OCCUPANTS' COMFORT IN RETAIL BUILDINGS: A REVIEW

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ABSTRACT

In the bid to improve occupants' thermal comfort while still minimizing energy usage, retail buildings have been undergoing transformations. New trends in retail building design can be noticed globally, from the adoption of day lighting to the incorporation of natural ventilation. It would be expected that these new trends in retail building design would attract research studies focused on users' comfort, perceptions and expectation. However, in recent years, comfort studies in retail buildings have focused mainly on Indoor Air Quality (IAQ), visual and acoustic comfort. Though, few studies have been done with in-depth evaluation of the thermal comfort conditions in retail buildings in particular. There is a need to have a compilation and review of these studies in order to encourage more studies to be done and to bring awareness to the issue of sustainability in retail buildings. This paper is thus a review of some of such studies. Relevant literature was search on popular easily assessable research databases (Google scholar, Scopus, and Science Direct.) this was done using appropriate keywords, and articles related to the Occupants' comfort in retail buildings were finally selected and reviewed for this study. Although, concerns were raised concerning the practicability of natural ventilation and other sustainable measures to achieve adequate comfort in large retail buildings, some studies have however revealed that natural ventilation has a great application potential in large retail buildings.

Keywords: *indoor air quality, natural ventilation, occupants' perception, retail buildings, thermalcomfort.*

INTRODUCTION

Occupants' comfort is often associated with a building's performance in relation to its Indoor Environmental Quality (IEQ) majorly thermal comfort and the indoor air quality. A building's Indoor Environmental Quality (IEQ) performance refers to the quality of a building's environment in relation to the health and well being of those who occupy the space within it. IEQ is one of the major issues affecting the general well-being of building occupants in terms of their health and productivity (Altomonte and Schiavon, 2013; Heinzerling et al., 2013; Frontczak, 2012; Kim and de Dear, 2012; Naziatul Syima et al., 2011). Factors that determine IEQ are thermal comfort, indoor air quality, acoustic comfort and visual comfort (Kim and de Dear, 2012a; Kim and de Dear, 2012b).

Over the years, retail building designs have evolved and have generally been designed with a similitude to the "American model" of retail design (Federico, 2008; Carrilho da Graça et al., 2012). The "American model" of retail design, according to Federico (2008) p.1, is "often artificially lit boxes, with uniform thermal environments throughout the year regardless of climatic conditions". Furthermore, it was emphasized that this artificially created environment actually encourages energy waste and at the same time creates "thermal shocks" as opposed to providing the users with a thermally comfortable environment.

This thermal condition created within the retail buildings' indoor environment was intended to provide comfort for the users but according to Federico (2008), they are indeed contributing to energy waste. The concern for energy extends to the building sector at large and as owners and designers explore various ways of minimising the operating costs and environmental impacts of buildings, still with the aim of increasing their functionality and appeal to occupants/users, "sustainable building" trends are becoming noticeable in the market today. This trend can be observed in retail buildings as well and since different retail typologies provoke different comfort expectations in users, retail buildings are becoming redefined making them more thermal friendly and energy efficient.

In light of these, retail buildings now take advantage of day lighting and natural ventilation in their design, thus creating a comfortable outdoor feeling for their users, and at the same time relieving the energy load needed for artificial lighting and ventilation. An example of a fully naturally ventilated and lighted retail building is the Eastgate shopping Centre, in Harare, Zimbabwe (Figure 1), a very good and famous example of biomimicry in architecture. The building was designed by Mick Pearce based on the concept of a termite hill, it has neither air-conditioning nor heating system yet remains thermally regulated all year round and uses only 10% of the energy needed by a similar conventionally cooled building (Pearce, 2015; Amal, 2014).

