Reliability and Validity of a New Energy - Efficient Building Performance Survey Framework in Hot and Humid Climatic Regions: A Review

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Received: 23.09.2012 Accepted: 17.10.2012

Abstract- There exists a well-known gap between occupants and building's energy-efficient designs. A comprehensive building evaluation which encompasses occupant's perspective may surpass the current evaluation method and reduce the gap between occupants and building's energy-efficient design. For these reasons, the aim of this research is to develop a survey instrument for the identification of problems in respect to energy-efficient design which affecting the occupants' comfort. This research will be conducted in Malaysian energy-efficient buildings. A new building performance survey framework will be constructed and tested on the selected energy-efficient building. The tested result will be analyzed by using Statistical Package for the Social Science (SPSS) in order to determine its reliability and validity. The research outcome shall contribute to the development of energy-efficient design for energy-efficient building through the identification of inefficiency of the existed building.

Keywords- energy-efficient design, energy-efficient building, survey framework, building performance, reliability, validity.

1. Introduction

In the current situation, reducing the consumption of energy from various sectors has been becoming the main agenda for sustainable development. According to United Nations Development Program (2009), in many countries, municipalities and public buildings have been the principal targets for energy efficiency programs, both at the national and local levels. The U.S. Congress drafted Section 914 of the Energy Policy Act of 2005 to address not just more energy efficient or "green" buildings but rather high performance buildings that combine the objectives of reducing resource energy consumption while improving the environmental impact, functionality, human comfort and productivity of the building (National Institute of Building Sciences, 2008). Since the energy-efficient designs of a building are aimed to fit occupants' comfort, hence it can be said that occupants are the end user of a building, and their requirements and perceptions towards energy-efficient design can bring a significant improvement to the building.

In this study, the term "energy-efficient building" is used as a collective term for different types of buildings made to reduce energy consumption, the aim of these buildings is to cope with the problems derive from the over consumption of natural resources mostly coal, which is used by building during its operational process. At present, there are three (3) office buildings specifically designed with energy-efficient features in Malaysia. They are Ministry of Energy, Communications, and Multimedia office building or well known as Low Energy Office (LEO); Secondly, Green Energy Office (GEO) which housed the office building for Malaysia Green Technology Corporations; and lastly, Energy Commission office building or known as ST Diamond. Those buildings are the initiatives demonstrated by the government to fully engage in the sustainable development, which is in line with the vision 2020 in the effort to become a developed nation.

2. Problems Statement

The development of green building rating system such as Leadership in Energy and Environmental Design (LEED), and Malaysian Green Building Index (GBI) reflected the current focus of the building performance objectives mostly on optimizing energy and resource efficiently. However, according to Department of Energy (2001), in the development of energy efficiency program for building, it is important to appreciate the fundamental purpose of the building is neither to save nor use energy. Somewhat, the building is there to serve the occupants and their activities. The above statements was further supported by Heerwagen & Associates (2005), from the research they have done, they found out that, sustainable building design strategies able to create improved indoor environmental quality (IEQ) and should, thus, be associated with improved occupant comfort, satisfaction, health, and work performance relative to buildings designed around standard practices.

A fine balance should exist between optimizing energy and resource efficiency in green buildings and providing a comfortable, healthy and productive indoor environment. Fundamentally, green buildings often rely on natural conditioning to meet the comfort needs of end-users, passive strategies were employed to provide indoor conditions that are more able to adapt and linked to the variation of temperature according to different season and climate. There are some of the environmental control systems either be designed to accommodate active user engagement, or to intelligently respond and adapt to changing external conditions only with minimal user engagement. Both approaches share a similarity, it is, rely on effective feedback to inform users of design intention and the environmental consequences of their actions. Feedback is particularly important where environmental systems and control are new to designers, operators and users, and matching technological and management capability is crucial (Cohen et al., 1999), furthermore, occupants demand high performance of energy-efficient design with the aim of improving their comfort, the result is, relationship between occupants' satisfaction and building's IEQ can be positively correlated with better building performance (Wilkinson et al., 2011).

