&M cost has been coupled with significant finding from previous studies that revealed management of HVAC O&M cost is expected to reduce 10% to 40% of building management cost, retain asset value, increase profitability, improving energy and system operates under optimum conditions (Lecamwasam et al., 2012). In addition, the subsequent impacts on the evaluation of the centralized HVAC system O&M cost is considered as an effective way for efficient building energy management, encourage optimization of system equipment function and increasing the cooling system life expectancy (Iwaro et al., 2015).

Although several attempts have been made to reduce centralized HVAC system O&M cost, however, the evaluation have not always been successful because there are still drawbacks in the existing centralized HVAC system such as uncertainties arising from system operation and degradation. This will increase the risk for unreliable decision making since existing centralised HVAC system are assumed working in ideal conditions based on design conditions. In addition, this study provides additional evidence with respect to current growing issue in centralised HVAC system operation of the main university office building due to the steadily rising of electrical energy cost every year. It is evidence from previous research that over the past 18 years, Malaysia commercial electrical energy cost is estimated with an annual increase of 10 % from 1980 to 2008 (Yusof & Bhattasali, 2008).

METHODOLOGY

Bangunan Canseleri Sultan Ibrahim (BCSI) is the main management office of Universiti Teknologi Malaysia (UTM) and was selected as the study area. The university campus located in Johor Bahru in the Southern part of Peninsular Malaysia. The BCSI building data information is listed in Table 1. The BCSI building is classified as medium-rise office building which consists of three floors with 12,606 m^2 accumulated total floor area. The total coverage of the cooling area is 8288.9 m^2. As stated in Table 1, the university management office operates from Sunday to Thursday and the usage hours of electrical equipment and facilities depend on the daily operating working hours. The average occupancy number per day is about 1200 people and its primary energy consumption is electricity. During this period, the building has an average total electrical energy consumption of 1315,439 kWh per year with the total average building energy management cost of RM 450,000 per year.

The scope of the study was limited to 10 years period from 2008 to 2017. The selection of this baseline period because the building may involve changes, unavailable tool, insufficient data and the information loss due to time lapse between system planning, construction and operation. Information listed in Table 1 is based on three important phases of Building Energy Audit (BEA) procedure which is preliminary building and system characteristics, building walkthrough evaluation and building and system energy analysis of the BCSI building. Building energy audit is the common method for evaluating performance of electrical building systems, understanding patterns in building thermal energy and building electricity consumption. Consequently, it has been proposed for prevailing building condition, assuring the need for building energy efficiency that represents one of the most remarkable aspects for increased building energy performance and reducing electrical energy consumption cost (Sorrell, 2015).

A standard detailed BEA procedure is followed the ASHRAE Commercial Building Energy Audits (ASHRAE, 2011). The building energy audit procedure also involved compiling a schedule of electrical and mechanical system operation, related technical documents, and obtaining on times of occupation and electrical equipment usage. The site survey was carried out to determine building layout and conditions, and size and type of other system and electrical equipment. Thus, the breakdown of different energy consumption by each systems installation such as centralised HVAC system can be determined by knowing basic information in Table 1 using bottom-up methods. In this study, the bottom-up method followed CIBSE TM22 procedure to benchmark the energy consumption of major building systems and identified end uses of individual energy consuming such as energy consumption of building with and without cooling energy (CIBSE, 2012).

Table 1
BUILDING INFORMATION

Parameters	Descriptions
Building Type	Medium-Rise office
Activity	Open Office (Design Max Occup: 10 m^2/person
Total building energy consumption (kWh/year)	3631806
Gross floor area (m^2)	12184
Gross lettable area (m^2)	11807.46
Occupancy rate (%) e.g. 0.80 for 80%	0.8
Weekly building operating hours (hours/week)	40
Building weekly mode operating hours (hours/week)	35

Futhermore, the BEA procedure is applied for centralised HVAC system audit to determine system configuration, system integration process, costs including capital costs, operation and maintenance costs, energy costs and replacement cost. The BCSI centralised HVAC system is broken down into two major subsystems which is chiller and cooling tower. Table 2 summarized the corresponding information of BCSI centralised HVAC system based on the type, number, arrangement of different components and the operational process to meet the building cooling requirements.

Table 2
BSCI COOLING TOWER SYSTEM SPECIFICATION

Cooling Tower Specification	
Number of Tower	1
Type of Cooling Tower	Induced Draft Cross Flow
Number of Chiller	2
Tower Type	3 cell 1 speed motor
Tower Capacity	
System Operation Time	3720 hours / year
System Typical Load	70 %
Operating Efficiency	65 %
Cycles of Concentration	3
System Maintenance and Cleaning	3 times / year

The information collected for centralised HVAC system operation and maintenance focused on subjects of energy consumption, system operation and monitoring, system accessibility and reliability. Table 3 listed a breakdown for operating, occupancy, service, maintenance and replacement costs along with an estimation of cooling energy consumption cost. The listed data in Table 3 are gathered and evaluated based on reviewing system monthly operation and maintenance technical reports and expert discussion. This study used current base costs and the predicted future costs are based on the inflation rate of 4% that is expected to occur at this point in the project life span. The estimation of O&M cost is considered to compromise with electrical energy consumption and the calculation of building energy consumption are based on current Malaysia electricity tariff of RM 0.35/kWh.

