A STUDY OF THE SIGNIFICANCE OF HEATING, VENTILATION AND AIR CONDITIONING (HVAC) MAINTENANCE IN HEALTHCARE FACILITIES IN MALAYSIA

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A project report submitted in partial fulfilment of the

requirements for the award of Master of Project Management

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

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ABSTRACT

Maintaining Heating, Ventilation, And Air Conditioning (HVAC) system in healthcare facilities always been different from commercial buildings. The HVAC system is critical not only for maintaining a comfortable temperature, but also for maintaining a healthy environment that affects patient well-being and prevents disease spread. The significance of HVAC system maintenance, especially in healthcare facilities, has yet to be properly addressed as the previous studies has primarily relied on HVAC system in commercial buildings. The research aims to enhance heating, ventilation, and air conditioning maintenance especially in healthcare facilities in Malaysia by acquiring its significance, the problems in maintaining it and solutions to enhance the maintenance of the system. This study investigates the significance of HVAC system in healthcare facilities, the problems that arises in maintaining it and followed by the solutions to enhance the maintenance of the system. Structured questionnaire survey was conducted with 100 number of respondents who are in this field to explore the significance of HVAC maintenance in healthcare facilities with returned of 84 number of responses. Most technical respondents correspond that the infection control is dominant with the mean of 2.55 over the comfort conditioning of 2.50 in terms of the significance of HVAC system in healthcare facilities. Besides, lack of adequate sensors is the most common problem in maintaining the HVAC systems at the mean of 4.79 of respondents consented to it, whereas, at the mean of 3.48 of respondents considers Organizational Simulation is the solution to enhance the HVAC maintenance in healthcare facilities. The results demonstrated the significance of HVAC system in healthcare facilities is persistent more on infection control over comfort conditioning, which is contradict to commercial building. The findings of significance of HVAC system in healthcare facilities, problems in maintaining the system followed by the solutions to enhance the HVAC system will helps the HVAC professionals to consider before designing the HVAC systems to prevent the breakdown.

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LIST OF SYMBOLS / ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
HVAC	Heating, Ventilation, And Air Conditioning
IAQ	Indoor Air Quality
OS	Organisational Simulation
PV	Personalised Ventilation
RFID	Radio-Frequency Identification
RH	Relative Humidity
SARS-COV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SBS	Sick Building Syndrome
SPSS	Statistical Package for The Social Sciences
UTAR	Universiti Tunku Abdul Rahman
WHO	World Health Organization
%	Percent Sign
α	Alpha

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Healthcare facilities are inhabited by a large group of people with a very variable state of health. Some illnesses need specific environmental criteria to promote their improvement and to inhibit their transmission to medical staff and other patients (nosocomial infections). Heating, ventilating, and air-conditioning (HVAC) systems in hospitals are an essential tool in the fight against nosocomial infections; as a result, providing sufficient indoor environmental conditions in hospitals is closely linked to people's health.

The air-conditioning facilities to be emphasized inside a hospital are operating theatres, isolated spaces, and other clean rooms, such as laboratories. Other factors different from the thermohydrometer ones are also used to define the requirements of the required air conditioning in these rooms. There is overpressure of the room, microbiological load, the rapidity of the impulsion and surface of the diffuser, etc. These variables must be combined in order to create an ultra-clean air movement pattern that aids in the lagging and removal of airborne bioparticles from the work environment (ASHRAE, 2019).

High concentrations of harmful microorganisms are normal in hospital environments. The primary goal of hospital design in terms of infection control is to locate the patient in a place where he or she is not at risk of infection while in the hospital. Hygiene, reliability, and safety are among the technical demands, and energy-related issues are also present in this state. Infections that which arise as a result of activities and initiatives carried out within the facility are a major source of concern. Three main paths that source of infectious diseases are contact, droplet, and airborne transmission, that are quite affected by room design and construction factors (Pygielski & Uden, 2016).

The hospitals are energy-intensive buildings so, the maintenance of HVAC systems and their equipment has a special economic and environmental significance. The more effective

maintenance plans will assist to satisfy the demand for continuous availability of equipment. The typical objectives of maintenance are efficiency, availability, and durability.

1.2 Importance of the Study

This study is to find out the significance of the maintenance of heating, ventilation, and air conditioning in healthcare facilities in Malaysia. It takes on an added level of significance in healthcare facilities where infection control and cross-contamination are among the concerns although proper HVAC systems are apparently key to keep up indoor air quality in any commercial building (Stewart, et al., 2019). In healthcare facilities, HVAC system is playing crucial role through upholding a sterile atmosphere to promote the health of patients, also to inhibit the infection as well as through sustaining comfortable settings of temperature and humidity management.

1.3 Problem Statement

The health care buildings have many users of indoor areas and functions because it is regarded as the most multifaceted indoor facilities. Due to the complex engineering services, the healthcare facilities are considered as one of the most complex indoor facilities among public sector buildings to maintain. The HVAC system maintenance must be more consistent, more efficient, and more cost-effective, because poor HVAC maintenance practices could lead to more frequent interruptions, which may cause inconvenience to catastrophe (Yousefli, et al., 2020). A healthy and comfortable indoor environment must be supported by well-maintained HVAC system. Nevertheless, intensified transmission of respiratory infections is related with poor ventilation in indoor spaces. The SARS-CoV-2 transmission can be caused by bad use of ventilation systems. The distribution of droplets in the air carrying SARS-CoV-2 will be spread out by the airspace produced by the air conditioning. Since SARS-CoV-2 was discovered in the air and the outburst of the Diamond Princess cruise ship, a research recommends that in addition to the major channel of transmission (person to person), other routes such as airborne through centralised air or drainage system should not be overlooked (Liu, et al., 2018). The aerosol spread is the allotment of contagious pathogens affects thru spreading of droplet nuclei that perseveres contagious once suspended within the atmosphere across long distances plus time concurring to WHO (2020). The SARS-CoV-2 could merge throughout the medical treatment which causes airborne. Moreover, the SARS-CoV-2 can be distributed through airborne in other circumstances. Through the maintaining HVAC

system, the enfeeblement airing, right route of airflow and pressure distinction are obtainable to alleviate the chance of SARS-CoV-2 spread efficiently. The statement formally differing the guidance not to operate domestic or commercial HVAC systems by The American Society of Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE (2019). The function of heating, ventilating, and air-conditioning (HVAC) systems has turn out to be critical drawback for the HVAC field because the HVAC system portrays a significant part in the spread of SARS-CoV-2 (Guo, et al., 2020). Thus, this study is to discover the significance of HVAC maintenance in healthcare facilities, which also comes with the problems related, and its solutions to enhance HVAC maintenance.

The significance of HVAC system maintenance especially in healthcare facilities has not been elucidated. The previous studies been highlighted about the HVAC system maintenance in commercial buildings. Hence, this study will be emphasising on the HVAC system maintenance in healthcare facilities and its extra level of significance in healthcare facilities where infection control, therapeutic purpose and other factors are related.

1.4 Aim

This research aims to enhance heating, ventilation, and air conditioning maintenance especially in healthcare facilities in Malaysia.

1.5 Objectives

To attain the research, aim as mention in 1.4, three objectives are formulated as follows:

a) To explore the significance of the HVAC system in healthcare facilities.

b) To identify problems in maintaining HVAC in healthcare facilities.

c) To determine the solutions to enhance the HVAC maintenance in healthcare facilities.

1.6 Scope and Limitation of the Study

The scope for this research is to study the significance of Heating, Ventilation, and Air Conditioning (HVAC) maintenance in healthcare facilities which is within Malaysia. This research is also limited to technical personnel like HVAC technicians, HVAC engineers, technical managers, facilities managers and HVAC contractors due to their knowledge and experience in handling HVAC maintenance.

1.7 Research Methodology

This study of the significance of HVAC maintenance in healthcare facilities in Malaysia was reinforced by quantitative research. By using the secondary data from the online library database by UTAR which assisted to access appropriate journal articles, published reports, published magazines, book section, etc. The questionnaire was derived from the variables obtained from the theoretical framework to validate the data from literature analysis. The questionnaire mainly focuses on the three objectives of the study which are the significance of HVAC maintenance, problems in handling it as well as solutions to enhance the HVAC maintenance in healthcare facilities. the questionnaire has been used in this study to collect data that validate the variables gained from Literature Review. In this survey, the data collected through the questionnaire was total 100 sets distributed with the returned amount of 84 sets. For the analysis of data collection, Statistical Package for the Social Sciences (SPSS) was used to manage and analyse quantitative data from the questionnaire distribution (Gregar, 1994). For this study, data collection was chosen to be quantitative data because it helps to articulate facts and reveal patterns of the variables collected for each objective. Besides, this design of the research is determined to conclude the data on its purpose and understand how dominant it is by looking for results that can be projected to a targeted scope of the healthcare facilities industry. The research methodology classified into three phases as shown in Figure 1.1. The first phase consists of problem statement of the study and followed by the theoretical background as known as Literature review. The Phase 1 is crucial because it has brief explanation of the significance of HVAC maintenance in healthcare facilities in Malaysia and helps to clearly identify the purpose by highlighting the gap of the study. Besides, research design is identified in Phase 2. Research design is the framework of research methods for this study was quantitative research, where statistical conclusions to collect actionable insights. Finally, the Phase 3 which consists of Data Collection, Data Analysis and Research Results.

This phase emphasises on the gathering the analytical data and interpreting the gathered data using analytical and logical reasoning to determine patterns, relationships or trends.

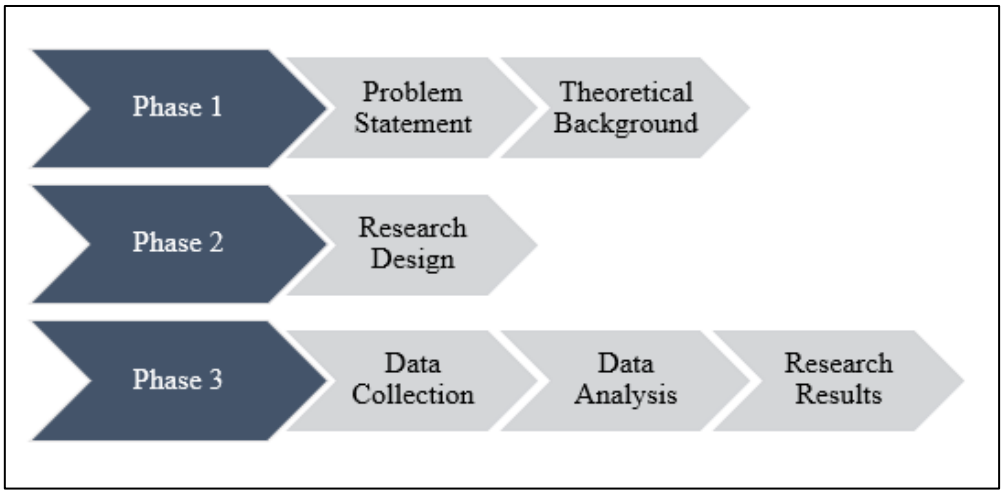

Figure 1.1 Framework of Research Methodology

1.8 Contribution of the Study

This research could be used as a guideline for future study of the significance of HVAC maintenance in healthcare facilities. The exploration of the significance of HVAC maintenance in healthcare facilities provides data reference to a better understanding of how poor HVAC maintenance will affect the patients and users of the healthcare facilities. This study also emphasizes identifying the problems in maintaining HVAC, also to how to enhance the HVAC maintenance as well as analyses the significance of HVAC maintenance, especially in healthcare facilities in Malaysia. With the finding of this research, the major barriers that prevented effective HVAC maintenance in healthcare facilities could be identified. Method or suggestion to improve on effective HVAC maintenance in healthcare facilities will be presented in this research. Lastly, this research could provide a guideline to prevent the factors that might give issues to the HVAC maintenance for the future.

1.9 Outline of the Report

The structure of the project is as below:

Chapter 1: Introduction

This chapter of the report would be introducing the relevant problems and issues of the project title. The problem statement shows the interest in the study, aims, and objectives of the research.