If a comprehensive building evaluation which encompasses occupant's perspective is not being conducted to the energy-efficient building, energy-efficient building design team would not easily identified the problems that affect the building performance, since, occupants are the end user of the building, and the occupants' behavior while using the building can directly affected the building performance. Even though, the development of energy-efficient building in Malaysia is still at the beginning stage, the industry player should focus not only on the development of new energy-efficient building solely but the study on the existing energy-efficient building must not be neglected as well. Owing to this limitation on the BUS, a comprehensive survey instrument is needed in order to reduce the gap between occupants and building's energy-efficient design. For these reasons, the aim of this research is to determine the comfort level of energy-efficient buildings in Malaysia, and to develop a survey instrument for the identification of problems in respect to energy-efficient design which affecting the occupants' comfort.

3. Research Objective

The research objectives of this study are:

(i) To determine the energy-efficient building in Malaysia.

(ii) To identify the effects of energy-efficient design problems towards IEQ criteria.

(iii) To propose a holistic occupant survey framework for the identification of problems in respect to energy-efficient design which affecting the occupants' comfort.

4. Research Scope

Relationship between occupants' satisfaction and building's IEQ can be positively correlated with better building performance (Wilkinson et al., 2011) as so, the evaluation measure criteria for the energy-efficient design of the buildings are based on the key physical environmental parameters of Indoor Environmental Quality (IEQ) performance; such as thermal comfort, ventilation, lighting, and noise etc.

Over the past decade, there is an increasing trend in the development of sustainable or energy-efficient building in Malaysia. The Ministry of Energy, Green Technology and Water (KeTTHA) building is the maiden energy-efficient building project in Malaysia; the building has even won the 2006 ASEAN building energy awards (Ministry of Energy, Green Technology and Water [KeTTHA], 2006). In the following years, the development of energy-efficient building in Malaysia continued to flourished, the development of the project such as Malaysia Green Technology Corporation and Energy Commission building or colloquially known as ST Diamond building are another two showcase energy-efficient building project initiated by the government following the success of the KeTTHA building. Both of the projects have obtained recognition from Malaysian sustainable building rating tools, Green Building Index (GBI) (Green Building Index [GBI], 2011). Malaysia Green Technology Corporation building was awarded Green Building Index (GBI) certified certificate; and the ST Diamond building was awarded GBI Platinum and Green Mark Platinum which is the Singapore sustainable building rating tool (Koay, 2011). Although, the buildings have obtained the award and certified by sustainable building rating tools assessment, the efficiency of the building performance still not on par as the expected performance. One of the Malaysian showcase energy-efficient building projects, Malaysia Green Technology Corporation office building has yet to achieve its desired performance though after three years in operation (Choong, 2009). Thus the proposed survey framework will be tested on the Malaysians' showcase energy-efficient buildings, the buildings are the Ministry of Energy, Green Technology and Water (KeTTHA) building and Energy Commission building which are situated in Putrajaya, and Malaysia Green Technology Corporation building located in Bandar Baru Bangi.

According to Peretti & Schiavon (2011), building occupants are a valuable source of information for IEQ. Hence, the sampling of research will be focusing on the occupants of the selected building. Random sampling is used to determine the sample size for each selected building.

5. Definition of Energy-Efficient Building

In literal meaning, energy-efficient building can be defined as a building require less energy to operate compared to conventional type building which usually consume a lot amount of energy in order to sustain its daily operation needs. Due to its low energy consumption characteristic, energy-efficient building seems to be the best solution to mitigate the current environmental problems faced by human being in this century. Although, there are countless of advantages of energy-efficient building contribute to the environment, to date, there is still no specific definition for energy-efficient building. The vague definition of energy-efficient building might cause a setback during its implementation and the desired effects will hard to achieve. As so it is crucial to draw and highlight a clear as well as thorough definition of energy-efficient building. In this section a definition of energy-efficient building will be derived from the summary of the previous research related to the term of energy-efficient building used by researchers from various studies and fields.

