Automation in Construction 43 (2014) 31–37

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Improving occupants' satisfaction with effective maintenance management of HVAC system in office buildings

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ARTICLE INFO

Article history:
Received 31 August 2013
Received in revised form 26 December 2013
Accepted 8 March 2014
Available online 25 March 2014

Keywords:
HVAC system
Office building
Maintenance characteristics
Occupations' satisfaction
Participants' involvement

ABSTRACT

Office buildings are equipped with HVAC system to provide a comfortable working environment. However, the level of the occupants' productivity and comfort is highly influenced by the reliability of HVAC system's service. Thus, the proper maintenance of HVAC system is necessary to ensure the smooth operations of an organisation. This paper seeks to investigate the maintenance characteristics of HVAC system that affect occupants' satisfaction and subsequently establish a relationship between the characteristics and occupants' satisfaction through questionnaire surveys and interviews; and finally develop a regression model for prediction purpose. The findings reveal that the maintenance characteristics which influence occupants' satisfaction include the skill and knowledge of the manager, the skill and knowledge of the labourer, the quality of spare parts and materials, as well as the response level towards failure and downtime. The study concludes that an effective communication platform which involves all key participants in the maintenance activities should be developed by the management to improve the maintenance outcomes.

1. Introduction

The heat, ventilation and air conditioning (HVAC) system is a system that provides proper ventilation and air circulation in a building. A central HVAC system may serve one or more spaces within the building. The HVAC system comprises two main sections, which are in-building section and out-building section. All the main components of an HVAC system perform their own function. A central HVAC system consists of [1]:

(a) Chilled water plants (chillers) complete with cooling towers
(b) Water distribution systems which consist of pumps and insulated steel pipes
(c) Air handling units
(d) Air distribution systems consisting of insulated ducts, fans, dampers and air terminals
(e) Electrical distribution systems
(f) Control systems

A central HVAC system is widely used in large buildings, such as office buildings, commercial buildings and shopping complexes. This is due to the advantages of the system. The central HVAC system allows major components to be isolated in a mechanical room. Thus, the maintenance personnel are able to perform the maintenance tasks without interrupting the daily activity within the building or its functions. Moreover, the isolation of components helps to reduce noise and enhances the building in terms of its aesthetic value.

According to Kwak et al. [2], the service reliability of the HVAC system highly relates to the level of the occupants' productivity and comfort. Suttell [3] supported that heating and cooling system is necessary for a building. A building without a heating and cooling system would be inhabitable. Furthermore, indoor air quality is a significant determinant of healthy life and human's well-being, because human spend up to 80% of their lifetime in indoor area [4].

However, improper operation or failure of the HVAC system may lead to poor ventilation which in turn caused Sick Building Syndrome (SBS). SBS develops when the indoor air contaminants build up, and subsequently resulting in poor health and low productivity [5]. The symptoms of illness related to SBS include eye, nose and throat irritation; skin allergy; mental fatigue; headache and difficulty in concentration [4,6]. Norhidayah et al. [4] further demonstrated that the failure to respond to the problem of poor indoor air quality can bring the disastrous impacts towards human health.

In fact, inefficient operation and maintenance of the HVAC system can cause energy wastage, customer complaints, poor indoor air quality and even environmental damage [7]. Thus, the maintenance of the HVAC system must be planned and carried out effectively to ensure the satisfaction of the occupants towards the system and service. Consequently, this paper seeks to identify and investigate the maintenance characteristics of the HVAC system that affect the occupants' satisfaction.

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http://dx.doi.org/10.1016/j.autcon.2014.03.013
0926-5805/

2. Maintenance of HVAC system

Generally, the manufacturers recommend the maintenance requirements and the operating environment to the users. Wu et al. [8] highlighted four types of maintenance programme for HVAC system which includes:

(a) Test and inspection
(b) Scheduled maintenance
(c) Condition-based maintenance
(d) Corrective maintenance

In order to plan, organise and execute the maintenance programme appropriately, it is vital to understand the components and functions of a particular system. Chandrashekaran and Gopalakrishnan [9] demonstrated that the most important HVAC components are the chillers, cooling tower, air handling unit, compressor and pump. Thus, the maintenance of a HVAC system should focus on these essential components to enhance the performance and the cost effectiveness of the system.

Since the HVAC system is centralised, it may affect the entire building when a failure occurs in any of its component. For example, the cooling of condensed water cannot be done if the chillers break down and hence the entire system cannot convert the hot air into cool air. Furthermore, the maintenance of the central HVAC system is more complicated and difficult because of the system's size and complexity. Hence, to minimise the HVAC system downtime, corrective maintenance shall be replaced with appropriate preventive maintenance strategies.

As argued by Wu et al. [8], most maintenance programmes of building systems are developed based on the HVAC maintenance programme. Thus, the HVAC system is selected as the scope of study in this paper. In addition, Lavy [10] demonstrated that HVAC system is the largest and most expensive component in a building. A high cost of maintenance is required to retain the conditions of the HVAC system without affecting maintenance performance.

