Developing a Research Framework for Studying Performance Evaluation of Engineering Facilities in Commercial Buildings in Hong Kong

C.S. Man[1], Joseph H.K. Lai[2] and Francis, W.H. Yik[3]

Abstract

The property value of commercial buildings in Hong Kong is in the top tier around the world. Underpinning the proper functioning of these buildings are various engineering facilities, which entail substantial resources for their operation, maintenance and management. In order to assess the effectiveness of such resources input, the performance of the facilities needs to be evaluated but a holistic scheme for evaluating the performance of engineering facilities in existing commercial buildings is yet to be established. This article reports on the initial phase of work of a research study that addresses this issue. Through a comprehensive literature review, a broad range of performance indicators were identified and the indicators have been systematically categorized under five aspects, namely physical; financial; task and equipment related; environmental; and health, safety and legal. On this basis, a research framework comprising four stages of work has been established. In addition to describing the tasks to be undertaken under this framework such as focus group discussion, questionnaire survey and case study, the future works needed are also identified.

Keywords: commercial buildings, engineering facilities, literature review, performance evaluation, research framework.

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[1] PhD student; Department of Building Services Engineering; Hong Kong Polytechnic University; Hung Hom, Kowloon, Hong Kong; m.c.sing@connect.polyu.hk.

[2] Associate Professor; Department of Building Services Engineering; Hong Kong Polytechnic University; Hung Hom, Kowloon, Hong Kong; joseph.lai@polyu.edu.hk.

[3] Professor; Department of Building Services Engineering; Hong Kong Polytechnic University; Hung Hom, Kowloon, Hong Kong; francis.wai-hung.yik@polyu.edu.hk.

1. Introduction

Commercial buildings in Hong Kong are well-known for their high sale and rental values but their values could be eroded by inadequate performance of their engineering facilities, such as air-conditioning, electrical and other installations. On the other hand, substantial amounts of resources need to be input for proper operation, maintenance and management of the facilities and, therefore, the output, viz. the performance of the facilities, needs to be evaluated such that whether the resources are utilized effectively can be measured.

Although there were studies that pinpointed at particular aspects of performance of engineering facilities in existing commercial buildings, e.g. their energy or environmental control performance, few have addressed holistically their performance, which covers a wide variety of operation and maintenance issues. With the objective of establishing a holistic scheme for evaluating the performance of engineering facilities in commercial buildings, a research study is being undertaken and this article reports on the outcomes of the initial phase of the study.

The findings of a literature review are summarized in the next section, which covers the typical range of engineering facilities in commercial buildings; the stakeholders of such buildings; the impetus for having a system that can enable evaluation of the facilities' performance; and the major evaluation tools relevant to the objective of the present study. Also reported in Section 2 are the large number of performance indicators identified from the literature and the categories into which they were classified. Section 3 describes the essential stages of work to be carried out in the study, including the approach for developing a scheme for evaluation of the performance of the facilities. In the concluding section, the key findings of the initial stage of the study and the planned stages of further work are reported.

2. Literature review

2.1 Engineering facilities and stakeholders

The engineering services (facilities) that are essential to buildings include those that provide: energy supply (gas, electricity and renewable sources); fire detection and protection; cooling, heating and ventilation; water supply and drainage; lighting; vertical transportation; refrigeration; communication; security and alarm; etc. (Chartered Institution of Building Services Engineers, 2012). They are means for delivering the services needed by users of buildings, which help maintain a safe, healthy, convenient and comfortable indoor environment suitable for the activities of the building users. Without them, buildings are but inhabitable cells that can hardly fulfil the purposes that they are intended to serve. In addition to the capital input for making available the facilities in the first place, further inputs of resources are needed in the delivery process of the services that the facilities provide, which include human resources, energy and spare parts and materials for their operation and maintenance (O&M) and for management of the O&M processes. The performance of the facilities may be gauged by the quantities of physical outputs that they turn out, such as the amount of ventilation air or cooling delivered or the number of persons transported, against the amount of resources input into the process; the precision and stability of the indoor environmental conditions that they are able to maintain; or the reliability of the facilities in providing the needed services. Nevertheless, the eventual performance of the services delivery process may also be judged by how well the needs of the end users are satisfied (Figure 1). The performance of engineering facilities in buildings, therefore, needs to be assessed from different perspectives. As engineering facilities may change with building function in response to new owner requirements or organisational revolutions (Then et al., 2004) and their performance may be affected by the effectiveness of the on-going management and a variety of endogenous and exogenous factors (e.g. wear and tear, end user demands), assessment of their performance should be a continual process.