Hauge et. al. (2010) define energy-efficient building as building made to reduce energy consumption to different degree, it includes, low-energy buildings, passives houses, LEED buildings, and green buildings. Another research done by Zhang & Leimer (2011) titled low energy certificate - An exploration on optimization and evaluation of energy-efficient building envelope, refer green building as energy-efficient building. Furthermore, according to Krope & Goricanec (2009), the awareness of the importance of energy efficiency of building has brought to the development of energy-efficient (saving) building, and it includes low energy buildings, 3 litres house, passive house, zero-energy house, energy self-sufficient house, and plus-energy house. Thormak (2001), conducted a research to analyze the recycling potential of a low-energy dwelling (45 kWh(162 MJ)=m2) in Sweden. In the research, the low energy building and passive houses were referred as energy-efficient building. In addition, Bauer & Scartezzini (1997), in their research on a simplified correlation method accounting for heating and cooling loads in energy-efficient buildings, one of the studied buildings is a simulated passive solar office room.

While, a research conducted by Ahmed et. al., (2009) in regard to the analyze of building performance data for energy-efficient building operation, during the research they have selected an energy-efficient building with many sustainable energy features such as solar panels, geothermal heat pumps and heat recovery systems as case study building. On the other hand, Kim et. al. (2010) conducted an analysis of energy efficient building design through data mining approach. In their research, the energy-efficient building design for the building includes the building location, envelope (walls, windows, doors, and roof), heating, ventilation and air conditioning (HVAC) system, lighting, controls, and equipment. Kantrowitz (1984), research on energy-efficient building, describes energy-efficient building is a building designed with energy-efficient design such as HVAC and lighting system.

Based on the research done in previous studies, it is found that, the researchers are tend to form a collective agreement between one another in term of their understanding of energy-efficient building. Energy-efficient building can be defined as a building using energy-efficient design strategies in reducing its energy consumption in order to achieve low energy consumption. It includes, zero energy building, passive house, low energy building, LEED buildings, green buildings, energy self-sufficient house, plus-energy house and any other buildings that has been specifically designed with the aim of achieving energy-efficiency.

6. The Variable of Terminology for Building with Energy Efficiency Features

6.1. Zero Energy Building

According to Torcellini et al. (2006), zero energy building (ZEB) is defined as a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies. In 1975, Professor Korsgaard from Danish Technical University has successfully built a Zero Energy House (ZEH) at Thermal Insulation Laboratory as shown in Figure 2.1. The building is the first solar heated building built in North Europe (Gram-Hansen & Jensen, 2005).

Fig. 1. A ZEH at Danish Technical University, Lyngby, Denmark (Seifert, 2006)

6.2. Passive House

Passive House concept is based on a holistic approach, improving the building envelope to a degree that allows for substantial simplifications of the heating system. Passive Houses offer increased comfort at affordable costs while significantly reducing the energy consumption (Feist, 2005). This concept was developed in Germany May 1988 by Bo

Adamson and Wolfgang Feist, and has since then been widely and successfully used in Germany and Austria (as cited in Janson, 2008). One of the examples of passive house is the Passive House in Darmstadt Kranichstein (Figure 2.2) which has been constructed in 1990/91 on design plans by architects Prof. Bott/Ridder/Westermeyer for four private clients (Steinmüller, 2008).

Fig. 2. Passive House in Darmstadt Kranichstein (Feist, 2006)

6.3. *Low Energy Building*

Low-energy building or simply low-energy refers to a building built according to special design criteria aimed at minimizing the building's operating energy (Sartori &Hestnes, 2006). According to European Commission (2009), low-energy buildings typically use high levels of insulation, energy efficient windows, low levels of air infiltration and heat recovery ventilation to lower heating and cooling energy. They may also use passive solar building design techniques or active solar technologies. The office building "SD Worx" as shown in Figure 2.3 is a low energy building which is located in Kortrijk, Belgium and consists of two office floors on top of a limited ground floor with building services (Breesch et. al., 2004).

Fig. 3. SD Worx, Kortrijk, Belgium (Breesch et. al., 2004)

6.4. *Green Building*

According to Burnett (2006), green building is a building that provides the specified building performance requirements while minimizing disturbance to and improving the functioning of local, regional, and global ecosystems both during and after its construction and specified service life. Moreover, it's optimizes efficiencies in resource management and operational performance; and minimizes risks to human health and the environment. Genzyme Corporation is a world-class example of green building construction, including advanced daylighting and thermal technologies. The building obtained LEED-Platinum due to its high efficiency and environmentally responsive architecture (Lockwood, 2006).