3. Research design

This research adopted the mixed method approach that was adopted by Ali [11] and Nik Mat [12] to study maintenance-related topics. The approach comprises literature review, questionnaire survey, semi-structured interview, and case study. This approach allows the researchers to address more complicated research questions and achieve higher reliability and validity of the research [13]. The research was divided into stages and conducted sequentially (see Fig. 1).

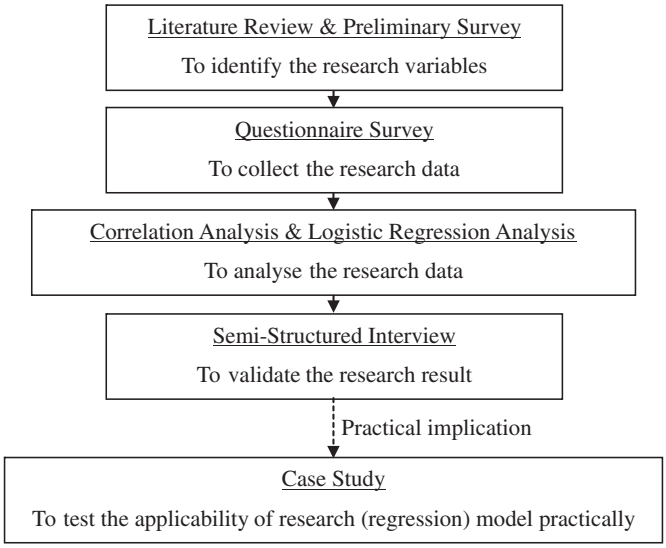

Fig. 1. Overall research flow.

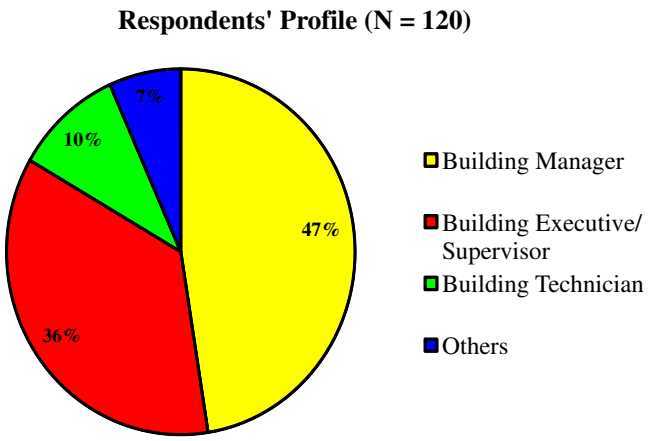

Fig. 2. Respondents' profile.

Firstly, the features of the maintenance system of the HVAC system were identified through literature reviews and preliminary survey. Subsequently, close-ended questionnaires were drafted in five-point Likert scale and multiple choices based on the findings of literature and preliminary survey. The questionnaires were developed with reference to the research of Ali [14]. It covered three sections, namely the respondent's particular, maintenance characteristics of the HVAC system, and occupants' satisfaction level (see Appendix).

Secondly, the simple random sampling method was adopted in the questionnaire survey to identify the relevant respondents who have been or are currently involved in the management of office building maintenance. This method ensures the accuracy of the sample by selecting the respondents at random and all elements in the population are considered [15]. Population criteria included building requirements, which were high-rise office buildings (7-storey and above) located in Klang Valley, Malaysia and must be completed more than 2 years. Overall, 398 office buildings met the criteria and hence, the figure was determined as the research population. A set of the questionnaires was sent out to each building from the research population and 120 sets of valid questionnaires were returned, which gave a return rate of 30%. The respondents were maintenance management personnel working in different office buildings. 83% of the respondents were building managers, building supervisors and executives specialising in the planning and execution of maintenance management activities (see Fig. 2). Meanwhile, 86% of the respondents had more than 5 years of working experience in the maintenance management field (see Fig. 3). Hence, the collected data was considerably reliable and accurate.

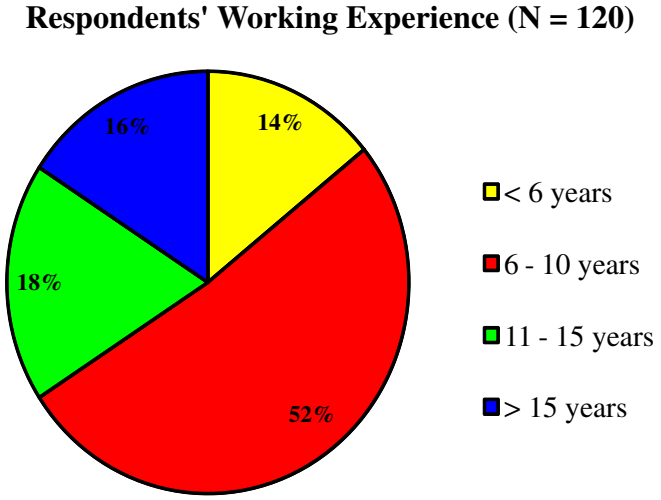

Fig. 3. Respondents' working experience.