Chapter 2: Literature Review

The literature review compiles with relevant and related research journals and studies on a similar area of research. It deliberates the background of the topic, an analysis on the related topic to help in the structure of the research methodology.

Chapter 3: Research Methodology

This chapter is to describe the justification of the research method and designs to achieve the research objective. It is also containing the strategy data collection, sampling, and data analysis.

Chapter 4: Results and Findings

The result of the survey will be generating by SPSS. The data will be analysed using Frequency Analysis, Cronbach's Alpha Test, Mean Ranking, and Kruskal-Wallis test.

Chapter 5: Discussion

This chapter will be a discussion on the analysed data generated based on the objective of this survey. The objectives of the study will be described based on the findings obtained from the research.

Chapter 6: Conclusions and Recommendations

Chapter 5 will conclude research achievement. Recommendations based on the respondents' perception provided in this research could use for a future researcher for future exploration.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Heating, Ventilation, and Air Conditioning (HVAC) play a significant role in healthcare facilities because it assists to upkeep the comfortable environment with humidity and temperature control that directed toward improved health of patients as well as restrain the spreading of diseases. Therefore, the causal aspect implies that the scheme of various of this system for healthcare facilities should consider various attributes that are deemed essential for this sector.

The air conditioning in healthcare facilities and hospitals does a far bigger role than just keeping comfort to employees and patients. The medical equipment requires an effective air control because of its high sensitivity to humidity and temperature levels. In addition, the intricacy of the HVAC system increases when the requirement of having rooms with varying degrees of use in healthcare facilities and hospitals. Therefore, it is important to bound the different spaces and their specific uses within these facilities. In order to prevent other patients from being exposed to various infectious and contagious diseases, it is essential to allocate wards to patients who has different bacterium for treatment (Saran et al., 2020). Moreover, other rooms should be provided, which are tailored towards keeping patients who require a certain level of isolation and for the patients with the depressed or weak immune system (e.g. neonatal rooms, intensive care rooms, & operating theatres), where it is important to control the arrival of various pathogens that are bound within the hospital. Therefore, healthcare facilities and hospitals are considered places, where higher rates of pathogens are concentrated, compared to average buildings, and most of these pathogens frequently spread within the hospital environment. This causes the medical equipment exposed to accumulation of large amounts of pathogens and serve as their main areas of cultivation, and consequently risking the health of the users (Mitchell & Braun, 2012). With the understanding of the significance of HVAC maintenance in healthcare facilities, all these challenges can be avoided and patients and healthcare workers, and visitors can be protected from the exposures of pathogens.

2.2 Types of Infection Transmission

A virus, bacteria, or other organism are source of irresistible agent or germ. In healthcare environment, there are germs found in numerous places. Individuals are one basis of germs comprising patients, healthcare laborers, guests and family individuals. People can be debilitated with symptoms of a disease or colonized with germs (not have side effects of a disease but able to pass the germs to others). Infections are a cause of fundamental concern from the activities and procedures taking place within the healthcare buildings. The direct contact, indirect contact and vehicle transmission are the most ways for disease, which are very influenced by room plan and construction variables (Pygielski & Uden, 2016).

2.2.1 Direct contact

Direct contact primarily transmitted when microorganisms are exchanged by coordinate physical contact with the contaminated or colonized person. One of the foremost common modes of transmission is direct contact. Direct-contact transmission includes the development of microorganisms from an infected person to a susceptible have by direct body-to-body contact. Vertical, horizontal, or droplet transmission are the three sorts of direct contact. During virus or germs are exchanged vertically from giving birth amid pregnancy, or breastfeeding, it is known as vertical direct contact transmission. Frequently, contact among mucous membranes is required for section of the pathogen into the new host, in spite of the fact that skin-to-skin contact can lead to mucous film contact in case the new have along these lines touches a mucous film (Stewart, et al., 2019).

2.2.2 Indirect contact

Indirect contact is additionally a common source of transmission. Indirect-contact transmission happens when a contaminated individual infects a lifeless object (such as instruments or dressings). Indirect contact transmission happens when bacterium from an infected person or source sully inanimate objects called fomites. For instance, a person who has cold might wheeze, producing drops which arrive on a non-living things such as a tablecloth or carpet, or indeed the person might clean their nose as well as after that transmit bodily fluid to a fomite such as a door handle or towel. When a new susceptible have afterward touches the fomite and passes the contaminated fabric to a susceptible section point, transmission happens indirectly. Fomites may moreover incorporate non-sterilized items utilized in clinical situations, such as

needles, syringes, catheters, and medical tools. Indirect pathogen transmission through such fomites may be a major source of healthcare-associated contaminations (Yousefli, et al., 2020).

2.2.3 Vehicle transmission

The terminology “vehicle transmission" alludes the bacterium being spread over mediums such as liquid, solid, and gas. Fine particles and dust referred to as particulates, which coast within the air, bacterium can be carried plus enable infection spreading through the air. As an example, minuscule particulates are the predominant form of transmitting of hantavirus to human creatures. Hantavirus can be discovered in mouse dung, pee, and saliva, but as the compounds dry out, it may deteriorate into tiny particulates which ended up airborne once it exasperates, causing a genuine and frequently lethal respiratory disease (Stewart, et al., 2019). Although short-distance droplet transmission is referred as contact transmission, longer-distance droplet transmission through the air is referred as vehicle transmission. Fine mucus droplets formed by coughs or sneezes, where the large particulates can fall rapidly from the air column while smaller particles stay in the air column longer. It can stay suspended for long periods of time and travel great distances. Droplets dehydrate quickly beneath certain conditions, creating a droplet nucleus able of spreading particulates; the ambient temperature plus the humidity could influence the potency of airborne transmission. Tuberculosis is most frequently spread through airborne diffusion at whatever point the have cell, Mycobacterium tuberculosis, is discharged in little pathogens with coughs. Since tuberculosis can begin up a new disease with less than 10 organisms, patients with tuberculosis must be handled in separate rooms with special ventilation, and anybody walking through the door should put on a mask (ASHRAE, 2019).

2.3 Studies of HVAC in Healthcare Facilities in Malaysia

Healthcare facilities are one of the most critical places in a country, and it demand adequate air conditioning to supply good indoor air quality for patients and workers. Hospital employees use the majority of their time at work rather than at home, exposing them to indoor air for extended periods of time. Since Malaysia's weather is hot and humid, most hospitals are outfitted with HVAC systems, both centralised or non-centralized air-conditioning and mechanical ventilation systems.

In Table 2.1, the six research papers are listed in chronological order. The table includes the title of the paper, the journal in which it was published, and the year in which the study was conducted in Malaysian hospitals. The analysis of thermal comfort and temperature adaptation

of users in Malaysian hospitals seemed common to all the articles. The temperature range for thermal comfort in Malaysian hospitals was researched by Yau and Chew (2009), and the temperature range of 25.3–28.20C was determined to be comfortable. The same authors recently conducted a related study in which the optimal internal neutral temperatures were found to be between 23.3 and 26.5 degrees Celsius (Yau and Chew, 2013). In the meanwhile, the researchers believed that the amount of initial works was inadequate to establish the connection among healthcare facilities efficiency and thermal comfort, and that empirical research in multiple hospitals are indeed necessary.

Furthermore, Azizpour et al (2012) conducted a thermal comfort assessment on hospitals in Malaysia, a country with a hot-humid climate. The same team performed a related study in Malaysia on large-scale hospitals (Azizpour et al, 2013). The correlation between the neutral point temperatures and the optimal temperature to the worldwide standard was demonstrated clearly in these two studies. In the same manner, two research articles on research project consisting of thermal environment evaluation and thermal comfort survey were carried out (Khalid, Zaki, Rijal and Yakub, 2018) (Khalid, Zaki, Rijal and Yakub, 2019). Both articles focused on the comfort temperatures for patients, visitors, and staff depending on the operative temperature. The researchers also explain the effects of outdoor temperature on indoor comfort temperature, as well as the relevance of international and national thermal standards.

All these papers are primarily concerned with the investigation of thermal comfort for patients, employees, and visitors in Malaysian hospitals. However, the study on significance of HVAC system and its maintenance has not been elucidated, especially in healthcare facilities in Malaysia. The thermal comfort been a main concern for the patients, visitors and workers. This research contributes to the understanding of how to deal with HVAC failures by exploring the problems and possible solutions for achieving and maintaining the thermal comfort of healthcare facility users. Before handling the HVAC systems in healthcare facilities, it is vital to understand the significance of the system so that the consequences of a system failure can be understood.

Table 2.1 Research Articles that performed in Malaysia

References	Title	Journal	Nature
(Yau and Chew, 2009)	Thermal comfort study of hospital workers in Malaysia	Indoor Air	Hospital
(Azizpour et al., 2012)	A thermal comfort investigation of a facility department of a	Indoor and Built Environment	Hospital

	hospital in hot-humid climate: Correlation between objective and subjective measurements		
(Azizpour et al., 2013)	Thermal comfort assessment of large-scale hospitals in tropical climates: A case study of University Kebangsaan Malaysia Medical Centre (KMMC)	Energy and Buildings	Hospital
(Yau and Chew, 2013)	Adaptive thermal comfort model for air-conditioned hospitals in Malaysia	Building Services Engineering Research and Technology	Hospital
(Khalid, Zaki, Rijal and Yakub, 2018)	Thermal comfort requirements for different occupants in Malaysian hospital in-patient wards	Journal of Advanced Research in Fluid Mechanics and Thermal Sciences	Hospital
(Khalid, Zaki, Rijal and Yakub, 2019)	Investigation of comfort temperature and thermal adaptation for patients and visitors in Malaysian hospitals	Energy and Buildings	Hospital

2.4 The significance of the HVAC system in healthcare facilities

To support the healthcare process, HVAC systems are required to perform several vital functions that influence the environmental conditions, hazard and infection control, as well as building life safety. Patients and staff comfort, and the availability of therapeutic space conditions may provide maximum outcomes in inpatient treatment. To perform these functions, environmental conditioning for the storage of electronic data, IT system support, and special imaging techniques is essential. Through dilution, containment, and removal of toxins and pathogens, the HVAC system is an essential element of infection control and facility safety. The significance of the HVAC system in healthcare facilities is demonstrated below.

2.4.1 Comfort Conditioning

Across various healthcare facilities and hospitals, the healthcare practices often expose staff and patients to some conditions that can dictate unique environmental conditions. Like in any other facility, the comforts of the occupants are fundamental to their productivity and wellbeing. In hospitals and healthcare facilities, a comfortable environment is important in facilitating recovery and healing (Sánchez-Barroso, & García Sanz-Calcedo, 2019). An injured or a sick patient within an uncomfortable condition may be subjected to thermal stress, which may inhibit the ability of the body to efficiently regulate the body heat, be psychologically harmful, and interfere with rest. Similarly, a healthcare provider who is stressed by uncomfortable working conditions may be unable to function at an optimal level. Therefore, the airflow patterns of rooms and the air exchange rates in such rooms may affect the thermal comfort of hospitals and healthcare facilities. In this regard, healthcare criteria and nodes often establish the need for space temperature, total air exchange rates, and relative humidity.

2.4.2 Therapeutic Conditioning

Some medical treatments, functions, or the healing process demand that there should be controlled environmental temperatures and relative humidity conditions that often deviate from the need for personal comfort. For instance, nursing units and operating rooms may require some range of room temperatures that spans various degrees, despite the season to enable a given procedure or the patient's condition. According to Joppolo and Romano (2017), the burn-patient bedrooms and treatments rooms often require an elevated relative humidity and temperatures (35%-40% RH and up to 37.7^0C respectively). Some healthcare providers desire the ability to reset the room temperatures in emergency departments to as high as 32.2°C to facilitate the treatment of hypothermia cases. Also, acceptable criteria demands for the long-term in-patient spaces to be humidified to a minimum level to avoid the cases of mucous membrane and dry skin related to low RH levels and contribute to the occurrence of discomforts and positively imbed the function of respiratory immunity (Joppolo & Romano, 2017).