Fig. 4. Genzyme Corporation Headquarter, Cambridge, Massachusetts, USA (Kats, 2003).

6.5. *Energy Self-Sufficient House*

One of the prominent examples of energy self-sufficient house is the Self-Sufficient Solar House (SSSH) in Freiburg, Germany (Figure. 2.5) which is built by the Fraunhofer Institute for Solar Energy Systems has. Its entire energy demands for heating, domestic hot water, electricity and cooking is supplied solely by solar energy (Voss et. al., 1996). According to Krope & Goricanec (2009), energy self-sufficient house capable to generate energy for heating, cooking, water heating and the operation of home appliances through active utilization of solar energy.

Fig. 5. Self-Sufficient Solar House (SSSH) in Freiburg, Germany (Bond, 2005).

7. The Development of Energy-Efficient Building in Malaysia

7.1. *National Energy Policies*

The first policy formulated concerning the energy sector in Malaysia was the Petroleum Development Act 1974, subsequently, the national oil company, Petroliam Nasional Berhad (Petronas) was established with the responsibility for exploration, development, refining, processing, manufacturing, marketing and distribution of petroleum products. In the following year 1975, the National Petroleum Policy (1975) was formulated under the Third Malaysia Plan (1976-1980), the objective of the policy was to encourage the utilization of the resource for industrial development efficiently, as well ensuring majority control in the management and operation of the industry was being implemented by the country. The Petroleum Development Act 1974 and National Petroleum Policy 1975 were considered the earliest energy sector policy in Malaysia. The policy pertaining to electricity sector was only formulated in 1979, which is the National Energy Policy 1979. Malaysia's National Energy Policy (1979) aims to have an efficient, secure and environmentally sustainable supply of energy in the future as well as to have an efficient and clean utilization of energy. The three primary objectives of the country's energy policy are the supply, utilization and environmental objectives (Energy Policies of Malaysia, 2005).

In the year of 1980 and 1981, the National Depletion Policy (1980) and Four-Fuel Diversification Policy (1981) were formulated in order to achieve the National Energy Policy (1979)'s objectives. The National Depletion Policy (1980) is intended to conserve the country's energy resources, particularly oil and gas. As a complement, the Four Fuel Diversification Policy (1981) was then designed to prevent over-dependence on oil as the main energy resource. Its aim was to ensure reliability and security of the energy supply by focusing on four primary energy resources: oil, gas, hydropower and coal (Hitam 1999).

In the year of 2000, the Four Fuel Policy was amended to become the Five Fuel Policy under Eighth Malaysia Plan (2001-2005) where renewable energy (RE) was announced as the fifth fuel in the energy supply mix. Energy efficiency was also encouraged to prevent Malaysia from becoming a net energy importer which will affect her economic growth (Malaysian Economic Planning Unit, 2001). The Ninth Malaysia Plan was to strengthen the initiatives for energy efficiency and renewable energy put forth in the Eighth Malaysia Plan that focused on better utilization of energy resources (Malaysian Economic Planning Unit, 2006).

The New Energy Policy (2011-2015) under Tenth Malaysia Plan (2011-2015) emphasizes energy security and economic efficiency as well as environmental and social considerations. The Policy was focus on five strategic pillars: initiatives to secure and manage reliable energy supply; measures to encourage energy efficiency (EE); adoption of market based energy pricing; stronger governance and managing change, During the Plan period, EE initiatives will gain momentum with the formulation of the Energy Efficiency Master Plan (EEMP), setting of minimum energy performance standards for appliances and development of green technologies (Malaysian Economic Planning Unit, 2011).