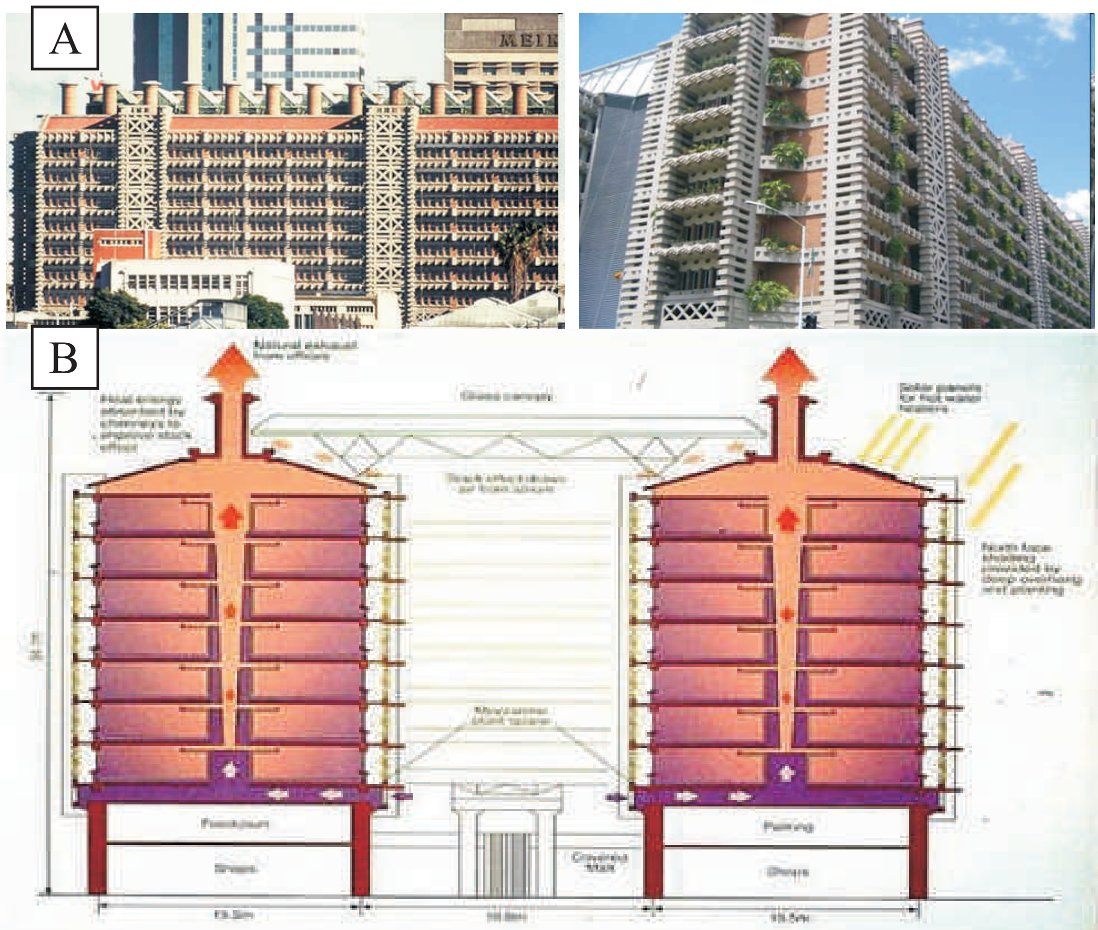

Figure 1 Eastgate shopping Centre, Harare, Zimbabwe. A: Elevations. B: Sectional view showing the air flow direction (Source: Pearce, 2015).

This particular design may not be applicable in other climatic conditions and since buildings in general are required to provide a climatically stable environment for its users/occupants, depending solely on natural ventilation in most climatic conditions might often be challenging and at times almost impossible to implement. Notwithstanding, natural ventilation is still been gently introduced in retail building designs, and what is common today is a large common space that is naturally ventilated and connecting to retail lots that are individually air conditioned (Ibiyeye, 2017 and Ibiyeye et al., 2018). This practice allows for considerable amount of energy to be saved (Huang et al., 2014; Thomas, 2014), and users are given the opportunity of moving between different climatic conditions under the same roof (Federico, 2008).

It would be expected that these new trends in retail building design would attract research studies focused on users' comfort, perceptions and expectation. However, in recent years, comfort studies in retail buildings have focused mainly on Indoor Air Quality (IAQ), visual and acoustic comfort. Though, few studies have been done with in-depth evaluation of the thermal comfort conditions in retail buildings in particular. There is a need to have a compilation and review of these studies in order to encourage more studies to be done and to bring awareness to the issue of sustainability in retail buildings, this paper is thus a review of some of such studies.

METHODOLOGY

Relevant literature was search on popular easily assessable research databases such as Google scholar, Scopus, and Science Direct. This was done using appropriate keywords, and articles related to the Occupants' comfort in retail buildings were finally selected and reviewed for this study.This review article discusses the concept of thermal comfort in general, comfort expectations under different building ventilation modes and conditions, indoor air quality as a factor influencing occupants' comfort, and finally a review of different studies from different climatic condition on comfort studies in retail buildings' performances, expectations, and users' perception with regards to retail buildings' performance.

THERMAL COMFORT

ASHRAE (2004) p.4 defines Thermal comfort as "that condition of mind which expresses satisfaction with the thermal environment". Thermal comfort is generally influenced by two major factors, one being the environmental parameters such as air temperature, mean radiant temperature, relative humidity, and relative air velocity, and the other being the physical parameters which include clothing or thermal resistance, and activity level or metabolic rate (Fanger, 1970;Awbi, 1991; Charles, 2003; ASHRAE, 2004; Nicol, 2004).

Thermal indices in buildings

In contemporary thermal comfort research, two major approaches exist which are 1) the heat balance models based on laboratory studies and 2) the adaptive models based on field studies (Yao et al. 2009). For the first approach, the Fanger's "Comfort Equation" and the J.B. Pierce two-node model of human thermoregulation are two of the well-known and widely accepted models which use detailed experiments to predict the degree of thermal comfort of people (Hensen, 1990). The Fanger comfort equation, which has been commonly adopted and best understood, relates thermal sensation to the existence of heat balance by observing a large number of people in laboratory experiments (Fanger 1970). Fanger further established a lab-based "Predicted Mean Vote" (PMV) and "Predicted Percentage of Dissatisfied" (PPD)model (Charles, 2003; Wei et al., 2011). The PMV model uses heat balance principles to relate the six key factors (air temperature, mean radiant temperature, relative humidity, relative air velocity, clothing and metabolic rate) for thermal comfort to the average response of people on the temperature scale of +3 (hot) +2 (warm) +1 (slightly warm) 0 (neutral) –1 (slightly cool) –2 (cool) –3 (cold).The PPD index is related to the PMV as defined in figure 2 and it is based on the assumption that people voting +2, +3, –2, or –3 on the thermal sensation scale are dissatisfied, and the simplification that PPD is symmetric around a neutral PMV(ASHRAE, 2004).