2.4.3 Infection Control

Despite few exceptions (e.g. sports medicine, freestanding behavioural health, or maternity care centres), hospitals and healthcare facilities are places where relatively high rates of

pathogenic microorganisms are concentrated by the population of infected patients or by the procedures that manipulate or handle infected bodily fluids and human tissues. According to Azimi and Stephens (2013), these pathogenic microorganisms are often spread by various contact and non-contact means. To some levels, the whole building population is at high exposure risks to these pathogens. The injured or sick patients, having compromised or suppressed immune function, are considered greatly susceptible to new infections. In addition, the visitors often accompany these injured or sick patients or the loved ones to high-exposure areas such as emergency departments and clinical waiting rooms. Besides, because of their profession, healthcare providers work near infectious pathogenic microorganisms on a day-to-day basis. Therefore, hospitals and healthcare facilities required strict operational practices as well as proper engineering controls to safeguard the population therein (Azimi & Stephens, 2013). In this regard, the HVAC system is one of the best practices that can be adopted in controlling infectious pathogenic microorganisms.

2.4.4 Environmental Control and Ventilation for Special Functions

Many healthcare facilities and hospitals often include processes or functions where aerosols, chemical fumes, or harmful gases are generated and stored, leading to the safety of health hazards. Examples of these include laboratories, where numerous aerosolizing chemicals are utilised to fix slide specimens, preserve certain tissues, or perform other specialised processes (Moscato, Borghini, & Teleman, 2017). Other factors include artificial limb shops and orthopaedic appliance that involve adhesives and other aerosolizing elements; anesthetizing locations where long-term exposures to the trace concentrations of various anesthetizing gases that can pose harmful impacts. In these applications, the HVAC equipment often operates alongside the primary containment equipment like radioisotope hoods, fume hoods, laminae flow benches, as well as the waste anaesthesia evacuation equipment to exhaust and contain these contaminates or take part in diluting these components to safer levels. Similarly, the HVAC system may assist in maintaining the sterile condition for the procedures or products that need to be protected from harmful environmental contaminants. Some pharmaceutical handling, laboratory-culturing procedures, and compounding procedures are cases where HVAC functions in association with other containment equipment to offer protection (Moscato et al., 2017).

2.5 The problems in maintaining HVAC in healthcare facilities

Despite the role played by the HVAC system in healthcare facilities, various challenges have been encountered in their development and implementation. Some of the most prevalent challenges are presented.

2.5.1 Poor hospital design

In spite of having critical knowledge on diverse mechanisms of the spread of diseases in hospitals, there are small endeavours to design hospitals, with a solid accentuation on infection protection components (Clark & de Calcina-Goff, 2009). The healthcare facilities are frequently planned by designers who are not learned on the capacities of contamination control. Concurring to Clark and de Calcina-Goff (2009), such designers are moreover challenged by the need of skills and know-how on how to actualize radical features, in any case, the ones that do have the skills frequently show up outside the satisfactory standards. When a healthcare facility being developed in conventional lines, the retrofit for high disease defence of patients is rarely a reasonable alternative (Clark & de Calcina-Goff, 2009).

2.5.2 Lack of adequate sensors

Many Indoor Discuss Quality (IAQ) detectors may not enough accomplished market achievement over the past a long time. In expansion, Ihasalo (2012) focuses out that there is an issue with the need of sufficient sensors introduced with HVAC systems. Although there is considerably becoming commercially available, more efforts are needed to develop sensors and ensure common interfaces for them are established. In this regard, the development of HVAC devices and sensors should feasible, simple, and functional with various common interfaces, otherwise it would be hard to be adopted by hospitals and healthcare facilities.

2.5.3 Poor Data Handling, Visualisation, and Archiving by the Building Automation System

According to Brambley et al. (2005), the existing building automation framework utilized to control and oversee the HVAC equipment presents restricted capacity to gather, document, and visualize basic data. They regularly can execute real-time monitoring of humidity and temperature, whereas other basic parameters of the quality of air inside the building are cleared

out unmonitored. The programs for visualization of the building automation system have basically been set up for the alteration of the system parameters as well as for monitoring the whole framework. In expansion, each program engineer regularly has their claim custom fitted program that causes challenges for the end-users. In this manner, the possibility and usefulness of building automation systems programs ought to be upgraded. In spite of the fact that studies have illustrated that it is conceivable for the recreation of building computerization systems to improve their perceivability, it is once in a while performed since it requires special ability inside the building automation systems. Likely, future eras can capitalize on building automation systems more productively.

2.5.4 The Complexity in the Prevention of the Spread of Airborne Infections

The prevision of the spread of irresistible airborne illnesses, especially, in hospital and healthcare settings has been demonstrated challenging within the past studies. Concurring to Tang et al. (2006), the era of irresistible aerosols out of contagious human virus able to take place in different ways, as well as in multiple circumstances within a hospital surroundings. For example, the droplets gotten from laughing, talking, wheezing, and coughing can lead to the generation of infectious aerosols. Ultimately, environmental conditions such as humidity and temperature impact the survival of these pathogenic microorganisms (Tang et al. 2006). In any case, there are varieties in season and indoor building situations. The airborne able to be transferred to wide space (e.g. little droplets or short distances (e.g. large droplet aerosols). This appears it is difficult to plan for the outbreak of airborne diseases.

Studies have also recommended that the ventilation system may have different microbial contaminations which will act as a source of contamination (e.g. Battalion et al., 1993; Rose & Hirsch, 1979). According to Ohsaki et al. (2007), unclean air passage and contaminated strainers can be destinations in favour of dispersal and intensification of a few indoor parasites. Hence, it is vital to ensure the nonappearance of humidity that condenses into the HVAC system and set up a legitimate sewage framework to guarantee that water condenses into humidifiers and coolers.

In another study, Morawska (2006) identified experimental complexities associated with the simultaneous characterisation of the physical and microbiological nature that has various viruses and the absence of scientific techniques and methods for accurate quantification of particles of the virus in the air. In this regard, the advanced method such as the polymerase

chain reaction that is based on the quantitative approaches of the application on various viruses chosen for studies was only available recently. In addition, there is a lack of realisation on the significance of the dynamics of the spread of viruses (Morawska, 2005). Because of the existing complexity of approaches involved within the inward ventilation, Beggs et al. (2008) argue that exact ventilation levels required in the prevention of the infections acquired in hospitals are still unknown.

Even in the different regions or countries, there are also significant variations between the infection-isolated practices (Humphreys et al., 2009). Moreover, "isolation" is a term for infection control as well as prevention poses significant challenges (Dettenkofer et al., 2011). In several establishment, “isolation” is interpreted like “quarantine-type” segregation of patients that are restricted from leaving the isolation room. However, other institutions base their augments on the separation of the patient in a multiple-bed room, whereas some permit the patients to move around, with only healthcare providers being encouraged to put on gowns and gloves during the patient care process. Diverse innovations and developments have been suggested which support disease control that incorporates the diminishment of surgical site diseases utilizing minimally intrusive methods (Dettenkofer et al., 2011). In any case, the utilize of innovative tools such as e-robots using amid operation can lead to a hazard of the transmittal of pathogenic microorganisms in case not appropriately kept up, which is today’s challenge in contamination control personnel.

2.5.5 Preferences of Conflicting Indoor Air between the Staff and Patients

The theory that patients and healthcare staff are regarded as an integrated parties of healthcare consumers with diverse inclinations and demands according to Skoog, Fransson, and Jagemar (2005). As for example, individuals who are in sick, regularly need warm climatic conditions at higher rates compared to the healthcare staff, conceivably since patients leave the healthcare facility within the predictable time (Skoog et al., 2005). Additionally, the doctors’ and the patients' inclinations of indoor humidity and temperature variations between winter and summer seasons (Skoog et al., 2005). Great physical and mental wellbeing frequently expedite the healing of patients and progresses endeavours of the doctors (Kumar, 2000). Hence, it is critical to fulfil a lot of consideration to the indoor air needs of each healthcare user independently.

2.5.6 Lack of Sufficient Knowledge on the HVAC Systems

Insufficient knowledge on the application of HVAC has been broadly cited as one of the preventions to its adoption. According to Hellgren et al. (2011), the need of great instructions for the design and support of ventilators and the inappropriate utilize of the HVAC systems have driven to an increase of diseases in healthcare facilities. Similarly, Clark and de Calcina-Goff (2009) state that the provision for the contamination control, especially, those associated with the HVAC system do not always operate as designed. The healthcare staff is not adequately trained to monitor such systems; hence, faults have been reported and they are often confused with the complexity as well as unreliable engineering controls (Clark & de Calcina-Goff, 2009).

2.5.7. High Energy Consumption of HVAC in Hospitals

According to a research study conducted in 2010, the plans of healthcare facilities pointed at energy-efficient and environmental supportability are being utilized in more than eighty percent of dynamic plans along with trend is inclined to proceed in no time (Bartley, Olmsted, & Haas, 2010). In any case, the application of a few HVAC systems is the most prominent customer of energy in healthcare facilities, accounting for nearly thirty percent of the generally energy of building utilization (Pérez-Lombard, Ortiz, & Mope, 2008). Additionally, the level of the energy utilization of HVAC frameworks five times higher than residences (Pérez-Lombard et al., 2011). The climate of the hospital setting plays a basic part within the decision-making on the energy-saving HVAC mechanism on healthcare facilities and solutions to the challenges ought to be decided.

2.6 Solutions to enhance the HVAC maintenance in healthcare facilities

The previous analysis has demonstrated the role and the challenges affecting HVAC system application in hospital settings. It is important to examine some of the solutions that can enhance HVAC maintenance in healthcare facilities. Here are some of the solutions for the healthcare HVAC system from the existing literature.

2.6.1 Organizational simulation

Li, Heo, and Augenbroe (2009) approved organisational simulation (OS) to analysis the viability of the HVAC mechanism in healthcare facilities. The authors demonstrated that OS could deliver HVAC engineers with beneficial knowledge that is mandatory as well as lessens the risks associated with poor HVAC system designing. The implementation presented by the author could directly calculate the HVAC load within the OS model and was able to feed the dynamic usage information into a dynamic building simulation technique where it able to assess how the HVAC system can perform in numerous functional situations. The analysis of the cost/benefit of the model indicated that the toll is desirable and possibly required within the dynamic organisational procedures (Li et al., 2009).

2.6.2 Improved Infection Control

The regulatory of infection sources through quarantine and usage of negative pressure ventilation are the ways to control the transmission of airborne infections, as stated by Tang et al. (2006). The author also expressed that usage of sliding doors rather to ordinary doors will improves the closures between the doors and windows. By using personal protective equipment (PPE), the both aerosols and direct infection transmission can be eliminated by protecting the exposed vulnerable individuals (Tang et al. 2006).

In addition, the risks associated with the infection of airborne diseases could be reduced in healthcare facilities using high air change rates. In the study conducted by Nielsen et al. (2010), the use of a ceiling-fitted diffuser at low speed was recommended because of its ability to generate vertical displacement and vertical ventilation flow within the room when utilised including high setting of distributed return openings. According to the authors, this kind of flow can generate a personal exposure index that is larger compared to the one produced when the supply temperature is less than the room air temperature. This system can handle high flow rates without necessarily causing high speed, hence, suitable on ventilator in healthcare environment (Nielsen et al., 2010).

2.6.3 The Use of Wireless Sensor Networks

In most modern healthcare facilities and hospitals, there is a challenge of having an interface with different sensor brands that measure different parameters of IAQ. Therefore, there is an urgent need of developing both sensor hardware as well as sensor information technology

software that aid the development of a feasible and functional system for HVAC systems in hospitals. According to Arens et al. (2005), the wireless sensor network reduces the need for cabling as well as enabling the placed sensors in areas where cabling is not mandatory. This facilitates better energy saving and indoor conditioning through an enhanced sensing element as well as able to effortlessly and promptly extend and modified (Arens et al., 2005). Some of the recommended wireless protocols of wireless sensor networks include the breath. This is a latest practice for command application, which transducer signal carry data over multi-domain route to a sink node (Park, 2011). This application in accordance with different modelling routing, duty cycling, as well as medium access control.