7.2. Energy-Efficiency Programs

The formulated policies could not be realized without the proper implementation of energy-efficiency programs. Throughout the implementation period, various programs have been planned and carried out in order to realize each policy's objectives. According to a report of peer-review on energy efficiency in Malaysia, the energy-efficiency programs which have been implemented by the government includes, energy efficient building showcase models, auditing and retrofitting existing buildings into energy efficient buildings, Green Building Certification (Green Building Index) GBI, Malaysia industrial energy efficiency improvement project (MIEEIP), electrical equipments labeling programs, and energy efficiency awareness campaign (APEC Energy Working Group, 2011). The efforts of each programs shows the determination of government to implement energy-efficiency policies in Malaysia. The details of each program will be discussed in the following section.

7.3. Energy Efficient Building Showcase Models

The first energy efficient building that was built is the Low Energy Office (LEO), housing the Ministry of Energy, Green technology and Water. The LEO building was completed in 2004 and had won the ASEAN Energy Award in 2006 under the efficient building category. Other energy efficient buildings are the Green Energy Office (GEO), the first green building in Malaysia and the Diamond Building. These buildings serve as demonstration project to encourage more energy efficient and green buildings to be built in the future especially in the private sector.

7.4. Auditing and Retrofitting Existing Buildings into Energy Efficient Buildings

Besides building new model buildings, the Malaysian Government is also auditing and retrofitting some of its existing complexes to turn them from normal buildings to energy efficient and green buildings. Thorough energy audits were carried out in these complexes and it shows that a minimum of 20% reduction in electricity consumption could be achieved through simple retrofitting.

7.5. Green Building Certification (Green Building Index, GBI)

GBI is Malaysia green building rating system that was launch on 21 May 2009 to rank commercial and residential buildings according to six (6) criteria namely energy efficiency; indoor environment quality; sustainable site planning; materials & resources; water efficiency; and innovation. GBI is undertaken by the Building Professional Bodies. Buildings that met the minimum "greenness" level will be awarded with GBI Certified. Higher levels of award are GBI Silver, GBI Gold and GBI Platinum with GBI Platinum as the highest rank. The awards will expire in three (3) years to ensure that building owners maintained their buildings in a proper manner.

7.6. Malaysia Industrial Energy Efficiency Improvement Project (MIEEIP)

MIEEIP is a collaborative project on energy efficiency between the Malaysian Government and United Nations Development Program (UNDP) - Global Environment Facility (GEF). The project started in 2000 and ended in 2007.

7.7. Electrical Equipments Labelling Program

Malaysia electrical appliances labelling program was introduced in 2005 and covers several item namely the refrigerator, air-conditioner, television, motor, lamp and fan. The labelling program is being expanded to cover more electrical appliances. Appliances are labelled in a scale of five (5) stars with three (3) stars as the average and the more stars an appliance gets, the higher its efficiency is.

7.8. Energy Efficiency Awareness Campaign

Awareness campaigns are carried out to educate the public on the benefits of energy efficiency and its practices. Besides the continuous awareness programs organized, a compilation handbook on energy efficiency practices in the household was published and distributed to the public in 2008. This handbook serves as a handy reference to the household.

7.9. MS:1525, Energy-Efficiency In Non Residential Buildings As Regulatory

The energy efficiency programs such as energy-efficient building showcase models, auditing and retrofitting existing buildings into energy-efficient buildings, and green building certification (Green Building Index, GBI), show the government determination in reducing the energy consumption in building sector. However, the success of each programs could not been achieved without the proper implementation from various industry players. Hence, a guideline is needed in order to let the people from the industrial know exactly how to achieve the objectives stipulated in the energy policies which advocated by the government. As so, MS: 1525, Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings has been outlined and is one of the approaches to achieve the objective of the policies.

8. Building Energy Index (BEI)

Building operational energy efficiency is measured by the BEI (Kannan, 2007). The BEI is the global yearly energy consumption of the entire building divided by the air conditioned floor area. According to MS1525 Guidelines for Energy Efficiency in Buildings, four typical buildings are defined to represent different expected levels of energy use in Malaysia. These four levels are: worst case, base case, proposed standard case and good practice case.

(i) The worst case represents buildings that are among the most energy intensive buildings that might be encountered in Malaysia today. BEI = 240 kWh/m²/yr.

(ii) The base case building reflect a typical range of construction and energy use features now prevalent in Malaysian new commercial building construction. BEI = 166 kWh/m²/yr.