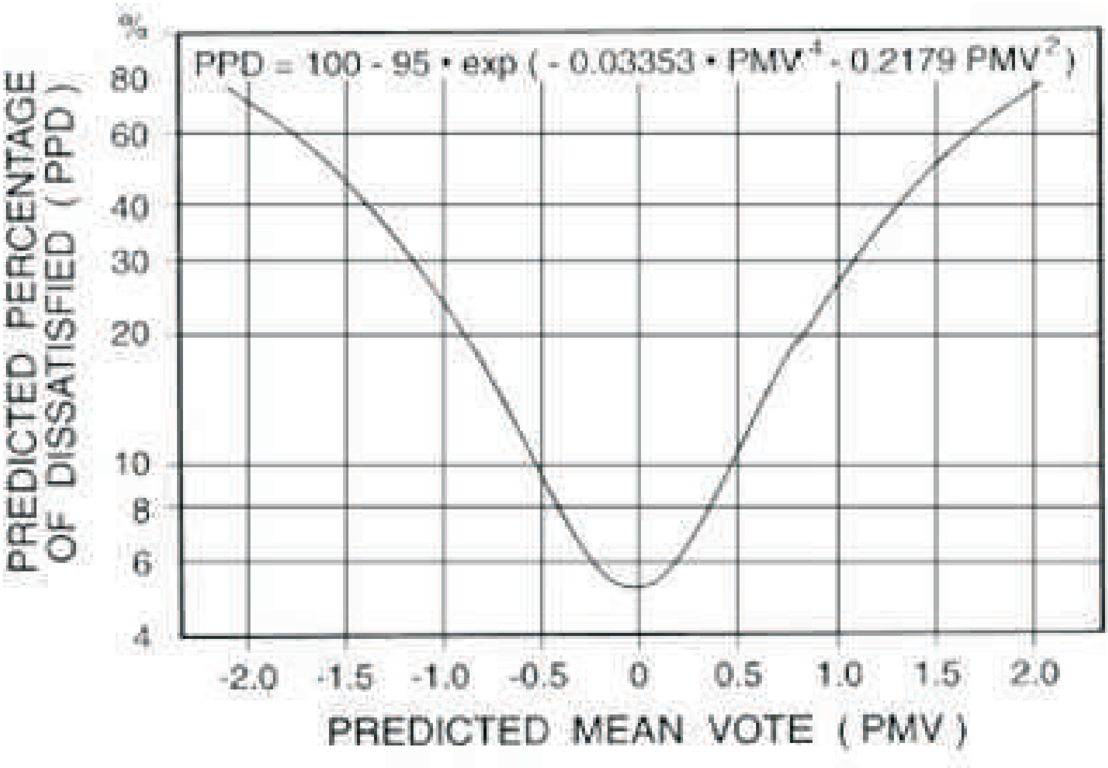

Figure 2: Predicted percentage dissatisfied (PPD) as a function of predicted mean vote (PMV). (Source, Figure 5.2.1.2: ASHRAE, 2004).

However, several studies (Humphreys, 1978; Auliciems, 1981) have reviewed the literature on thermal comfort field studies and found that PMV generally over predicted the actual neutral temperature thus concluded that preferred temperatures are variable. The adaptive model was thus introduced from the observation that humans tend to adapt to the environment that they have been used to for a long period of time. The adaptive approach, unlike the PMV model, is based on findings conducted during field studies focused on gathering information on the thermal responses of people under real circumstances (De Dear and Brager, 1998; De Dear and Brager, 2002). In real life, many factors can contribute to human responses to the thermal environment. In the light of these, three different categories of human self-regulation to the thermal environment were revealed, and these are: physiological, psychological, and behavioural adaptations (Figure 3). The study of adaptive thermal comfort is essential for developing suitable thermal environment standards that help shape building legislation, technical requirements, and policies worldwide (Baizhan and David, 2013).