Table 3
O&M BASE COST FOR BCSI COOLING TOWER SYSTEM

Cost Element	Current Base Cost
Management (RM)	17, 000
Service &Spare parts (RM)	85, 000
Chemical Treatment (RM)	2, 500
Labor Cost/hr	8.00
Number of Labor	5
Electricity Cost/kwh	0.35
Annual Inflation Rate	4

Based on the case study, different centralised HVAC system operation and energy efficiency measures were calculated and total energy use was derived. The HVAC system energy consumption is calculated using the Equation 1 proposed by Saidur et al. (2009) based on the data tabulated in Tables 1-3. This equation has been used to compare the actual HVAC system energy consumption with the calculated building cooling energy requirement.

$$AEC^a = UH^a \times C^a \times LF^a \quad (1)$$

Where, AEC^a is the annual energy consumption of equipment a in kWh; UH^a the usage hours of the equipment a; C^a the capacity or power rating of equipment a, in kW; and LF the loading factor of equipment a. It was suggested from previous research that the loading factor for all the electrical equipment is set to 1 for a worst-case scenario.

For a comparison, the centralised HVAC system energy consumption can also be determined from the total operations within a year and the operating hours as shown in Equation 2.

$$HVAC\ system \frac{Operation}{year} = Number\ of\ calendar\ days\ \times Number\ of\ operations/day \quad (2)$$

In this study, electrical energy consumption for HVAC system is assumed including an operation of the cooling tower and auxiliary AHU's equipment such as a chiller, condenser, fans, ventilation systems and pumps. This assumption is recommended by Berg et al. (1964) as a good preliminary estimate. They also mentioned that for lack of a specific application, maintenance costs may be assumed equal to the power costs. The current energy cost per year of HVAC system is based on the cooling tower operation and can be calculated using Equation 3.

$$Cooling\ Tower_{Energy\ Cost}/Year \quad = (A/C\ ton)(kW/ton)(load\ factor)\left(\frac{Operation\ Hours}{Year}\right)(cost/kWh)$$

(3)

The cost to maintain the chemicals in the cooling tower as a part of centralised HVAC system maintenance cost is assumed to be proportional to the cooling tower tonnage (Cox, 1996) as stated in Equation 4.

$$Maintenance\ Chemical\ Cost = RM6\ \times \eta_{ch} \times tonnage \times \left(\frac{Number\ operating\ hours}{Annual\ Operating\ Hours}\right) \quad (4)$$

η_{ch} is a correction factor to account for the cost savings associated with a cooling tower operation. Here a correction factor, η_{ch} is assumed and set to 1.0.

RESULTS AND DISCUSSION

The breakdown of BCSI electrical energy consumption and specification O&M cost for BCSI Cooling Tower System is illustrated in Figures 1 and 2, respectively. From Figure 1, the appearance of cooling energy consumption (calculated using Equations 1 and 2) is approximately half of the total building energy consumption. Fracture of the O&M costs for cooling tower is breakdown into total cooling tower energy consumption, cooling tower management, and service, materials and spare parts cost. In addition, the cooling tower management costs including routine costs consists of supervising and labour cost, spare parts and replacement costs and chemical treatment for fouling and corrosion control.

Figure 2 shows that average O&M cost (calculated using Equations 2 and 3) for BCSI cooling tower is RM 14,000 between 9 years of operation and average total building electrical energy cost is RM 52,000. The results for the O&M cost significantly confirm would increase at average 5% annually. This corresponds to an annual consumption cost and thus constitute to the accelerating rising cost. The calculation of Equation 1 is using monthly electrical bill data which is based on electric rate plan or Tariff that includes demand (capacity) charges as well as energy (consumption) charges. A flat electrical power tariff of 30 cent/kWh is used to obtain reference values and show effects of the energy management and remain unchanged throughout study period. Even, the energy consumption cost is not related to a variable electricity tariff, but is mostly associated with occupancy behaviour and density as in agreement with the results reported by Yuan et al. (2016).