(iii) The proposed standard case reflects the level of energy efficiency expected to be achieved by the proposed Guidelines. BEI = 136 kWh/m²/yr.

(iv) The good practice case represents a combination of energy efficient practice (including daylighting) that surpasses the requirements of the Guidelines proposed. BEI = 98 kWh/m²/yr.

9. Energy-Efficient Design Problems Which Affecting the Occupants' Comfort With Respect To IEQ Criteria

The research done by Wong, N. H. et. al. (2005) in Singapore showed that fully glazed facade that has been increasingly used in the country causes higher energy consumption and thermal discomfort due to higher solar gain. Meanwhile, Altan, H. et al. (2008) revealed that glazed facades are potential sources of unwanted overheating and glare effects that cause indoor discomfort and result in necessity for ventilation and cooling services which again increase energy consumption in buildings. Bülow-Hübe, H. (2008) studied on glazed office building in Sweden identified lack of window blinds/shades can cause thermal discomfort. In Denmark, a research conducted by Sebastian, W. (2008) shown that, windows and doors ranked the top of the identified problems which causing the air leakage in the building. Paul, W. L. & Taylor, P. A. (2008) study showed that occupants of the green building were more likely to perceive their work environment as warm, and occupants who felt warm was more likely to describe their work environment as poor and this might caused by the poor air conditioning system in the building. Mumma, S. A. (2002) in his research identified that radiant cooling system facing the design problem such as condensation and radiant asymmetry. Lim, J. H. et al. (2006) research found that in radiant floor cooling system, floor surface condensation and comfort are major concerns for field application. Zhen, T. & James, A. L. (2006) research on the building with radiant cooling system showed that local discomfort are the identified problem that can cause occupant's discomfort. Wagner, A. et. al. (2007) conducted a study in German low energy office building found out that, the result of four week summer field study on thermal comfort with 50 subjects in a naturally ventilated office building in Karlsruhe, Germany, show that thermal sensation votes do not correspond to calculated predicted mean votes. Heerwagen, J. & Diamond, R. C. (1992) research found that only 20% said daylight was sufficient for working, 92% said they used the electric ceiling light to supplement daylight and 91% who said daylight was "just right" also used electric lights. A research done by Wilkinson, S. J et. al. (2011) showed that most of the energy-efficient buildings share a common problem which is lack of privacy. The summaries of findings from the studies that were carried out by the above researchers are tabulated based on the part of energy-efficient design in Table 1.0 (Please refer to Appendix I).

10. Research Methodology

Research Methodology is an important part in executing an academic research. The purpose of the research methodology is to arrange the research mechanism and so the research can be carried out smoothly and effectively.

10.1. Area of Study

Malaysian Green Technology Corporation is the first ZEB in Malaysia. The building completed in 2007 and occupying an area of 5 acres situated in Bandar Baru Bangi with 40km distance from Kuala Lumpur. ZEB components applied in Green Tech Malaysia building, including passive and active techniques and onsite renewable energy generation.

10.2. Preliminary Study

Preliminary study is the information or data obtained before the research is being carried out, and the information is based on the previous research carried out by researchers.

10.3. Data Collection

In the research methodology, the obtained data can be categorized into two categories; they are primary data and secondary data.

10.4. Mapping Previous Study (MPS) (Information Mapping)

The purpose of MPS is to identify the energy-efficient design problems affecting the IEQ performance. The identified energy-efficient design problems will be grouped according to its effects towards IEQ.

10.5. Interview

Interview is a method to obtain the information or data from respondent through verbal communication, the responses from the interviewed respondent can be either opinions or advises. The information is very important because the interviewed respondent can explain the answer thoroughly. Interview will allow two ways communication between the interviewed respondent and researcher, this situation can contribute the additional opinions and different perspectives.

10.6. Survey Framework Development

i) The initial questions will be formed based on its effects to the occupants' comfort.

(ii) Content validity test will be performed (key people in the energy-efficient building design).