2.6.4 The Use of Personalised Ventilation

In a study conducted by Nielsen et al. (2008), it was suggested that the use of an individual diffusor or the diffusors that are associated with hospital beds to offer personalised ventilation (PV), which minimizes the possibility of cross-infection of diseases. By utilizing PV, the receptionists that work in the hospital counters are protected from the infections transmitted by the concerned patients. In addition, the use of PVs can significantly enhance the comforts of occupants, reduce the risk of transmission, and decrease sick building syndrome (SBS) symptoms among the occupants in healthcare buildings (Nielsen et al. (2008). Similarly, Li et al. (2012) presented a discussion on the RFID-based system and argued that it can be used for the PVs in healthcare facilities and hospitals. In this regard, the individual concern for every patient and employees can reserve to proposed system database and the IAQ criterion, which have adopted to real time subject to location of an individual within a hospital.

2.6.5 The Use of HVAC Optimization Techniques

According to Pantelic, Raphael, and Tham (2012), optimization techniques are increasingly be applied to various designs of HVAC mechanisms. However, the authors argue that majority emphasises on maximisation of one purpose that has mostly been minimising the usage of energy. Sub-optimisation techniques such as the improvement of energy efficiency at the indoor conditioning should not adapted in healthcare facilities (Ihasalo, 2012). Therefore, there is necessity to further studies on the multicriterial optimisation techniques which optimises various settings, comprising the levels of carbon dioxide, IAQ (e.g. smoke, dust, etc.), rates of

airflows, lighting, energy, and acoustics usage as well as balancing it generate optimum conditions for the hospital staff and patients (Ihasalo, 2012).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the study methodology that underpins the data collection process. Specifically, the study presents the analysis of the research design, sampling technique, the development of the questionnaire, data analysis, as well as the concluding remarks.

3.2 Research Design

The process of research entails gathering data and trying to make the best of it. This is accomplished by imposing or recognizing trends in the accumulated data or information. Quantitative and qualitative approaches are used based on the size of data, the expected application, and the researcher's preference. The method of quantitative analysis is the prevalent and earliest, also originally came since the native sciences. Surveys, questionnaires, and structured observations are among the quantitative tools of choice (Gregar, 1994). Measurement, defining relationships, generalization, and replication are all aspects of quantitative study (Brown, 2006). The practice of statistics to generalize beginning with small representative samples and progressing to large populations is a main potency of quantitative approaches. Nevertheless, Quantitative research has been chastised for attempting to connect the social and natural dimensions therefore, neglecting the fact that people give value to their experiences in life (Robson and McCartan, 2016).

Qualitative research is not involved with statistics and proving connections depending on numbers. Rather, it is related to discover how the research fields perceive experiences, what specific collective phenomena mean to them, and how it evolves or expand their insights as a result (Robson and McCartan, 2016). Qualitative research consequently emphasizes the perspectives of research respondents, detailed overview and classification of scope, accountability of procedures, adaptability and lack of a universal structure and theoretical frameworks as the results of the research development (Brown, 2006). Quantitative studies oppose qualitative approaches for being too subjective since they depend on the researchers' perspectives, expertise, and relationships with participants. Quantitative studies also point out that research results in qualitative studies do not aim at generalization as they do not utilize representative samples. Qualitative research methods also are assumed to lack transparency in terms of participant selection and data analysis (Saunders et al., 2007). As these claims are focused on a quantitative understanding of research, they have made a significant contribution to a third option, mixed method research.

For this study, a quantitative research design is adopted. This approach was selected to determine the characteristics of Heating, Ventilation, and Air Conditioning (HVAC) maintenance in healthcare facilities in Malaysia. In this regard, the study takes on a quantitative approach through questionnaires. The quantitative approach will be applied to evaluate the relationship between the study variables. According to Apuke (2017), quantitative methods deal with the quantification and assessing of variables to obtain the results. It incorporates using and analysing numerical data through specific statistical techniques to provide answers such as what, who, how much, when, how, and how many. Aliaga and Gunderson (1999) interpret the quantitative research approach as the elaboration of a phenomenon by gathering data in numerical form and assessing them with the help of analytical methods.

The Figure 3.1 shows the overview of research approach used for this study. The overall framework is split to three phases which are Phase 1, Phase 2 and Phase 3. As once the topic of Significance of Heating, Ventilation and Air Conditioning (HVAC) Maintenance in Healthcare Facilities in Malaysia has finalised, the problem statement of the topic has been determined because it facilitates in defining the objectives of the study and defining the scope of the research. The objectives in a study provide a clear vision. The scope is established as soon as the author specifies the objectives. Further processes, such as primary and secondary data collection, data analysis, drawing interpretation, and research conclusions, are carried out based on the objectives. The Phase 1 supported with the Literature Review as well. The Literature Review explores sources relevant to the Significance of HVAC Maintenance in Healthcare Facilities in Malaysia and offers a description, overview, and critical assessment of these works in relation to the research problem under review. The Phase 1 of the thesis is comprised of Chapters 1 and 2.

The Phase 2 comprises the research design and instrument selection in Chapter 3. The research design is anticipated to deliver an appropriate framework for the study. The choice of research method is a crucial decision in the research design process since it decides how important information for the study can be collected. In this case, the quantitative research was selected for this study. The survey questionnaire will be utilised to collect the data. A questionnaire is a set of questions asked to individuals to obtain statistically useful information on the topic chosen. The questionnaire is designed based on the objectives of the study which are significance of HVAC systems in healthcare facilities, problems in maintaining it and solutions to enhance the system. Closed-ended questions responds by having only feedback

that fall into predetermined categories. Nominal data is information that can be classified into a certain category.

The Data Collection, Data Analysation and Research Findings report are falls under Phase 3. The data collection is done through online Google form. It is simple to incorporate and require the respondents to spend the least amount of time. The data is obtained in real time so that the steps can be analysed and decided. The data collection surveys collect information from a targeted group of people such as HVAC technicians, HVAC engineers, technical managers, facilities managers and HVAC contractors. The quantitative data that obtained from the questionnaire will be analysed using the Statistical Package for the Social Sciences (SPSS) software. The software assists to evaluate, create, and generate the pattern from data variables. It also helps to create distribution of trend plots, as well as descriptive statistics like means, medians, modes, and frequencies, as well as more detailed statistical analysis like Kruskal Wallis. The findings of the study are presented with supported by the discussion. The Phase 3 comprise of Chapter 4, Chapter 5 and Chapter 6. The Chapter 6 is more to the conclusion and recommendation for the overall research.

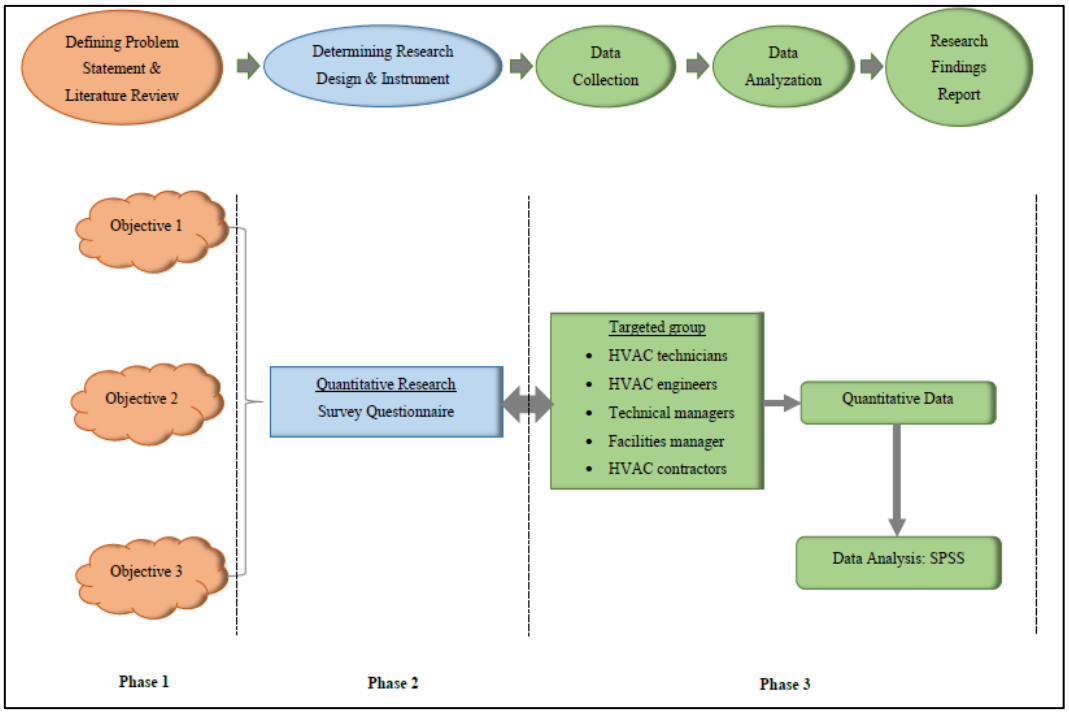

Figure 3.1: Outline of Research Approach

3.3 Questionnaire Development

Since the current study employs a quantitative means of data collection, a structured questionnaire will be used for data collection. Questionnaires were selected for this study because they are a reliable and fast way to collect data from a large number of people in a short amount of time. This is particularly critical when working on a topic with many complex goals and time as a major constraint. This study was no exception and questionnaires were a quick and effective way for the author to reach multiple respondents from the targeted group within several weeks. The questionnaire was developed in Google form and distributed the link to the targeted group. The questionnaire will consist of four sections, which cover the background information of the participants as well as the study objectives. In the first section, the questionnaire will present the demographic information of the participants, which includes gender, age, and experience with handling HVAC in a healthcare facility setting. In section two, information about the significance of the HVAC system in healthcare facilities will be provided. Section three will presents questions concerning the problems in maintaining HVAC in healthcare facilities. Lastly, section four will comprise questions that will seek to determine the solutions to enhance HVAC maintenance in healthcare facilities. For the section 2, 3 and 4, the questions will be on a 5-point Likert scale, with statements that the respondents will be required to either strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree in scale of 1 to 5.

3.4 Sampling and Population

3.4.1 Target population

According to Majid (2018), the population of interest refers to the study's target population that it intends to investigate. In hospitals and healthcare settings, it is normally not appropriate or feasible to recruit the entire population of interest into the study. Instead, the researcher recruits a sample from the overall population of interest to be included in the study. In this case, the main of the study is to give generalisations of the study findings from the sample of the population of interest (Van den Broeck, Sandøy, & Brestoff, 2013). In the current study, the population of interest includes technical personnel like HVAC technicians, HVAC engineers, technical managers, facilities managers and HVAC contractors due to their knowledge and experience in handling HVAC maintenance.

3.4.2 Sampling Size

Sampling refers to the process of selecting a statistically representative sample of the population of interest. Sampling is an essential tool for any research because the population of interest often comprises too many individuals for the study to be included as participants. According to Browner et al. (1988), a good study sample is statistically representative of the target population and is often adequate to provide answers to the research question. Various sampling techniques have been proposed in the previous studies, which include cluster, stratified, simple random, and purposive/convenience sampling (Majid, 2018). According to MacCallum (1999), a sample size of 100 participants is considered adequate for a study. Therefore, in the current study, purposive sampling of 100 participants will be adopted. Tongco (2007) posits that purposive sampling is a type of non-probability sampling, which is most effective when the researcher wants to study a certain phenomenon with knowledge experts within.

3.5 Data Collection

3.5.1 The Data Collection Process

The data collection process consists of four steps as shown in Figure 3.2. The application of ethics is moral principles that direct researchers in conducting and reporting research without deception or the intent to harm survey respondents or society, whether intentionally or unintentionally. It is important to follow ethical standards when researching and publishing studies in order to ensure the authenticity of the findings. Besides, emails were sent to the hospitals to seek permission to conduct the survey. This is to inform the hospitals that all information obtained will be treated as confidential and purely for academic purposes. Then, the pilot study is conducted to recognise potential problem areas and deficiencies in the survey questionnaire and its procedure prior to implementation during the full study before the actual data being collected.