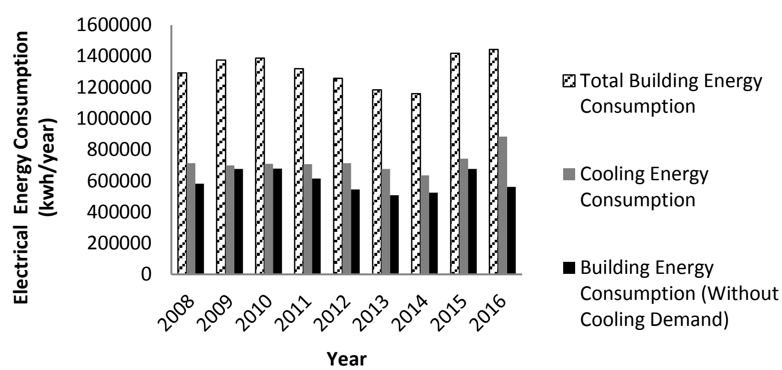


FIGURE 1
COMPARISON OF BCSI ELECTRICAL ENERGY CONSUMPTION FOR 2008 TO 2016

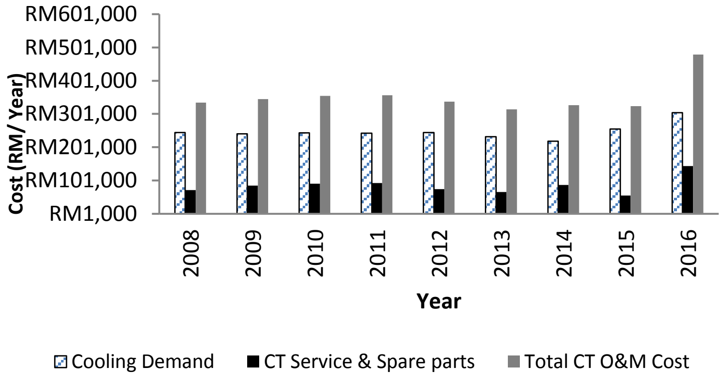
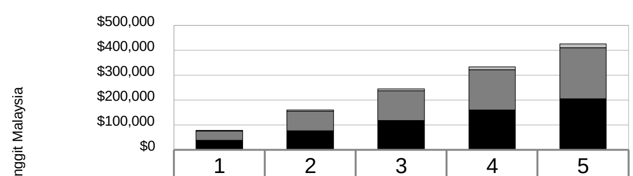


FIGURE 2
BUILDING MANAGEMENT COST FOR BCSI FOR 2008 TO 2016

On the other hand, evidence from the effect of the inflation rate to the total O&M cost (calculated using Equations 3 and 4) is evaluated to gradual increased as shown in Figure 3. The incremental trend for total O&M cost is considered with the inflation rate of 4 % per year. The increasing trend of O&M costs could relate on many parameters, such as labour rates, the experience of the workers, the age of the system, and the length of time of operation as supported by Al-Taqi & Maheshwari (2000).

On the other hand, Buys et al. (2005) revealed that the cost of the electrics and control including labour overheads and profit are found to be between 5% and 10% of the overall building cooling system cost. This is verified from his building costing analysis from three existing projects. The increasing trend in the cooling tower O&M costs is likely largest compared with other system costs and it also depends on chiller size (Buys et al., 2005). Thus, the increasing trend of cooling tower O&M costs will consider having a significant effect on the overall building electrical energy consumption and building energy efficiency require constant maintenance and management to ensure optimal performance of cooling tower. The significantly increased of operation and maintenance cost for centralised HVAC system could be related to persistence of maintenance practice and frequency, and isolated with spare parts and materials cost as supported by Wang (2013). Based on this finding, Wang (2013) argued that different practices of HVAC system maintenance can result in substantial differences in building energy consumption. The increasing of maintenance cost is also thought to be due by a few factors including changes in system operation; material replacement frequency and system life-cycle that need to be further investigate.



	1	2	3	4	5
Chemical Cost	$2,700	$5,508	$8,428	$11,465	$14,624
Tower Maint	$38,010	$77,540	$118,651	$161,406	$205,872
Chiller Maint	$37,700	$76,908	$117,684	$160,092	$204,195

FIGURE 3
PREDICTED 5 YEARS O&M COSTS WITH INFLATION RATE FOR BCSI COOLING TOWER SYSTEM

CONCLUSIONS

This study was devoted to evaluate the centralised HVAC system O&M costs for university office building. The O&M costs are gradually increased every year without and with the inflation rate. The calculated O&M cost for the cooling tower at study building at a cost of about RM 350,000 per year from total building management cost of RM 1 million per year. The cost value is expected to increase by 3% annually. It can be concluded that cooling tower O&M costs can make a substantial impact on the overall annual building management cost. Even some of the results are not comparable between different locations; however, the results of this study still have the advantage of making energy comparisons possible between similar system configurations using the same reference unit. The results of this study showed that there is a need for an improvement in the estimation approach of the cooling tower O&M costs in order to determine the accurate building management cost as a whole. The selected elements of HVAC system O&M cost in this study are related will also reflect the importance of overall building system performance along with investigation on the fault diagnosis and fault adaptive control methods for sub-system of centralised HVAC building system. It should be noted that frequent changes in university building functions, it is also expected with increasing cooling energy requirements and O&M cost to be expended from the university budget for operation of centralized HVAC system each year. Therefore, the finding of this study can be implemented as a benchmark to provide as a guideline for practitioners and building energy managers to gain knowledge of maintaining HVAC systems in efficient operations, and prioritize HVAC maintenance work plan under limited university financial management due to the decreasing allocation budget from government. This study also recommended further investigation to determine maintenance and replacement frequency which depends on the current and future operation of the HVAC system.

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