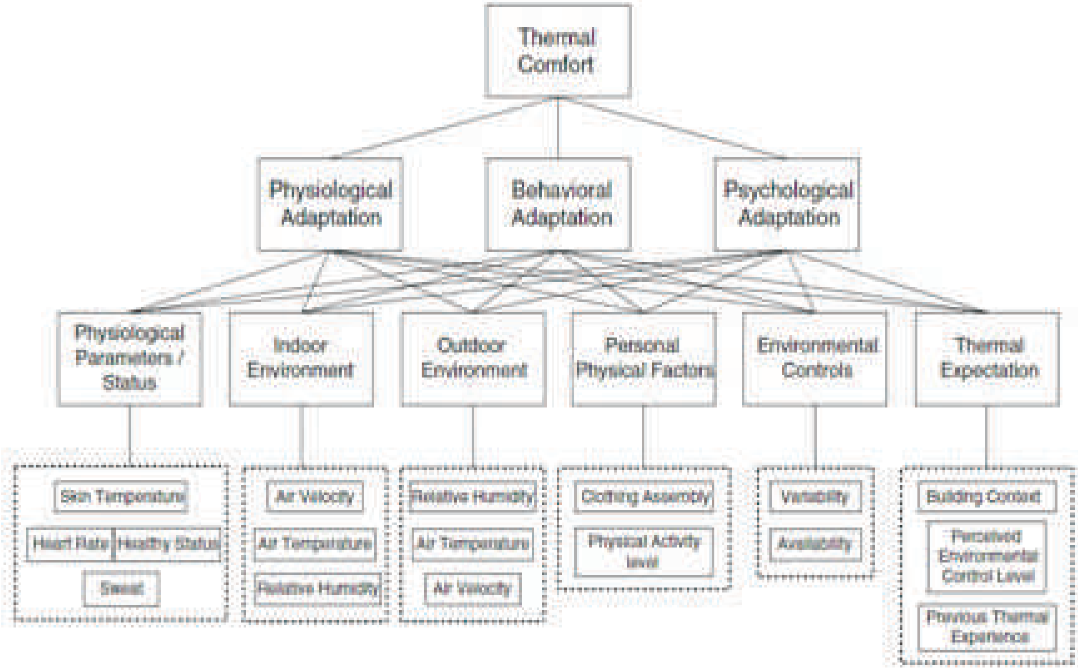

Figure 3 Analytic hierarchy process method for thermal comfort (Source, Baizhan and David, 2013 p. 293).

The PMV model was therefore revealed to have predicted thermal comfort to be below actual acceptance for warmer climates, and higher than actual acceptance for colder climates. Admittedly, Charles (2003)stated that the PMV models have been suggested by different thermal comfort studies not to be accurate in predicting the actual thermal sensation of people, mainly in field settings. Fanger's PMV, was therefore revealed to be inappropriate for thermal comfort in warmer climatic conditions and in naturally ventilated buildings by several researchers, including Nicol and Humphreys (2002); Yang and Zhang (2008); Peeters et al. (2009); Cândido et al. (2010); Wei et al. (2011); Baird and Field (2012); Eusébio et al. (2012).

In the hot-humid climate of Malaysia, a broad study by Mohd Saleh in 1989 was one of the first to suggest a comfort zone (Nugroho et al., 2007). Nguyen et al. (2012) also proposed an adaptive model giving a full account of a study over Southeastern Asia, which could be adopted generally for hot-humid climates and in naturally ventilated buildings. Studies like Sadafi et al. (2008); Daghigh (2009); Hussein and Rahman (2009); Ismail et al. (2009); Yau et al. (2011) have also defined various comfort temperatures ranging from 22.58-30.7 ^{0}C, therefore proving that Malaysians can adapt to a higher temperature than those predicted by the Fanger's model.

Thermal comfort in naturally ventilated buildings

Field studies have shown that occupants' thermal responses in naturally ventilated spaces depend in part on the outdoor climate and may differ from thermal responses in buildings that are air-conditioned mainly due to the different thermal experiences, availability of control, changes in clothing, and shifts in occupant expectations (Nicol and Humphreys, 2002; ASHRAE, 2004;

Cândido et al. 2010; Wei et al., 2011; Baird and Field, 2012; Eusébio et al., 2012). The allowable indoor operative temperatures for naturally ventilated spaces that meet the ASHRAE comfort criteria can be determined from Figure 4; it is based on an adaptive model of thermal comfort that is derived from a global database of 21,000 measurements taken primarily in office buildings (ASHRAE, 2010). In Figure 4, two sets of operative temperature limits are shown, the first one for 80% acceptability and the second for 90% acceptability. The 80% acceptability limits are for typical applications and will be considered when other information is not available. The 90% acceptability limits may be used when a higher standard of thermal comfort is desired (ASHRAE, 2010).