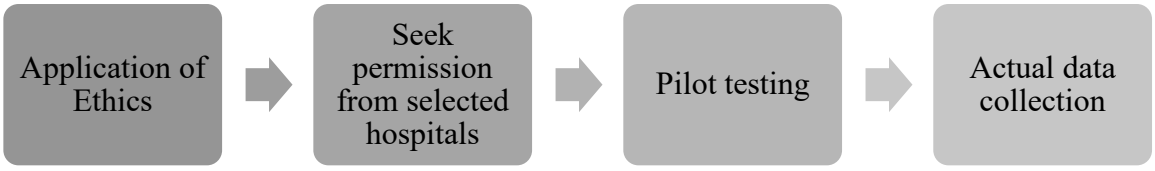

Figure 3.2: The Data Collection Process

3.5.2 Ethical Consideration

The study will keep the details of the participants anonymous and confidential. According to Fouka and Mantzorou (2011), anonymity is ensured when the identity of the subject cannot be linked to the responses obtained at the end of the study. However, the author posits that if the research cannot promise the principle of anonymity, then he/she must adequately address the concerns of confidentiality; the management of private data by the study to protect the identity of the respondents. Protection of the integrity of research participants is a mostly important ethical norm in research. This standard emphases on protection against numerous forms of risk involved in participation in research and the protection of the identity of participants, including concerns for avoiding stigmatisation of particular populations or groups.

3.6 Data Analysis

Statistical Package for Social Science (SPSS) software version 21 will be employed in the analysis of the collected data. In this regard, the data will be presented in form of Frequency Analysis, Cronbach's Alpha, Mean Ranking, and the Kruskal-Wallis Test.

3.6.1 Validity of the Research Instrument

Face and content validity will be applied to the questionnaire. According to Kothari (2004), validity refers to the extent to which given research measures what it is meant to measure. Face validity is a subjective assessment of a construct's operationalization. Face validity is the degree to which a measure directly correlates to a specific construct, in the judgement of nonexperts such as test takers and representatives. In general, content validity is the process of evaluating a new survey instrument to ensure that it contains all the required items while excluding those that are irrelevant to a specific construct domain. To measure face and content validity, the researcher will consult the supervisor to assess whether the items in the questionnaire measure what they are meant to measure and accurately address the study objectives (Bashir and Marudhar, 2018).

3.6.2 Reliability of the Research Instrument

According to Roberts and Priest (2006), reliability of the study instrument refers to the extent to the designed tool can be used repeatedly under constant conditions and produce the same

results. It refers to the constancy and stability of a research tool and is used to assess the consistency of the values executed at various intervals to similar subjects and the similarity of the sets of items from the test (Bashir and Marudhar, 2018). In the current study, Cronbach's Alpha will be used to test the reliability of the questionnaire, where values reflect the better consistency of the data.

3.6.2.1 Cronbach's Alpha

Cronbach (1951) developed Cronbach's Alpha to measure reliability or internal consistency. This test is to measure the internal consistency reliability of the data. The higher the values reflect the better consistency of the data. It is most widely used when the questionnaire has multiple Likert questions in that form a scale and to evaluate if the results are consistent. Cronbach Alpha is a crucial concept in the assessment and questionnaire evaluation process. Assessors and researchers should measure this number in order to enhance the validity and accuracy of their data analysis. The table 3.1 shows the Cronbach's Alpha rule of thumb.

Table 3.1 Cronbach's Alpha rule of thumb

Cronbach's Alpha	Level of Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha$	Poor

3.6.3 Frequency Analysis

Frequency Analysis is a part of statistical analysis. The frequency of an occurrence is defined in statistics as the number of times it occurs. Frequency Analysis is a branch of statistics that examines measures of central tendency, dispersion, percentiles, and other statistics related to the number of occurrences (D. Hulshof, 2001). Frequency analysis is used to analyse the

frequency of times the total respondent chosen on each question. Mean can also be calculated by using the SPSS software tool.

3.6.3.1 Mean Ranking Analysis

The mean rank method is an analysis method that using collected data the generate the mean that has the same frequency average occurring and then rank it by sorting out the data. This method is to establish the priority among the same topic of interest. This method is frequently used to rank the items from best to worst in a group. The purpose is to provide a set of numbers that clearly expresses the main tendency of people's preferences.

3.6.4 Kruskal-Wallis Test

Kruskal-Wallis Test is a rank-based nonparametric test, which will use to test and compare if there are statistically significant differences between two groups in the questionnaire. Kruskal-Wallis is widely used as a test of equality of medians or even means. The Kruskal-Wallis test does not presume that the data come from a distribution that can be totally defined by two parameters, mean and standard deviation (the way a normal distribution can). The purpose of this test is to test whether independent variables and the dependable variable will have significant differences in results toward two or more groups.

3.7 Summary

In conclusion, this chapter has presented the study presents the analysis of the research design through the outline of the research approach, the development of the questionnaire, the sampling population, data collection and data analysis. The details of each subsection described accordingly which can be categorised into three phases. The study adopts a descriptive research design and quantitative approach that uses a structured questionnaire.

CHAPTER 4

RESULTS & FINDINGS

4.1 Introduction

This chapter provides the data analysis collected through structured questionnaires. The presentation data in regard is based on the objectives of the study. First, this chapter begins by demonstrating the response rates. This is then followed by the data on the significance of the HVAC system, the problems in maintaining HVAC, the solutions to enhance the HVAC maintenance in healthcare facilities. Besides, this chapter will discuss the finding of the survey that has been carried out. The major outcome of the findings in the survey are discussed in this section, and any recommendations for future study can be suggested at the end of this section.

4.1.1. Response Rate

The study distributed 100 questionnaires representing the sample population to the respondents. The positive respondents were 84 that represented 84% of the total population. On the other hand, 16 were non-respondents, implying that 16% did not participate in the study as expected. According to Mugenda and Mugenda (2003), a number of responses of 50% is satisfactory, and a number of responses of more than 70% is excellent. As a result, the study's success rate was optimal. This success rate could be due to the research methods, in which the researcher pre-notified target respondents via the administration before conducting the study.

Table 4.1 Response Rate

Variable	Frequency/Percentage
Number of distributed questionnaires	100
Positive respondents	84
Non-respondents	16
Response rate	84%

4.2 Frequency Analysis

4.2.1 Respondents Background

The findings in Table 4.2 show the respondents' background who took part in the study. First, in terms of the level in the HVAC, it was noted that 32.1% (n=27) of the respondents were based on building management, 28.6% (n=24) were in facility management, 22.6% (n=19) were mechanical contractors, and 16.7% (n=14) were electrical contractors. Secondly, in terms of the types of healthcare facilities, the majority 39.3% (33) were from public hospitals, while the rest (private hospitals, military hospitals, and teaching hospitals) were 20.2% (n=17) respectively. Thirdly, in terms of the experience in the maintenance of HVAC, the majority 36.9% (n=31) had an experience of fewer than 3 years, while the rest, which is, 3-6 years, 7-10 years, and more than 10 years were 19.0% (n=16) , 27.4% (n=23), and 16.7% (n=14) respectively.

Table 4.2 The Respondents' Background

Respondents' Background	Frequency	Percentage
1) Level in The HVAC Maintenance		
Facility Management	24	28.6
Building Management	27	32.1
Mechanical Contractor	19	22.6
Electrical Contractor	14	16.7
2) Type of Healthcare Facilities		
Public Hospital	33	39.3
Private Hospital	17	20.2
Military Hospital	17	20.2
Teaching Hospital	17	20.2
3) Experience in HVAC Maintenance		
Less Than 3 Years	31	36.9
3-6 Years	16	19.0
7-10 Years	23	27.4
More Than 10 Years	14	16.7

4.2.2 The significance of the HVAC system in healthcare facilities

The study sought to determine the significance of the HVAC system in healthcare facilities. The study findings demonstrated that the majority of the respondents (54.8%, n=46) agreed that HVAC was helpful in comfort conditioning in terms of facilitating recovery and healing. Similarly, most of the respondents (64.3%, n=54) agreed that HVAC was helpful in therapeutic conditioning where some medical treatments, functions, or the healing process demand the controlled environmental temperatures and relative humidity conditions. It was further noted that the majority of the respondents (42.9%, n=36) strongly agreed that HVAC helped facilitate infection control because it requires strict operational practices in controlling infectious pathogenic microorganisms. In addition, a slight minority of the respondents (38.1%, n=32) agreed that HVAC helped in environmental control and ventilation for special function by assisting in the maintenance of sterile conditions for the procedures or products that need to be protected from harmful environmental contaminants. These findings are demonstrated in Table 4.3.

Table 4.3 The Significance of The HVAC System in Healthcare Facilities

Significance of The HVAC System in Healthcare Facilities	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree	
	n	%	n	%	n	%	n	%	n	%
Comfort Conditioning	26	31.0	46	54.8	4	4.8	5	6.0	3	3.6
Therapeutic Conditioning	22	26.2	54	64.3	4	4.8	2	2.4	2	2.4
Infection Control	36	42.9	25	29.8	10	11.9	5	6.0	8	9.5
Environmental Control and Ventilation for Special Function	28	33.3	32	38.1	15	17.9	8	9.5	1	1.2

4.2.3 The problems in maintaining HVAC in healthcare facilities

The study further sought to determine the problems encountered in the maintenance of HVAC within healthcare facilities. The study findings demonstrated that slightly above 40% of the respondents either or strongly disagreed that the main problems in maintaining HVAC include lack of adequate sensors, high energy consumption, poor data handling, visualisation, and archiving the building automation system. On the other hand, the respondents above 30% either agreed or strongly agreed that the main problems in the maintaining HVAC include complexity in the prevention of the spread of airborne infections and lack of sufficient knowledge on the HVAC systems. The respondents below 30% agreed that the main problems include poor

hospital design and lack of sufficient knowledge on the HVAC systems. The summary of the study findings is demonstrated in Table 4.4.

Table 4.4 The Problems in Maintaining HVAC In Healthcare Facilities

Problems in HVAC maintenance	Strongly agree		Agree		Neutral		Disagree		Strongly disagree	
	n	%	n	%	n	%	n	%	n	%
Poor Hospital Design	13	15.5	23	27.4	19	22.6	17	20.2	12	14.3
Lack of Adequate Sensors	31	36.9	37	44.0	5	6.0	5	6.0	6	7.1
Poor Data Handling, Visualisation and Archiving the Building Automation System	37	44.0	22	26.2	8	9.8	11	13.1	6	7.1
The complexity in the prevention of the spread of airborne infections	28	33.3	29	34.5	8	9.5	12	14.3	7	8.3
Preferences of conflicting indoor air between staff and patients	12	14.3	23	27.4	20	23.8	15	17.9	14	16.7
Lack of sufficient knowledge on the HVAC systems	27	32.1	29	34.5	3	3.6	20	23.8	5	6.0
High energy consumption	37	44.0	22	26.2	8	9.8	11	13.1	6	7.1

4.2.4 Solutions to Enhance the HVAC Maintenance in Healthcare Facilities

The study further sought to determine the solutions to enhance HVAC maintenance in healthcare facilities. the study findings demonstrated that the majority of the respondents (53.6%, n= 45) agreed that hospitals and healthcare facilities should adopt the use of wireless sensor networks by developing both sensor hardware as well as sensor information technology software that aid the development of a feasible and functional system for HVAC systems in hospitals. In addition, 48.8% (n=41) of the respondents proposed the use of Personalised Ventilation (PV) through a separate diffuser or the diffusers that are integrated into the hospital beds to offer PV. Similarly, 48.8% (n=41) of the respondents strongly agreed that hospitals should use HVAC optimization techniques, which include multi-criteria optimisation techniques that optimise various parameters, including the levels of carbon dioxide, IAQ (e.g.

smoke, dust, etc.), rates of airflows, lighting, energy, and acoustics consumption. The rest of the respondents (below 40%) either agreed or strongly agreed that hospitals and healthcare facilities should adopt organizational simulation (OS), and improved infection control mechanisms. These findings are demonstrated in Table 4.5.