(iii) Exploratory Factor Analysis (EFA) will be carried out after the content validity test. Exploratory factor analysis (EFA) is a variable reduction technique closely related to PCA but it is more focused on identifying latent constructs and the underlying factor structure of a set of variables. Traditionally factor analysis has been used to explore the possible underlying factor structure of a set of measured variables without imposing any preconceived structure on the outcome (Child, 1990);

(iv) Pilot Study - The initial questionnaire will be distributed to the building's occupants

(v) Constructed survey framework will be tested in 3 energy-efficient building. Construct validity test (correlation with Building Usable Studies) and Inter-class correlation coefficient (ICC).

10.7. Analysis Method

After retrieving the feedback from the respondents, the data will be analyzed through SPSS software. The data will be collected through the questionnaire and incomplete questionnaire will not be used for analysis purpose. The reliability test is by using Cronbach α coefficient as a measurement tools. If Cronbach α less than 0.3, reliability is in low level and cannot be accepted. If Cronbach α is greater than 0.7, this reveal that consistency is in high level and is acceptable. Basically for each question, respondents have four options which are strongly affect, moderately affect, slightly affect and does not affect. This data will be analyzed based on the degree of severity of the factors to the respondents.

The severity index is computed by the following equation:

Severity Index (IS) = [(Σ4i=0(ai* xi) / 3] × 100 %

Where:

ai = constant, expressing the weight given to i th response, i =1,2,3,4

xi= the variable expressing the frequency of the i th responses, for i= 1,2,3,4 and illustrated as follows :

x1= the frequency of "strongly affects response".

x2= the frequency of "moderately affects response".

x3= the frequency of "slightly affects response".

x4= the frequency of "does not affects response"

11. Conclusion

The energy-efficient design problems which affecting the occupants' comfort have been identified and reviewed from the recent studies done through literature analysis and mapping. Furthermore, the identified energy-efficient design problems were organised and classified according to the Indoor Environmental Quality criteria. The information gathered was later translated into the questionnaire format. Hence, this research shall able to identify the inefficiency of the energy-efficient design that leads to poor building performance. Critical user satisfaction towards energy-efficient design will be highlighted in order to provide clearer information regarding the perception of users towards energy-efficient design. Problems causing the inefficiency of energy-efficient design will be identified and hence will improve the future design of the energy-efficient building. Hope this research will be a useful reference and guidance for local contractors, architects, engineer, energy consultants, or even academic to ensure the continuous development of energy-efficient building.

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Appendix

Table 1.0. Energy-efficient design problems affecting the occupants' comfort with respect to IEQ criteria

No.	Researchers	IEQ criteria	Part of energy-efficient design	Identified problems
1.	Wong, N. H. et al. (2005), Altan, H. et al. (2008)	Thermal comfort	Window glass	Fully glazed façade cause thermal discomfort due to higher solar gain (heat)
2.	Bülow-Hübe, H. (2008)	Thermal comfort Lighting	Window blinds/shades	Lack of window blinds/shades cause thermal discomfort Inefficient control system
3.	Sebastian, W. (2008)	Air quality	Envelope tightness (Door, window)	Door/ window constantly open causing envelope air leakage
4.	Paul, W. L. & Taylor, P. A. (2008)	Thermal comfort	Room air-conditioning unit	Air-conditioning system not functioning well (too cold/warm) Control system
5.	Mumma, S. A. (2002), Lim, J. H. et al. (2006), Zhen, T. & James, A. L. (2006)	Thermal comfort	Radiant cooling system (floor slab unit, chilled metal ceiling)	Floor slab cooling, and chilled metal ceiling (condensation) Radiant asymmetry (local cold discomfort in the arm-hand and the leg-foot regions) Control system
6.	Wagner, A. et. al. (2007)	Thermal comfort Air quality	Ventilation system	Poor air movement Ventilation control system
7.	Altan, H. et al. (2008)	Lighting	Orientation/Daylighting (window/skylight)	Window glass (glare) Window location Skylight location
8.	Heerwagen, J. & Diamond, R. C. (1992)	Lighting	Artificial lighting system	Occupants use additional artificial lighting in the office Control system
9.	Wilkinson, S. J et. al. (2011)	Acoustic	Office layout	Lack of privacy