Figure 1: Service delivery process of facilities

2.2 Need for a performance evaluation system

Managing the engineering facilities in buildings is a key application of facilities management (FM), which has emerged as a professional discipline that deals with facilities that support the core business of an organization. FM covers a wide spectrum of property and user related functions that may be brought together for the benefit of an organization, by optimizing the efficiency, cost and quality of the support services (Amaratunga et al., 2000).

FM also emphasizes putting in place a performance evaluation scheme to identify and measure the effectiveness of the FM functions. Performance measurement, which enables facility managers to monitor the output quality of the works they manage and to compare and identify any needs for improvement (Kincaid, 1994), is a key management activity that informs effective decision making (Webster and Hung, 1994), including decisions on allocation of resources (Thor, 1991). A multi-dimensional and balanced performance measurement system can provide impetus that drives a company forward (Najmi et al., 2005).

2.3 Performance evaluation tools

Fit-for-purpose measurement tools are a prerequisite to performance evaluations, and many such tools have been devised and widely used in various sectors. For example, the “Balanced Scorecard” (BSC) was developed for assessing financial and non-financial aspects of companies in the business sector (Kaplan and Norton, 1992), which measures performance in four perspectives, namely financial, customer, internal business process, and innovation and learning.

The SERVQUAL model (Parasuraman et al, 1985) is for measuring and managing quality of services, which can be an efficient tool for an organization to shape up their efforts in bridging the gap between perceived and expected services (Ingram and Daskalakis, 1999). This model, however, cannot be applied in a straightforward manner to measurement of the performance of engineering facilities in commercial buildings because the “customers” are laypersons to engineering and they would not normally realise how the facilities are operated and maintained. Nevertheless, their perceived levels of satisfaction about the availability of services, degree of thermal comfort, quality of lighting output and water supply, etc., is indeed a reflection of the ultimate performance of the facilities. It follows from this argument that reference should be made to the dimensions covered by the SERVQUAL model in developing a scheme for performance evaluation of engineering facilities in buildings.

Key performance indicators (KPIs) are meant to provide objective quantifications of the critical aspects of performance of a process. Appropriate KPIs are essential to measurement of the performance of maintenance processes, which will allow performance to be compared internally and, where applicable, against external benchmarks, through which to identify strengths and weakness and to control progress and changes over time (British Standards Institution, 2007). In the construction sector, some KPIs were established for reflecting the performance of construction projects (Chan and Chan, 2004). In the study of Ho et al. (2000), which attempted to develop a set of performance metrics for facilities management, corporations in the Asia Pacific region were asked to rate the importance of 97 metrics on a five-point scale and indicate if the metric was being used in their FM practice. They found that there was limited understanding and practice of FM benchmarking in the region and the awareness of the impact of FM on overall business was low.

For engineering facilities in existing commercial buildings, some initiatives have been taken to develop KPIs for evaluation of their performance. In the work of Lai and Yik (2006), it was found that the hurdles to the development of KPIs include the knowledge, financial, motivation and information barriers of the FM practitioners. Nevertheless, a hierarchy incorporating some common KPIs has been suggested for measuring the performance of different levels of O&M works (Table 1). With reference to this hierarchy, further work is needed to develop KPIs for applications on existing commercial buildings.