Table 4.5 Solutions to Enhance the HVAC Maintenance in Healthcare Facilities

Solutions to Enhance the HVAC Maintenance in Healthcare Facilities	Strongly agree		Agree		Neutral		Disagree		Strongly disagree	
	n	%	n	%	n	%	n	%	n	%
Organizational Simulation (OS)	33	39.3	32	38.1	11	13.1	8	9.5	0	0
Improved Infection Control	19	22.6	32	38.1	14	16.7	13	15.5	6	7.1
The Use of Wireless Sensor Networks	15	17.9	45	53.6	7	8.3	7	8.3	10	11.9
The Use of Personalised Ventilation (PV)	10	11.9	41	48.8	16	19.0	9	10.7	8	9.5
The Use of HVAC Optimization Techniques	41	48.8	15	17.9	11	13.1	8	9.5	9	10.7

4.3 Mean Ranking Data

The purpose of the mean ranking data was to rank the respondents' feedback on the significance of HVAC maintenance in healthcare facilities in Malaysia. The mean ranking test is to show the position of the variable, that is, frequency that is more common.

4.3.1 Mean Ranking for The Significance of The HVAC System in Healthcare Facilities

On the significance of the HVAC system in healthcare facilities, the mean ranking of variables starting from the highest to the lowest include infection control, comfort conditioning, therapeutic conditioning, and environmental control and ventilation for a special function, as demonstrated in Table 4.6.

Table 4.6. Mean Ranking for The Significance of The HVAC System in Healthcare Facilities

The Significance of The HVAC System in Healthcare Facilities	**Mean**	**Ranking**
Comfort Conditioning	2.50	2
Therapeutic Conditioning	2.49	3
Infection Control	2.55	1
Environmental Control and Ventilation for Special Function	2.46	4

4.3.2 Mean ranking for the problems in maintaining HVAC in healthcare facilities

The study sought to determine the mean ranking for the variables on the problems encountered in the maintenance of HVAC in healthcare facilities. Based on the study findings demonstrated in Table 4.7, the problems encountered in order of the most significant ones include lack of adequate sensors, poor data handling, visualisation, as well as archiving the building automation system. The complexity in the prevention of the spread of airborne infections, the high energy consumption of HVAC in hospitals, preferences of conflicting indoor air between staff and patients, poor hospital design, and preferences of conflicting indoor air between staff and patients.

Table 4.7 Mean Ranking for The Problems in Maintaining HVAC In Healthcare Facilities

The Problems in Maintaining HVAC In Healthcare Facilities	**Mean**	**Ranking**
Poor Hospital Design	3.27	6
Lack of Adequate Sensors	4.79	1
Poor Data Handling, Visualisation, and Archiving the Building Automation System	4.58	2
The Complexity in The Prevention of The Spread of Airborne Infections	4.14	3
Preferences of Conflicting Indoor Air Between Staff and Patients	3.10	7
Lack of Sufficient Knowledge on The HVAC Systems	4.05	5
High Energy Consumption of HVAC In Hospitals	4.07	4

4.3.3 Mean Ranking for The Solutions to Enhance the HVAC Maintenance in Healthcare Facilities

The study further determined the respondents' opinion on the solutions that can be adopted in enhancing HVAC maintenance. The study findings as demonstrated in Table 4.8 demonstrate that the solutions to enhance the HVAC maintenance in healthcare facilities, in order of the most significant ones to the least significant ones include the use of OS, HVAC optimization techniques, wireless sensor networks, improved infection control, as well as the use of personalised ventilation (PV).

Table 4.8 Mean Ranking for The Solutions to Enhance the HVAC Maintenance in Healthcare Facilities

The Solutions to Enhance the HVAC Maintenance in Healthcare Facilities	Mean	Ranking
Organizational Simulation (OS)	3.48	1
Improved Infection Control	2.80	4
The Use of Wireless Sensor Networks	2.81	3
The Use of Personalised Ventilation (PV)	2.68	5
The Use of HVAC Optimization Techniques	3.24	2

4.4 Cronbach's Alpha Test

The internal consistency of the study questionnaire was tested using the Cronbach's Alpha Test, where the values above 0.9 were considered excellent, above 0.8 was considered to be good, and above 0.7 considered acceptable. From table 4.9. It was demonstrated that the Cronbach's Alpha values of the tested variables were above 0.7, indicating that the internal consistency of the study instrument was acceptable, hence reliable.

Table 4.9. The Cronbach's Alpha Test

Variable	Cronbach's Alpha	N of Items
Background Information	.701	3
The significance of the HVAC system in healthcare facilities.	.745	4
The problems in maintaining HVAC in healthcare facilities	.803	7
Solutions to enhance the HVAC maintenance in healthcare facilities	.705	5

4.5 Kruskal-Wallis Test

Kruskal-Wallis test was adopted in the current study to determine the significant differences between the level in the HVAC maintenance in Healthcare facilities and the significance of the HVAC system, problems in maintaining HVAC, and Solutions to enhance the HVAC maintenance. The significance value was determined at 0.05. If the p-value is less than or equal to the significance level, the null hypothesis will be rejected and conclude that not all the group medians are equal. On the other hand, if the p-value is greater than the significance level, it does not have enough evidence to reject the null hypothesis that the group medians are all equal. Therefore, if the value is more than 0.05, this meaning that the group is significant.

4.5.1 Kruskal-Wallis Test for The Significance of The HVAC System in Healthcare Facilities

The study sought to determine the Kruskal-Wallis test on the variables representing the significance of the HVAC system in healthcare facilities. The study findings as demonstrated in Table 4.10 show the out of the four variables, two (comfort conditioning and infection control) had a significant value that was greater than 0.05; hence, the group was significant. On the other hand, two (therapeutic conditioning and environmental control and ventilation for special function) having a significant value less than 0.05.

Table 4.10. Kruskal-Wallis Test for The Significance of The HVAC System in Healthcare Facilities

Variable	Chi-Square	Df	Asymp. Sig.
Comfort Conditioning	5.214	3	.157
Therapeutic-Conditioning	7.997	3	.046
Infection Control	.600	3	.896
Environmental Control and Ventilation for Special Function	10.765	3	.013

a. Kruskal Wallis Test

b. Grouping Variable: level in the HVAC maintenance in Healthcare facilities

4.5.2 Kruskal-Wallis Test for The Problems in Maintaining HVAC in Healthcare Facilities

The study further sought to determine the significance between the variables on the problems in the maintenance of HVAC and level in the HVAC maintenance in Healthcare facilities. The study findings demonstrated in the table the majority of the variables (5 out 7) had a significance value larger than 0.05. This indicates that these variables had statistically significant differences with the levels in the HVAC maintenance in Healthcare facilities. In this case, the variables that had statistically significant differences with the levels in HVAC maintenance include lack of adequate sensors, poor data handling, visualisation and archiving of the building automation system, the complexity in the prevention of the spread of airborne infections, preferences of conflicting indoor air between staff and patients, and lack of sufficient knowledge on the HVAC systems, as shown in Table 4.11.

Table 4.11. Kruskal-Wallis Test for The Problems in Maintaining HVAC in Healthcare Facilities

Variable	Chi-Square	Df	Asymp. Sig.
Poor Hospital Design	15.006	3	.002
Lack of Adequate Sensors	4.125	3	.248
Poor Data Handling, Visualisation, and Archiving the Building Automation System	1.943	3	.584
The Complexity in The Prevention of The Spread of Airborne Infections	5.783	3	.123
Preferences of Conflicting Indoor Air Between Staff and Patients	1.279	3	.734
Lack of Sufficient Knowledge on The HVAC Systems	4.860	3	.182
High Energy Consumption of HVAC In Hospitals	8.081	3	.044

a. Kruskal Wallis Test

b. Grouping Variable: level in the HVAC maintenance in Healthcare facilities

4.5.3 Kruskal-Wallis Test for the Solutions to enhance the HVAC maintenance in healthcare facilities.

The study further examined the differences in the variables of the solutions to enhance HVAC maintenance and the level of HVAC maintenance in healthcare facilities. The study findings as demonstrated in Table 4.12 show that all variables had a significance value more than 0.05, specifying that they had statistically significant differences. Therefore, there was a statistically significant difference between organizational simulation (OS), improved infection control, the use of wireless sensor networks, the use of HVAC optimization techniques, and the level of HVAC maintenance in healthcare facilities.

Table 4.12. Kruskal-Wallis Test for The Solutions to Enhance the HVAC Maintenance in Healthcare Facilities.

Variable	Chi-Square	Df	Asymp. Sig.
Organizational Simulation (OS)	4.922	3	.178
Improved Infection Control	1.088	3	.780
The Use of Wireless Sensor Networks	7.316	3	.062
The Use of Personalised Ventilation (PV)	5.287	3	.152
The Use of HVAC Optimization Techniques	6.087	3	.107

a. Kruskal Wallis Test

b. Grouping Variable: The level of the HVAC maintenance in Healthcare facilities

4.6 Summary of the Results

This section of 4.2 has presented the data that was collected and analysed using various methods. A total of 84 participants, representing 84% positively responded to the study questionnaires and was considered to be satisfactory for analysis. The frequency analysis was used to determine the respondents' background, as well as the significance of the HVAC, problems in maintaining HVAC, and the solutions to enhance the HVAC maintenance in healthcare facilities. The outcomes from the Cronbach's Alpha Test presented in this chapter have a value of more than 0.7. The mean ranking analysis was used to determine major factors on the significance of the HVAC system, problems in maintaining HVAC, and the solutions to enhance the HVAC maintenance in healthcare facilities. Lastly, the Wallis Test was used to identify if there are significant differences between the group variables.

CHAPTER 5

DISCUSSION

5.1 Introduction

This chapter provides the discussion for the results and findings presented in previous chapter. The presentation of the discussion is based on the objectives of the study. First, this chapter begins with respondent's background and how it can be related to the objectives. Besides, this chapter will discuss the three objectives of the study which are the significance of the HVAC system, problems in maintaining it and solutions to enhance it.

5.2 Respondent's Background

The study findings demonstrated that the respondents were widely distributed in terms of building management, facility management, mechanical contractor, and electrical contractors. This demonstrates that the study respondents were individuals with first-hand information regarding the use and maintenance of HVAC in hospitals and healthcare facilities. In addition, the respondents were also widely distributed among different types of hospitals, with a slight majority coming from public hospitals, and others from the private, military, and teaching hospitals. This ensured that the data obtained was not biased in any way to a healthcare setup. It was also noted that the study respondents were individuals with adequate experience in the use and maintenance of HVAC systems. In this regard, all the respondents had more than three years of experience working in busy healthcare facilities that had adopted HVAC systems in their operations. The Figure 5.1 illustrates the clustered bar chart of percentage of respondents' background.