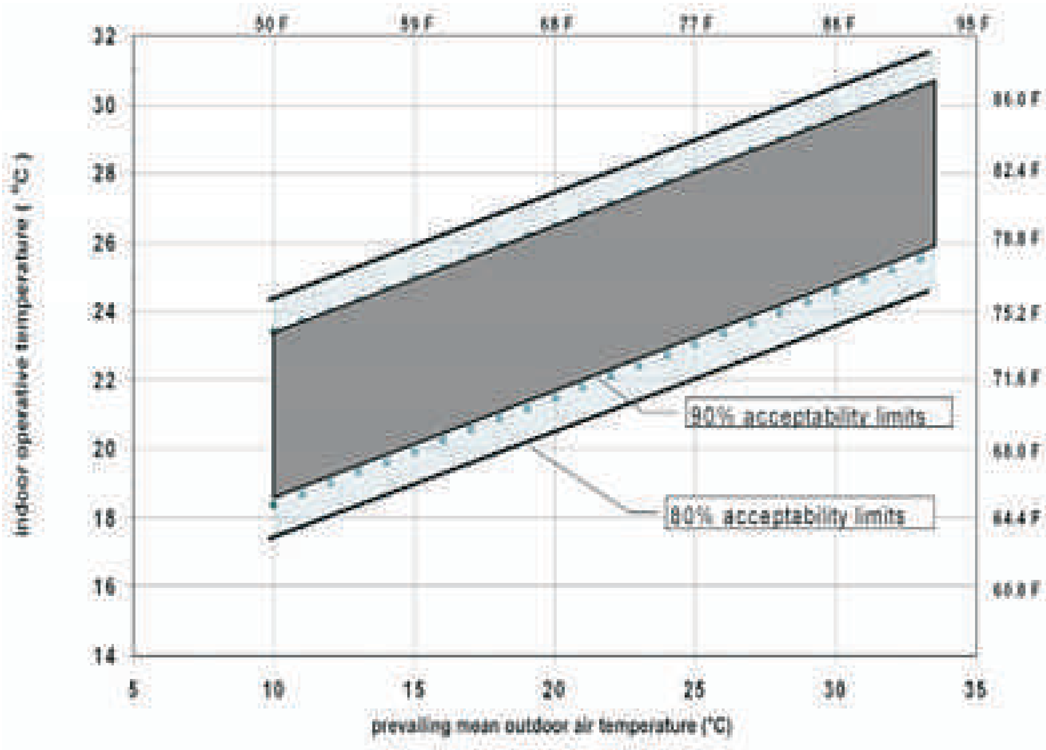

Figure 4 Acceptable operative temperature ranges for naturally conditioned spaces (Source: Figure 5.3, ASHRAE, 2010).

Thermal comfort in mixed-mode ventilated buildings

Despite numerous comfort studies on mixed-mode ventilated buildings, there is presently no comfort model specifically designed for mixed-mode ventilated spaces (Drake et al., 2010; Deuble and de Dear, 2012; Luo et al., 2014; Rupp and Ghisi, 2014). In most comfort standards, including the recent ASHRAE Standard 55-2013, the application of the adaptive comfort model is still conservatively restricted to pure naturally ventilated spaces (Drake et al., 2010; Borgenson and Brager, 2011; Deuble and de Dear, 2012; Honnekeri et al., 2014; Luo et al., 2014). By restricting adaptive to pure naturally ventilated spaces, these standards majorly classify mixed-mode ventilated buildings as AC buildings (Luo et al., 2014). According to Luo et al. (2014), this not only limits the operation of mixed-mode buildings to more restricted indoor thermal conditions; it also fails to maximize the energy-saving potential of these buildings.

ASHRAE 55 gives conditions for the applicability of adaptive model in certain spaces termed "naturally conditioned spaces", such spaces according to ASHRAE 55 are those spaces where thermal conditions are controlled primarily by the occupants through the opening and closing of windows (i.e. the space most be equipped with operable windows). Furthermore, these spaces must not employ mechanical cooling for space conditioning but mechanical ventilation with unconditioned air can be utilized in these spaces. However, the unanswered question is still whether the adaptive model can be adopted for comfort study in mixed-mode ventilated spaces. In this regard, Borgenson and Brager (2011) argued that since mixed-mode ventilated buildings feature natural ventilation, the adaptive comfort can be partially applied in studying their comfort conditions.

Studies conducted on mixed-mode ventilated spaces in different building types have concluded that the adaptive comfort model can best predict comfort conditions in mixed-mode ventilated spaces especially during the natural ventilation periods (Drake et al., 2010; Borgenson and Brager, 2011; Deuble and de Dear, 2012; Honnekeri et al., 2014; Luo et al., 2014; Rupp and Ghisi, 2014). Specifically, Honnekeri et al. (2014) studied thermal performances and occupants' responses of naturally ventilated and AC ventilated zones of mixed-mode ventilated buildings separately. The study revealed the operative temperature of 23 – 29℃ in the AC zones while a range of 29 – 36℃ was recorded in the naturally ventilated zones. Also, the majority of occupants in both zones voted within the thermal sensation limit of ±1(slightly cool to slightly warm). And what is more interesting is the fact that when the indoor temperatures in the naturally ventilated zones were very high (between 30℃ – 38℃), the occupants in this zone did not feel overly warm, rather they adapted to the indoor condition through means within their control (e.g opening their windows).

Generally, it is expected that occupants of naturally ventilated zones within mixed-mode ventilated buildings would desire cooler temperatures due to their visits to the AC zones (Honnekeri et al., 2014). However, Honnekeri et al. (2014)'s study proved that occupants of naturally ventilated zones would rather adapt to the environment in which they found themselves. The study concluded that naturally ventilated zones in mixed-mode buildings can be modelled as purely naturally ventilated spaces. Also, another study by Rupp and Ghisi (2014) conducted computer simulation on two office models under hot-humid climatic condition using three comfort assessment methods (Givoni's Building Bioclimatic Chart for hot and humid climates, PMV-PDD model, and ASHRAE adaptive model). The office models were simulated as operating on changeover mixed-mode ventilation category (i.e. spaces changes over between natural ventilation and AC on a seasonal or even daily basis). The study concluded that for mixed-mode ventilated spaces in hot-humid climates, the most suitable method is the Givoni comfort model for hot and humid climates. Givoni (1976) developed his Building Bioclimatic Chart (BBCC) (Figure 5) based on an Index of Thermal Stress (I.T.S.) which he himself developed through investigating various thermal indices that affect human comfort (Givoni, 1963). The BBCC was developed to address the problems associated with the Olgyay's bioclimatic chart.