Table 1: A hierarchy of KPIs for engineering facilities *(adapted from Lai and Yik (2006))*

Hierarchical level	Key Performance Indicator		
	Input	Process	Output
Strategic	$\frac{O\,\&\,M\ cost}{Building\ area}$	-	$\frac{Building\ income}{Building\ area}$
Tactical	$\frac{O\,\&\,M\ cost}{Capacity\ of\ installation}$	*% compliance with required response time*	*% users dissatisfied*
Operational	$\frac{No.\,of\ manhours}{Capacity\ of\ installation}$	*No. of equipment faults per month*	*No. of completed work orders per staff*

2.4 Performance indicators and performance categories

From the literature, 71 indicators have been identified as potentially suitable for performance evaluation of engineering facilities (as listed in the Appendix). For facilitating effective management and reporting of performance, these indicators should be systemically classified into different categories with reference to the aspects of performance (British Standards Institution, 2007; Lavy et al., 2010; Muchiri et al., 2011; Parida and

Chattopadhyay, 2007; Shohet, 2006) or the stages of the process (e.g. Muchiri et al., 2011) to which they apply. A summary of the past classification efforts is shown in Table 2.

Table 2: Past efforts in classifying performance indicators

Research	Field/ application	Methods	Number of indicators	Categories classified
Gilleard and Wong (2004)	FM	Identified by a director of facility management services at a property development company	Not specified	(1) Financial performance, (2) productivity, (3) project performance, (4) equipment availability, (5) compliance, (6) complaint and accident frequency, (7) customer satisfaction
Shohet (2006)	Healthcare facilities management	KPIs were developed based on statistical and quantitative analysis	11	(1) Asset development, (2) organization and management, (3) performance management, (4) maintenance efficiency
British Standards Institution (2007)	Industrial and supporting facilities (buildings, infrastructure, transport, etc.)	Not specified	71	(1) Economic, (2) technical and (3) organizational
Parida and Chattopadhyay (2007)	Process and utility industries	Literature survey and interviews	28	(1) Equipment related indicators, (2) maintenance task related indicators, (3) cost related indicators, (4) impact on customer satisfaction, (5) learning and growth, (6) health, safety, security and the environment (HSSE) and (7) employee satisfaction
Lavy et al. (2010)	FM	Literature review and a brief survey with eleven FM professionals who are involved in FM services and consultancy	35	(1) Financial, (2) functional, (3) physical, (4) survey-based
Muchiri et al. (2011)	Manufacturing industry	Literature review	31	(1) Leading (work identification, work planning, work scheduling and work execution), (2) lagging (measures of equipment performance and measures of cost performance)

The 71 performance indicators can be grouped into five categories - (1) physical (impact on customers' satisfaction), (2) financial, (3) task and equipment related, (4) environmental, and (5) health, safety and legal. Physical indicators, e.g. thermal comfort, visual comfort, aural comfort, etc., include those representing the physical quality of services delivered by the engineering facilities. While reflecting the feelings or perceptions of end-users, the quality of the services impacts on the customers' satisfaction. Financial indicators (e.g. percentage of contractor cost, O&M cost per building area) are those indicators related to costs and expenditures associated with O&M works for the facilities. Task and equipment related indicators (e.g. work request response rate, mean time to repair) are those indicators that can reflect how well the equipment are operated and maintained, and whether O&M tasks are effectively managed and implemented. Environmental indicators (e.g. energy use index (EUI), energy consumption per person) measure the impact of the facilities' operations on the environment. Health, safety and legal indicators (e.g. number of accidents per year, number of legal cases per year) reflect how well the FM team has done in safeguarding the health and safety of the building occupants as well as its performance in avoiding legal costs arising from any malpractices of facilities operation and maintenance.

3. Development of a performance evaluation scheme

Grounded on the above, a study has commenced in order to develop a scheme for evaluation of the performance of engineering facilities in existing commercial buildings. The study comprises four stages of work (Figure 2).