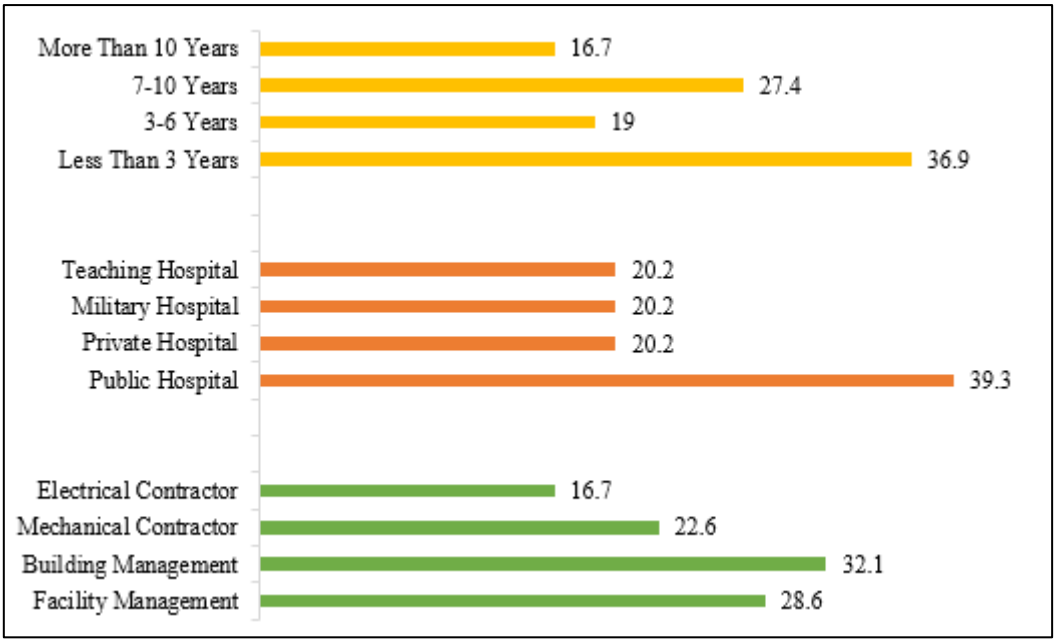

Figure 5.1 Clustered Bar Chart of Percentage of Respondents' Background.

5.3 Significance of the HVAC System in Healthcare Facilities

The study examined the significance of the HVAC system in healthcare facilities. From the study outcomes, it was demonstrated that HVAC systems were significant in comfort conditioning in terms of facilitating recovery and healing, therapeutic conditioning where some medical treatments, functions, or the healing process demand the controlled environmental temperatures and relative humidity conditions. It was also noted that HVAC systems helped in facilitating infection control because it requires strict operational practices in controlling infectious pathogenic microorganisms. Finally, the study found that some hospitals also used HVAC in environmental control and ventilation for special function by assisting in the maintenance of sterile conditions for the procedures or products that need to be protected from harmful environmental contaminants. The mean ranking of variables starting from the highest to the lowest includes infection control, comfort conditioning, therapeutic conditioning, and environmental control and ventilation for a special function. These findings are in line with Sánchez-Barroso and & García Sanz-Calcedo (2019), Joppolo and Romano (2017), Azimi and Stephens (2013), and Moscato et al. (2017) who found that the significance of HVAC system include facilitating infection control, comfort conditioning, therapeutic conditioning, and environmental control and ventilation for a special function. The Figure 5.2 shows the bar chart represents the mean of Significance of the HVAC System in Healthcare Facilities.

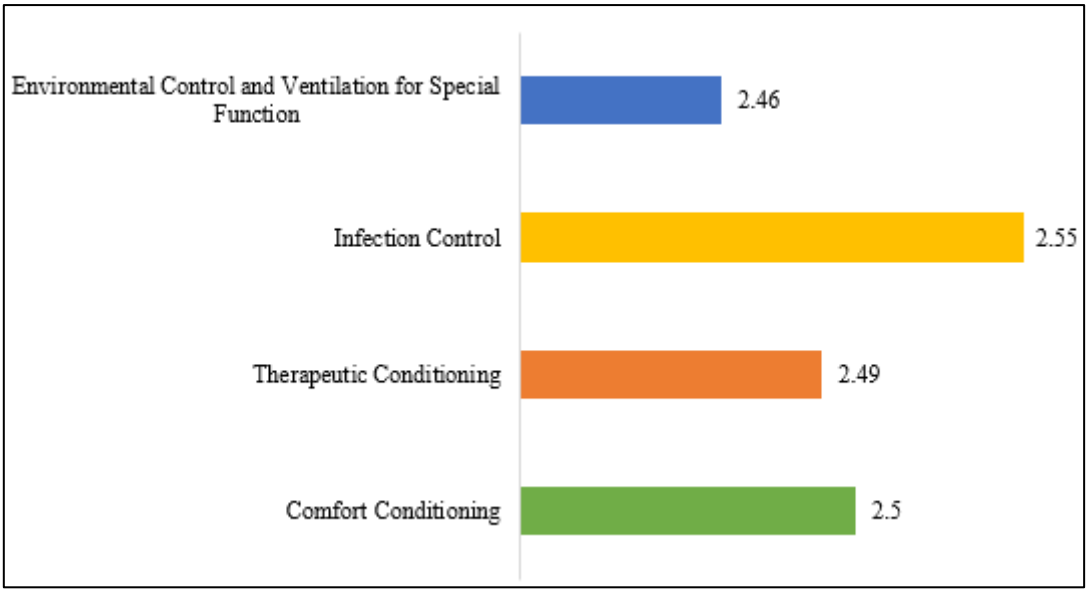

Figure 5.2 Bar Chart of the Mean of Significance of the HVAC System in Healthcare Facilities.

Moreover, the Kruskal-Wallis test demonstrated that out of the four variables, two (comfort conditioning and infection control) had statistically significant differences with the levels in HVAC maintenance, while therapeutic conditioning and environmental control and ventilation for special function demonstrated otherwise.

5.4 Problems in Maintaining HVAC in Healthcare Facilities

Despite the positive significance experience by the use HVAC system, the study found significant problems in the maintenance of the system. these problems include lack of adequate sensors, high energy consumption, poor data handling, visualisation and archiving of the building automation system, complexity in the prevention of the spread of airborne infections, lack of sufficient knowledge on the HVAC systems, poor hospital design, and lack of sufficient knowledge on the HVAC systems. Based on the mean raking data, the problems encountered in order of the most significant ones include lack of adequate sensors, poor data handling, visualisation and archiving the building automation system, complexity in the prevention of the spread of airborne infections. The other problems include high-energy consumption of HVAC in hospitals, preferences of conflicting indoor air between staff and patients, poor hospital design, and preferences of conflicting indoor air between staff and patients. Similar studies were reported in Clark & de Calcina-Goff (2009), Ihasalo (2012), Brambley et al. (2005), Tang et al. (2006), Morawska (2006), Fransson and Jagemar (2005), Hellgren et al.

(2011), as well as in Bartley et al. (2010). The Figure 5.3 shows the bar chart represents the mean of Problems in Maintaining HVAC in Healthcare Facilities.

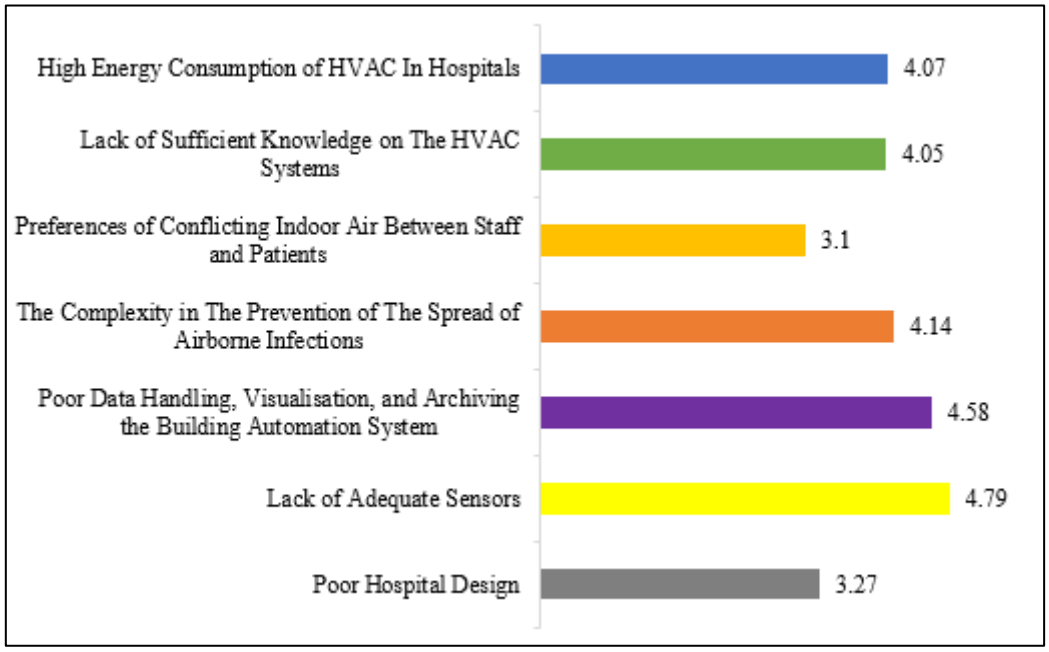

Figure 5.3 Bar Chart of the Mean of Problems in Maintaining HVAC in Healthcare Facilities

Moreover, the study determined the significance between the variables on the problems in the maintenance of HVAC and level in the HVAC maintenance in Healthcare facilities. The study found that 5 out 7 variables had statistically significant differences with the levels in the HVAC maintenance, which include lack of adequate sensors, poor data handling, visualisation and archiving the building automation system, the complexity in the prevention of the spread of airborne infections, preferences of conflicting indoor air between staff and patients, and lack of sufficient knowledge on the HVAC systems.

5.5 Solutions to Enhance the HVAC Maintenance in Healthcare Facilities

Based on the problems encountered in the HVAC maintenance in healthcare facilities, the study outcomes presented various solutions. These include using wireless sensor networks by developing both sensor hardware as well as sensor information technology software that aid the development of a feasible and functional system for HVAC systems in hospitals. The other solutions include the use of Personalised Ventilation (PV) through an individual diffusor or the diffusors that are incorporated to the hospital beds to offer PV, use of HVAC optimization techniques that include multi-criteria optimisation techniques that optimise various parameters,

including the levels of carbon dioxide, IAQ (e.g. smoke, dust, etc.), rates of airflows, lighting, energy, and acoustics consumption, organizational simulation (OS), and improved infection control mechanisms. Based on the mean ranking data, the most significant solutions include the use of OS, HVAC optimization techniques, wireless sensor networks, improved infection control. All the factors tested in this regard had statistically significant differences. These include organizational simulation (OS), improved infection control, use of wireless sensor networks, use of HVAC optimization techniques, and the level in the HVAC maintenance in healthcare facilities had statistically significant differences with the levels of HVAC maintenances. These findings are like what were reported in Li et al. (2009), Nielsen et al. (2010), Arens et al. (2005), as well as in Pantelic et al. (2012). The Figure 5.4 shows the bar chart represents the mean of Solutions to Enhance the HVAC Maintenance in Healthcare Facilities.

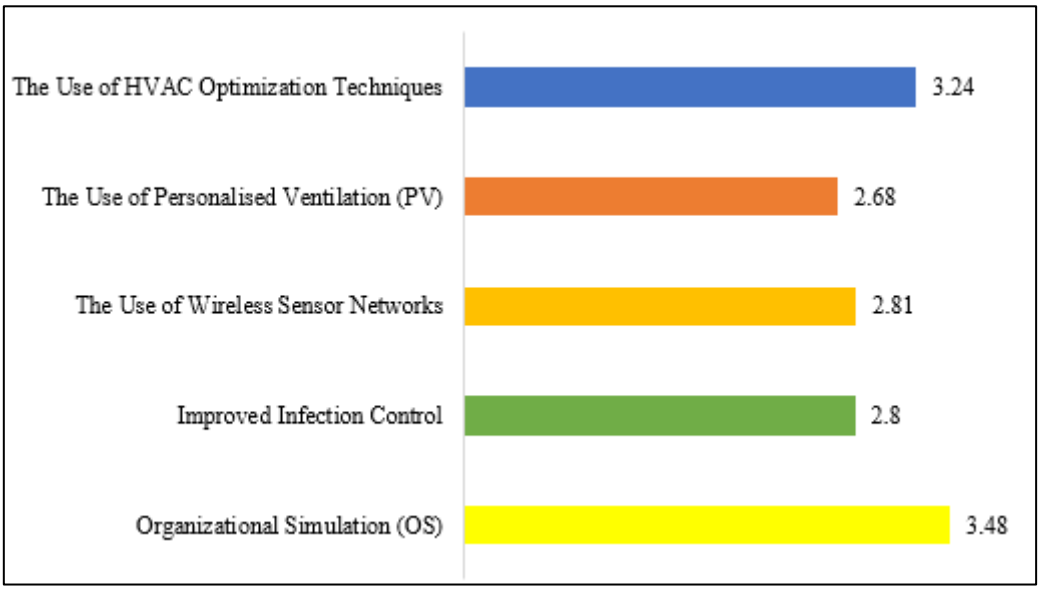

Figure 5.4 Bar Chart of the Mean of Solutions to Enhance the HVAC Maintenance in Healthcare Facilities

5.6 Summary

In conclusion, this chapter has presented the discussion based on the data analysis from the results and findings. Basically, the data analysis results which are Cronbach alpha, Mean Ranking and Kruskal Wallis in previous chapter contributed the discussion and how it can relate to the research objectives.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter is the summary of the objective of this survey. Conclusion of the overall data collected and the outcome of the findings. Limitations and recommendations for future research are suggested.