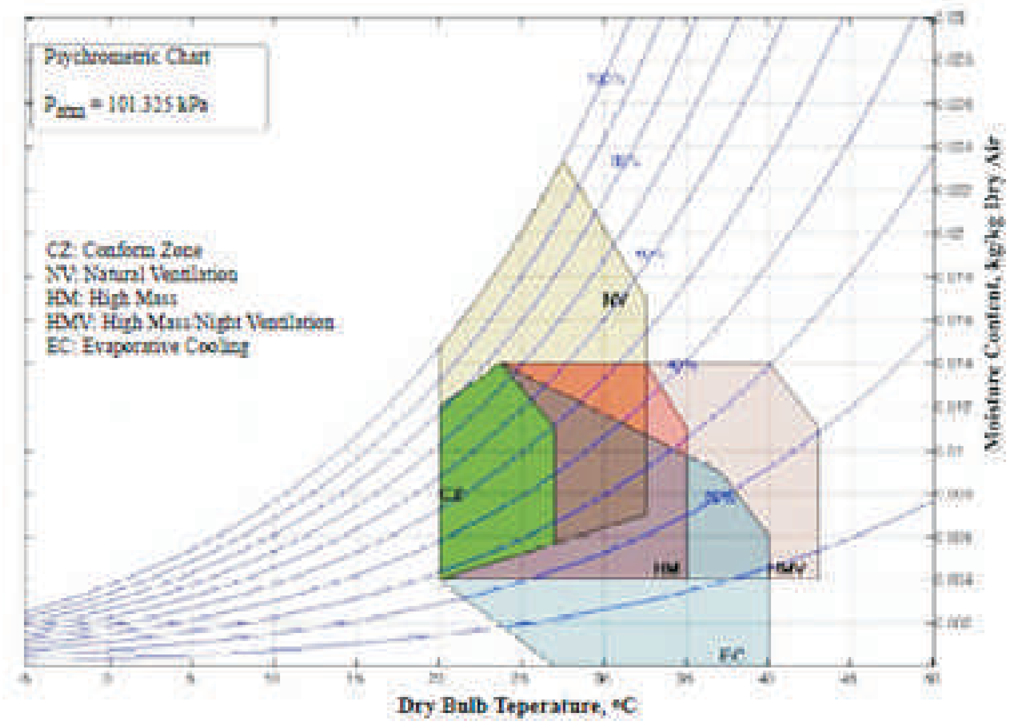

Figure 5 Typical Givoni's BBCC (Source: Al-Azri et al., 2013a)

The BBCC which was aimed at predicting the indoor conditions of buildings from the outdoor prevailing conditions, Givoni in 1992, justified the comfort boundaries for various countries with different climate conditions (Givoni, 1992). For hot-humid climates, it was argued that the combined effects of high temperature and high humidity levels reduce the dissipation of excess heat from the body and that people in this climatic zone under unconditioned space tends to adapt themselves to their thermal condition (Givoni, 1992). Therefore, the upper limits of both the accepted temperature and humidity were extended to higher levels and recommendation was also made for an increased air movement for adequate thermal comfort (Givoni, 1992). The linear relationship between the temperature amplitude and vapour pressure of the outdoor air in various regions and zones as represented on the chart are: thermal comfort, natural ventilation, high mass, high mass with night ventilation and evaporative cooling (Givoni, 1992). However, the BBCC is mainly applicable to office and residential buildings where the heat gain through the building is at a reduced level (Al-Azri et al., 2013). The BBCC has been widely used for studies in hot-humid climate regions (Visitsak, 2007; Al-Azri et al., 2013; Al-Azri et al., 2013a; Rupp and Ghisi, 2014; Rupp and Ghisi, 2014a)

Occupants' transient thermal comfort in buildings

The conventional theory of human thermal comfort in buildings assumes steady-state conditions, however, due to the interaction between various elements of the building structure, its occupants, climatic conditions, and the HVAC system, thermal conditions in buildings are seldom steady (Hensen, 1990). Within buildings, occupants often move from one space to another; at the same time movement within the building, semi-outdoor space and the outdoor space may be necessary. Thus, when occupants transit within spaces involving apparent temperature differences, the conventional thermal comfort theory is adopted for thermally adapted individuals e.g. the ASHREA Standard 55 may not be applicable (Parkinson et al., 2012; Wu and Mahdavi, 2014).