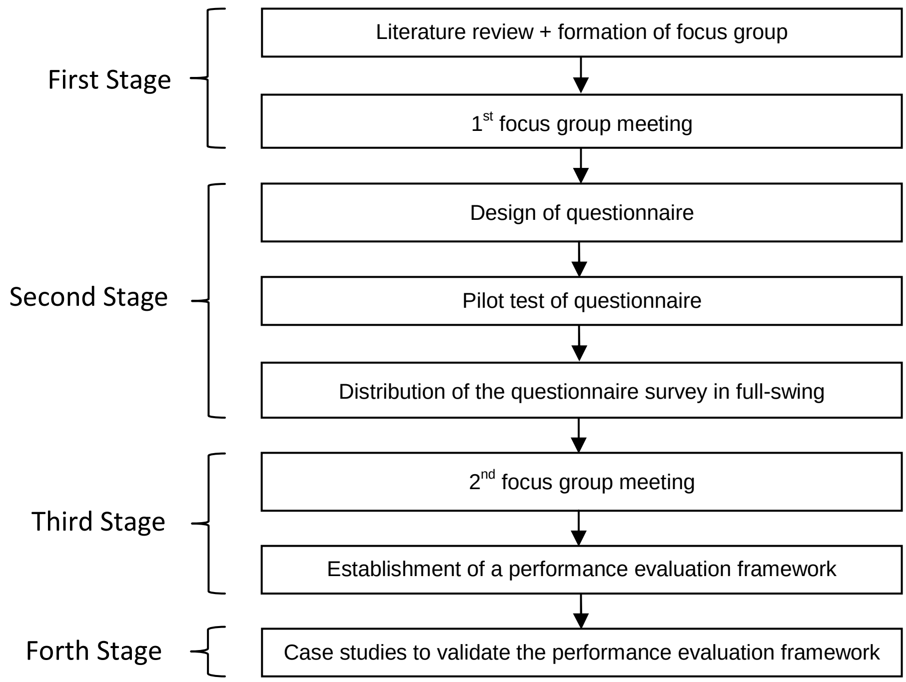

Figure 2: Flow chart of the 4-stage study

In the first stage, as has been reported in the preceding section, performance indicators that are usable in the context of the present study were identified from the open literature. Then, experienced FM practitioners working on typical commercial buildings in Hong Kong will be invited to provide their opinions on the usability of the indicators. For this purpose, a focus group discussion will be arranged, through which direct interaction between the researcher and participants will provide rich data. While this method will allow certain flexibility in discussion in terms of format, types of questions and desired outcome, the findings may not represent the views of the whole population. To minimize this limitation, careful selection of the group members who are experienced and representative in the field is necessary, and good facilitation skills are required to enhance the efficiency in obtaining the findings (Fern, 2001; Hesse-Biber and Leavy, 2004).

During the focus group meeting, the participants will be facilitated to discuss and identify the typical and major engineering facilities in their buildings and the criticalities of such facilities. Besides asking them to comment on the suitability of applying the listed performance indicators on existing commercial buildings, the participants will be guided to brainstorm and suggest any other essential indicators which are beyond those on the list. Furthermore, the identified indicators will be subdivided into four kinds: (a) important and feasible to find; (b) important but hard to find; (c) less important but feasible to find; and (d) less important and hard to find. Shortlisting of indicators will be made on a balance between their importance and the feasibility of finding out such indicators.

Based on the shortlisted indicators, a questionnaire will be designed in the second stage to investigate the levels of usefulness of the performance indicators. To ensure that the questionnaire will be effective in collecting useful responses, it will be pilot-tested before a full-scale survey is carried out. The questionnaire will be adjusted to address any problem discovered in the pilot test. Upon finalization of the questionnaire, it will be distributed in full swing to FM practitioners. Through a questionnaire survey, a large amount of data can be obtained from a large number of practitioners in the field (Thomas, 2003). By requesting the respondents to indicate their opinions in a written questionnaire, there is no guarantee of how many responses will be received and whether they can be received in a timely manner. Therefore, telephone invitations and explanations will be made to the target respondents to help raise the response rate, followed by allowing sufficient time for them to return the questionnaires.

In the third stage, the responses collected from the second stage will be analysed to screen out the less useful indicators. The useful indicators will be organized into a hierarchical structure and a second focus group meeting will be arranged. Based on the hierarchical structure (Figure 3), the focus group members will be asked to make a series of pairwise comparisons between the performance indicators using a 9-point scale. Each comparison, expressed as equal, moderate, strong, very strong or extreme, is assigned a number (i.e. how many times more): 1, 3, 5, 7, 9. The numbers 2, 4, 6, 8 are used for compromise between two adjacent judgements, and reciprocals are used to represent inverse comparisons. Each paired comparison made by the respondents requires the estimation of how many times more one indicator has over the other indicator. The ratings obtained in such comparisons will be computed by Saaty's (1980) analytic hierarchy process (AHP) to generate importance weights for the indicators. With such weights determined, an assessment scheme will be established, which can be used to evaluate the performance of engineering facilities in commercial buildings when the performance levels of the engineering facilities are made available.