6.2 Discussion of Research Objective

The objective of this survey is to explore the significance of the HVAC system in healthcare facilities, to identify problems in maintaining HVAC in healthcare facilities and to determine the solutions to enhance the HVAC maintenance in healthcare facilities. The questionnaire had been divided into four sections and distributed to respondents who are in healthcare facilities such as HVAC technicians, HVAC engineers, technical managers, facilities managers and HVAC contractors. First objective was achieved by exploring the significance of the HVAC system in healthcare facilities. Majority of the respondents agreed that infection control is the top priority of HVAC system in healthcare facilities. Second objective of identify problems in maintaining HVAC in healthcare facilities was done by mean ranking and the results shows that lack of adequate sensors has agreed by the people in this field. The topmost solution to enhance the HVAC maintenance in healthcare facilities has been highlighted by the respondents which was Organizational Simulation where this method can prevent the HVAC system from unnecessary breakdowns.

6.3 Summary of Objectives

6.3.1 The Significance of the HVAC System in Healthcare Facilities

Based on the study outcomes, the study concluded that HVAC systems were significant in comfort conditioning, therapeutic conditioning, facilitating infection control, and environmental control and ventilation for special function by assisting in the maintenance of sterile condition for the procedures or products that need to be protected from harmful

environmental contaminants. Among these factors, only comfort conditioning and infection control have statistically significant differences with the levels in HVAC maintenance.

6.3.2 Problems in Maintaining HVAC in Healthcare Facilities

Based on the study outcomes, it can be concluded that the main problems affecting the maintenance of HVAC system include lack of adequate sensors, high-energy consumption, poor data handling, visualisation and archiving of the building automation system. The problems include complexity in the prevention of the spread of airborne infections, lack of sufficient knowledge on the HVAC systems, poor hospital design, and lack of sufficient knowledge on the HVAC systems.

6.3.3 Solutions to Enhance the HVAC Maintenance in Healthcare Facilities

The study concluded that the main solutions for HVAC maintenance in healthcare facilities include the use of organizational simulation (OS), improved infection control, use of wireless sensor networks, and use of HVAC optimization techniques.

6.4 Limitations of Research

The study did not achieve the 100% response rates, which may have significant impacts on the Kruskal-Wallis. This might have been because of uneven distribution of the study questionnaire. In addition, some respondents were unwilling to provide information because of the policy on data disclosure. The time-consuming factor was also a limiting factor especially the data collection process. Besides, the topic of the study is focusing on healthcare facilities, where the author had difficulties to access the respondents during this COVID 19 pandemic. This is because people in this field are classified as front liners, so they are occupied as well.

6.5 Recommendations

In practice, the study recommends that healthcare facilities and hospitals in Malaysia should adopt organizational simulation (OS), improve infection control, use wireless sensor networks, and optimisation techniques to enhance maintenance of HVAC systems. Basically, the respondents in the related knows the significance of the HVAC system in the healthcare

facilities which are infection control, comfort condition, therapeutic control and finally environmental control and ventilation for special function. In terms of future studies, the study recommends similar studies to be conducted using a different methodology that can use more respondents such as case studies or cross-sectional designs to obtained comparative outcomes. A highly recommended study that can be looked at in the future would be the innovations in HVAC technology in healthcare facilities. Gathering information on how technology is influencing HVAC for the better, Smart HVAC technology, HVAC systems with sustainable technology and thermally driven air conditioning using solar energy would be helpful for the HVAC professionals to enhance their knowledge to implement it.

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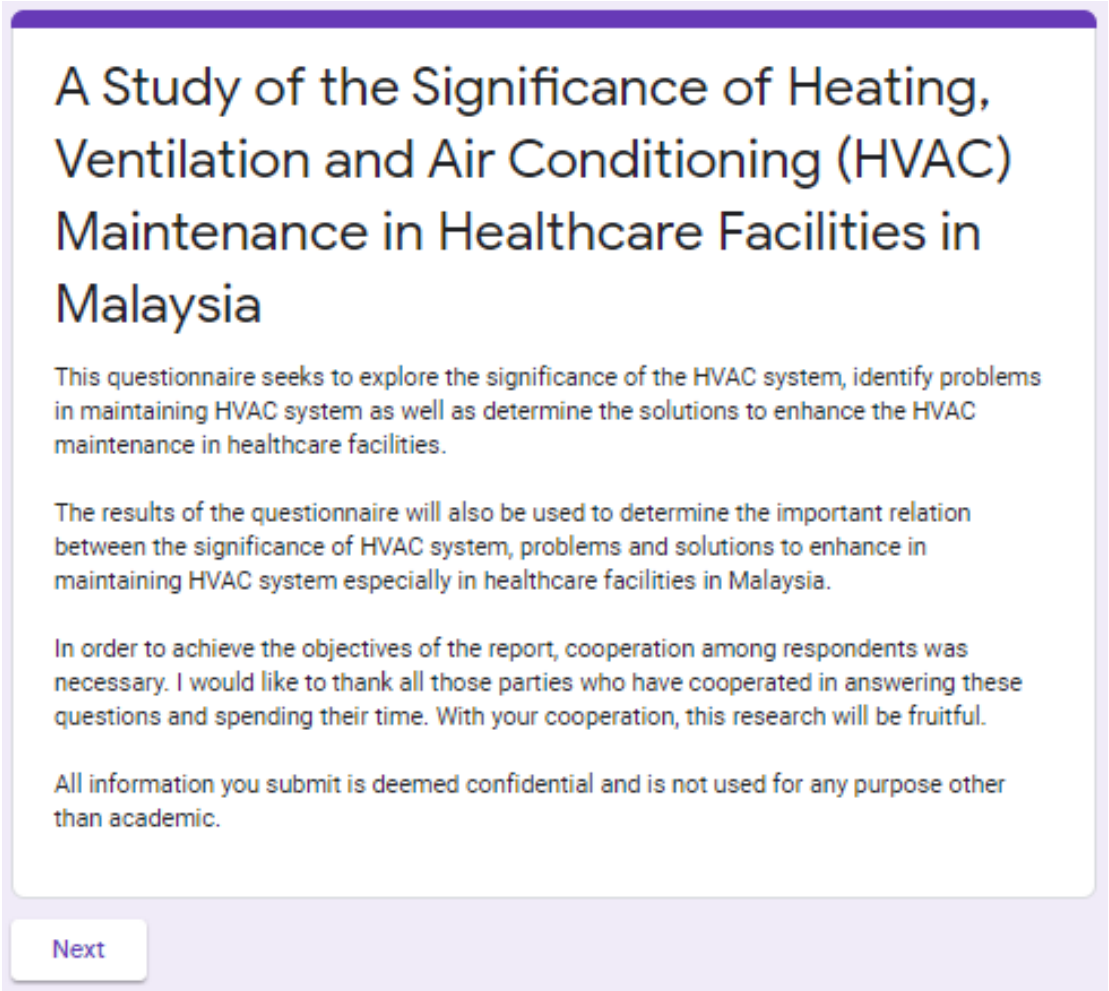
APPENDIX

Appendix 1: The Survey Questionnaire

A Study of the Significance of Heating, Ventilation and Air Conditioning (HVAC) Maintenance in Healthcare Facilities in Malaysia



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This questionnaire seeks to explore the significance of the HVAC system, identify problems in maintaining HVAC system as well as determine the solutions to enhance the HVAC maintenance in healthcare facilities.

The results of the questionnaire will also be used to determine the important relation between the significance of HVAC system, problems and solutions to enhance in maintaining HVAC system especially in healthcare facilities in Malaysia.

In order to achieve the objectives of the report, cooperation among respondents was necessary. I would like to thank all those parties who have cooperated in answering these questions and spending their time. With your cooperation, this research will be fruitful.

All information you submit is deemed confidential and is not used for any purpose other than academic.

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Section A - Respondent Profile

This segment covers details of survey respondents include the level of industry experience, years of participation in HVAC system & maintenance in healthcare facilities. The respondent's position is considered in order to ensure adequate expertise in the profession.

1. Which level in the HVAC maintenance in Healthcare facilities most represents you? *

- ◯ Facilities Management
- ◯ Building Management
- ◯ Mechanical Contractor
- ◯ Electrical Contractor
- ◯ Other: _____

2. Please indicate type of healthcare facilities you are involved in. (You can choose more than one) *

- ☐ Public Hospital
- ☐ Private Hospital
- ☐ Military Hospital
- ☐ Teaching Hospital
- ☐ Other: _____

3. How many years you have been involved in HVAC maintenance in healthcare facilities? *

- ◯ Less than 3 years
- ◯ 3 – 6 years
- ◯ 7 – 10 years
- ◯ More than 10 years

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Section B – Significance of HVAC system in Healthcare Facilities

This section is highlighting the list of most stated for significance of HVAC system in healthcare facilities. The respondent was asked to show what could impact a count of 1 to 5 based upon the LIKERT scale.

1. Comfort Conditioning - comfortable environment is important in facilitating recovery and healing. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

2. Therapeutic Conditioning - Some medical treatments, functions, or the healing process demand the controlled environmental temperatures and relative humidity conditions. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

3. Infection Control – HVAC system requires strict operational practices in controlling infectious pathogenic microorganisms. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

4. Environmental Control and Ventilation for Special Function - HVAC system assist in maintaining the sterile condition for the procedures or products that need to be protected from harmful environmental contaminants *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

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Section C - Problems in Maintaining HVAC System in Healthcare Facilities

This section specifies the problems occurs in maintaining HVAC system especially in Healthcare Facilities. It was also demanded that a LIKERT scale of 1 to 5 be calculated.

1. Poor Hospital Design *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

2. Lack of Adequate Sensors *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

3. Poor Data Handling, Visualization and Archiving the Building Automation System *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

4. The Complexity In The Prevention of The Spread of Airborne Infections *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

5. Preferences of Conflicting Indoor Air Between Staff and Patients *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

6. Lack of Sufficient Knowledge on The HVAC Systems *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

7. High Energy Consumption of HVAC in Hospitals *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

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Section D - Solutions to Enhance the HVAC Maintenance in Healthcare Facilities

This section denotes the solutions to enhance the HVAC maintenance in healthcare facilities. It was also required that a LIKERT scale of 1 to 5 be calculated.

1. Organizational Simulation (OS) - OS to test the feasibility of the HVAC system in healthcare facilities to check how the HVAC system can perform in various operational situations. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

2. Improved Infection Control - Quarantine facilities, using sliding hospital doors instead of the hinged doors and protecting the exposed vulnerable individuals from aerosols and contact infection transmissions using personal protective equipment. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

3. The Use of Wireless Sensor Networks - Developing both sensor hardware as well as sensor information technology software that aid the development of a feasible and functional system for HVAC systems in hospitals. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

4. The Use of Personalized Ventilation (PV) - Use of a separate diffuser or the diffusers that are integrated into the hospital beds to offer PV. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

5. The Use of HVAC Optimization Techniques - Multi-criteria optimization techniques that optimizes various parameters, including the levels of carbon dioxide, IAQ (e.g. smoke, dust, etc.), rates of airflows, lighting, energy, and acoustics consumption. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

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