Many studies have been conducted to investigate the influence of temperature changes experienced during transition phases on occupants' thermal comfort (Hensen, 1990; Chun et al., 2004; Chun and Tamura, 2005; de Dear, 2011; Parkinson et al., 2012; Wu and Mahdavi, 2014; Xiong et al., 2015; Dahlan and Gital, 2016; Parkinson and de Dear, 2016). Wu and Mahdavi (2014) studied the thermal sensation and comfort evaluations of participants during difference transition stages. Subjects' thermal sensation and comfort was studied before transition, immediately after the transition, and shortly after adaptation. The results of the study suggested that the likelihood of a change in participants' thermal sensation instantly after a transition phase was generally dependable on the difference in temperature experienced in the transition spaces. Furthermore, with regards to the participants' thermal comfort, a relationship was revealed to exist between thermal comfort and the comfort temperature distances before and after the transition.
Parkinson et al. (2012) went further in studying the relationship between perceived pleasures during thermal transition (alliesthesia). The findings from the study revealed that according to the thermal state of the subjects, the same change in ambient temperature was both found to be pleasant and unpleasant and this thermal pleasure experienced by the subject last for short periods and depend on the nature of the physiological change caused by the thermal transitions.Similarly, Dahlan and Gital (2016) studied the observed sensory and affective responses resulting from the hysteresis effects experienced in transient thermal conditions. The findings from this study concluded that for people living in a hot-humid climate condition, PMV is an acceptable alternative to predict thermalsensation immediately after a down-step thermal transition.

Indoor Air Quality (IAQ)
A building's interior air quality (IAQ), as indicated by the Leadership in Energy and Environmental Design (LEED), is the most crucial factor in maintaining the safety, productivity, and wellbeing of occupants. ASHRAE defined an acceptable IAQ as the air that contains no contaminants at a harmful concentration, and where a reasonably large percentage (at least 80%) of a population exposed to this air does not show dissatisfaction. Kubba (2010) indicated the primary sources that contributed to poor IAQ to be those that release gases or particles into the air. The study further mentioned other major sources such as outdoor pollutants near the building, pollution due to poor ventilation systems, different combustion sources, and emission from building materials.

Kubba (2010) groups the sources of these contaminant into four; namelyinorganic contaminants (e.g. lead and radon),contaminants generated by combustion (e.g particulate matter, CO, CO_2, SO_2),organic contaminants (e.g VOCs and Formaldehyde), andbiological contaminants (e.g pests, fungus, and bacteria). In particular, the accumulation of CO_2 in a building is not only a warning in itself, but can also be used as an indicator of the build-up of other contaminants and the performance of ventilation systems. Although not perfect, CO_2 concentration levels are often taken as an indication of air quality in general.

Indoor Air Quality regulations and guidelines

A number of regulations and guidelines have been laid down and adopted for air quality in buildings, the World Health Organization standards: WHO, 1987; 2000;2010), the European standards, Limit Value for Air Quality (LVAQ), the USEPA standard, National Ambient Air Quality Standards (NAAQS) and more from other countries (Baldasano et al., 2003). ASHRAE standards: "Ventilation for Acceptable Indoor Air Quality" (ANSI/ASHRAE Standard 62.1-2007) and "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings" (ANSI/ASHRAE Standard 62.2-2004) are all recognized standards.

The Singapore guidelines from the Singapore Institute of Environmental Epidemiology (1996)is also one of the recognized standards in Malaysia since an IAQ standard has not yet been created for residential buildings in Malaysia (Ahmed et al., 2004). By recognizing IAQ as a critical issue, the Department of Occupational Safety and Health in Malaysia (DOSH) established the Malaysian Industrial Code of Practice on Indoor Air Quality (MCPIAQ, 2005) in industries (Edimansyah et al., 2009). Consequently, MCPIAQ (2010) was approved as an improvement on MCPIAQ (2005), where the aim was to create a minimum standard as a guideline for indoor contaminants and to safeguard the health and well-being of occupants and workers (MCPIAQ, 2010; Sulaiman and Mohamed, 2011).

Indoor Air Quality studies in retail buildings

Retail buildings are prone to high contamination level, part of which is due to the fact that they are mostly located within close proximity of main roads which attracts heavy traffic and thus attracts contamination from cars' exhaust (Li et al., 2013). Also, indoor contaminant emission sources from different products and chemicals within the retail building can contribute to the high level of contamination and poor indoor air quality (Tang et al., 2005; Xu et al., 2014). Studies (Tang et al., 2005; Klinmalee et al., 2009; Li et al., 2013; Amodio et al., 2014; Xu et al., 2014) identified various contaminants which include VOCs, SO2,NO2,CO, CO2, PM2.5, carbonyl compounds, aromatic hydrocarbons, TVOC, Phthalates and polybrominated diphenyl ethers in different retail space in different countries. These contaminants have been revealed to affect building occupants at different degree of complications, from mild symptom such as the sick building syndrome (Aizat et al., 2009; Wong et al., 2009; Sulaiman and Mohamed, 2011) to serious complications such as negative impact on the nervous system and increase learning disabilities in children (Zhou et al., 2011; Ramírez et al., 2012; Amodio et al., 2014).