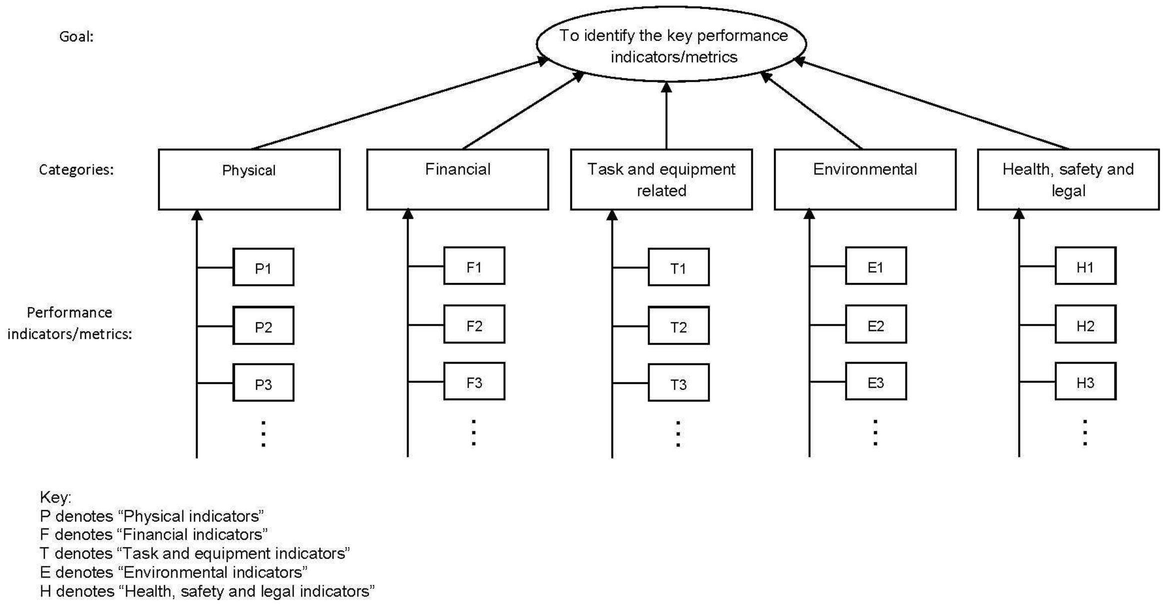

Figure 3: Analytical hierarchy of the performance indicators

In the final stage, a group of commercial buildings of different grades and scales will be the targets of investigation. For each of these buildings, an in-depth case study will be carried out. Empirical data which are essential for computing the KPIs identified in the preceding stage will be retrieved from relevant records of the buildings. To enable collection of reliable data, interviews will be held with the responsible FM personnel. In particular, face-to-face interviews will be used, as they can allow more opportunity to: i) assess the respondent's understanding and interpretation of the questions; and ii) clarify any confusion that arises about the meaning of the questions or the response. Furthermore, interviewing the practitioners face-to-face will help establish a relationship of trust between the interviewer and the interviewee, enhancing the opportunity to solicit answers to questions which the interviewees are reluctant to answer (Greenfield, 2002; Thomas, 2003).

Performance levels of the facilities, which may be figured out based on the buildings' records or determined according to the perceptions of the interviewees, will be taken to validate the applicability of the performance evaluation scheme. Where necessary, fine tuning will be made to improve the scheme further and when this is done, the scheme will be ready for application for holistic performance evaluation of engineering facilities in existing commercial buildings.

4. Concluding remarks

Over the years, a number of performance evaluation methods have been developed but one that is tailored for monitoring and assessing specifically the performance of engineering facilities in commercial buildings is yet to be seen. A review of the relevant literature has identified a long list of performance indicators, which can be categorised by the hierarchical level of a FM organisation as well as the stages of a FM delivery process. Classification of the indicators by their nature and characteristics revealed that they fall into different groups, namely physical, financial, task and equipment related, environmental, and health, safety and legal.

Based on the five groups of indicators, a research framework comprising four stages of work has been established for developing an evaluation scheme for assessing the performance of engineering facilities. The initial findings obtained from the first stage of work have been reported in the above. Results of the subsequent stages will be published in future.

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Appendix: List of performance indicators/metrics

(Sources: British Standards Institution, 2007; Building Services Research and Information Association, 2011; Campbell, 1995; Chan et al., 2001; Electrical & Mechanical Services Department, 2007; Electrical & Mechanical Services Department and Environmental Protection Department, 2010; Hinks and McNay, 1999; Ho et al., 2000; Hong Kong Quality Assurance Agency, 2012; Lai and Yik, 2006; Lavy et al., 2010; Leung et al., 2005; Lukzkendorf and Lorenz, 2006; Muchiri et al, 2011; Parida and Chattopadhyay, 2007; Tsang et al., 1999; Vesela and Michael, 2001).

Physical (impact on customer satisfaction)

(1) Thermal comfort (e.g. temperature, mean radiant temperature, humidity and air speed)
(2) Visual comfort (e.g. illuminance and glare)
(3) Acoustic comfort (e.g. reverberation)
(4) Indoor air quality (e.g. total volatile organic compound, CO_2 level, concentration of radon)
(5) Percentage users dissatisfied
(6) Number of users' complaints per year

Financial

(7) Percentage cost of personnel
(8) Percentage cost of subcontractors
(9) Percentage of contractor cost
(10) Actual costs within budgeted costs
(11) Direct maintenance cost
(12) Breakdown severity
(13) Equipment replacement value (ERV)
(14) Maintenance stock turnover
(15) Percentage of maintenance material cost
(16) Percentage of corrective maintenance cost
(17) Percentage of preventive maintenance cost
(18) Percentage of condition based maintenance cost
(19) O&M cost per building area
(20) O&M cost per capacity of installation
(21) Cost of equipment added or replaced
(22) Energy expenditure per building area
(23) Energy expenditure per person
(24) Total safety and security expenditure
(25) Security expenditure per building area
(26) Security expenditure per person
(27) Building income per building area
(28) Total rentable value of the building

Task and equipment related

(29) Work request response rate
(30) Scheduling intensity
(31) Manpower utilization rate
(32) Manpower efficiency
(33) Manpower utilization index
(34) Preventive maintenance ratio (PMR)
(35) Percentage of reactive (corrective) work
(36) Percentage of proactive (preventive) work
(37) Percentage of condition based maintenance work
(38) Percentage of improvement work
(39) Number of manhours per capacity of installation
(40) Number completed work orders per staff
(41) Area maintained per maintenance staff
(42) Quality of scheduling
(43) Schedule realization rate
(44) Schedule compliance
(45) Work order turnover
(46) Backlog size
(47) Urgent repair request index (URI)
(48) Corrective maintenance time
(49) Preventive maintenance time
(50) Response time for maintenance
(51) Percentage compliance with required response time
(52) Number of maintenance induced interruptions
(53) Failure/breakdown frequency (number of equipment faults per month or per year)
(54) Mean time between failures (MTBF)
(55) Mean time to repair (MTTR)
(56) Availability
(57) Efficiency of facilities
(58) Gross floor area under safety and security patrol

Environmental

(59) Energy use index (EUI)
(60) Energy consumption per person
(61) Greenhouse gas emission per building area
(62) Conduction of energy audit
(63) Conduction of carbon audit
(64) Conduction of environmental assessment (e.g. LEED, BREEAM, BEAM Plus, HKQAA SBI)

Health, safety and legal

(65) Number of accidents per year
(66) Number of legal cases per year
(67) Number of compensation cases per year
(68) Amount of compensation paid per year
(69) Number of health and safety complaints per year
(70) Number of lost work hours per year (i.e. convalescent leave given by doctor)
(71) Number of incidents of specific diseases in building per year (e.g. legionnaire's disease)