Zaatari et al. (2014), after conducting a critical review of 28 kinds of literature on IAQ in retail buildings, revealed seven most important pollutants present in retail buildings. These pollutants which include: PM2.5, trichloroethylene, PM10, formaldehyde, acetaldehyde, benzene, and acrolein were found to exceed the recommended limits in most of the studies. It was also revealed that ventilation measurements conducted in those studies met the required standards in most cases. Nonetheless, the recorded ventilation rates were not sufficient to keep all pollutants below their most conservative limits. Malls don't only present ventilation issues, according to Xu et al. (2014) malls also contain a wide range of products that can emit various indoor pollutants which have been associated with serious health issues. Several studies have looked into the indoor air quality aspect of IEQ in malls to identify those pollutants that could threaten the health of both shoppers and retailers. Li et al. (2013) revealed that large shopping malls are microenvironments for formaldehyde and acetaldehyde carbonyl exposure. Carbonyl concentrations were at its highest in supermarkets, furniture store, department store and bookstore. The study was conducted on eight shopping malls in different geographical areas of Nanchang city, China.

Similarly, Klinmalee et al. (2009), Hu and Li (2015) found that $PM_{2.5}$ was the major pollutant in malls. Klinmalee et al. (2009) studied the concentration level of $PM_{2.5}$ in a Thailand mall while Hu and Li (2015)'s study was conducted in a mall in Changsha city, China during Autumn. The two studies both recorded high indoor pollutants during the weekends compared to the weekdays. This was also the case with Wai-Ming et al. (2001) after monitoring CO_2 levels in nine shopping malls in Hong Kong. Furthermore,Tao et al. (2015) and Amodio et al. (2014) studied VOCs concentration level of multi-storey shopping malls in China and Italy respectively. Their studies revealed that the highest VOC concentration was recorded in the food department during the routine cleaning.

Jiang et al. (2013) recorded very high indoor concentration levels of carbonyl compounds, aromatic hydrocarbons and TVOCs compared to an outdoor concentration level in furniture mall located in Beijing, China. The study confirmed that furniture and building furnishing materials play an important role as major sources indoor air pollutants. Sun et al. (2015) investigated the influence of IAQ and thermal comfort performance on users exposure to SBS in two malls in Tianjin, China, users' perception were also sourced through a questionnaire survey. It was found that formaldehyde concentration level exceeded the Chinese National Indoor Air Quality Standard and the study revealed that serious SBS symptoms were reported by the users, therefore, high formaldehyde concentration in malls should be of great health effect concern.

COMFORT STUDIES IN RETAIL BUILDINGS.

Acoustic comfort in retail buildings

Acoustic factor plays a significant role in the overall physical comfort in retail buildings with large atrium spaces e.g. malls (Chen and Kang, 2004). After studying acoustic comfort of three (3) atriums in three main malls in the UK, Chen and Kang (2004) concluded that the sound pressure level was affected by the number of customers, space features of the atrium, as well as background music. In summary, the study revealed that though retailers are more tolerant in terms of communication comfort than customers, all users (shoppers and retailers) feel more satisfied with the communication quality than with the overall acoustic comfort. Similarly, Meng and Kang (2013) conducted both objective and subjective measurement in six shopping malls in Harbin City, China, to determine the influence of social and behavioural characteristics of shoppers on their evaluation of subjective loudness and acoustic comfort. The analysis of social characteristics revealed that evaluation of subjective loudness is influenced by income and occupation, while for behavioural characteristics; the evaluation of subjective loudness is influenced by the reason for visit, the frequency of visit, and length of stay.

However, Della Crociata *et al.* (2013) argued that acoustic comfort satisfaction is indeed influenced by other factors such as sources of acoustic annoyance. Meng and Kang (2013) concluded that their findings can contribute to a better understanding of the acoustic environment in shopping malls, and are also useful for the establishment of acoustic comfort prediction models. In addition, Omar (2012) studied the role of natural light in determining individual's performance in interior spaces of shopping malls. The study revealed that IEQ must be enhanced to achieve a sustainable interior space and to successfully integrate energy efficiency. Omar (2012) further stated that shopping malls have the potential of reducing electrical energy consumption for illumination by using the new strategies of providing natural lighting.

Thermal comfort in retail buildings

In recent years, IEQ studies in retail buildings have focused mainly on IAQ, visual and acoustic comfort. A few number of studies with an in-depth evaluation of the thermal comfort conditions in retail buildings are Chow and Fung (1995) and Chun and Tamura (1998). These two studies are quite old has recent literature with an in-depth analysis of thermal comfort conditions in retail buildings can hardly be found. A recent study by Karyono et al. (2015) however, looked into thermal comfort in a naturally ventilated market compared to a naturally ventilated cathedral and museum in Jakarta, Indonesia. The study revealed a similar comfort temperature in users of all three buildings; however, the spread of the users' comfort range in the three buildings was significantly different. Carrilho da Graça *et al.* (2012) also presented results from thermal and airflow simulation of an existing naturally ventilated shopping mall in Lisbon, Portugal. The simulation was carried out on the present natural ventilation system design in order to address winter thermal comfort problems. The simulation results shows that the natural ventilation system design was able to successfully addresses the mall's winter discomfort problem.

Chow and Fung (1995)'s study was particularly on air-conditioned malls in Hong Kong. Three key thermal comfort parameters (indoor air temperature, relative humidity, and air speed) were measured in the occupied zone and subjective evaluation was acquired from shoppers. A limitation of the study is the relatively small number of respondents used, only 5-15 respondents were interviewed in each 84 malls considered in the study. Also, no continuous physical measurement was done; only 4 measurement points were allocated in each mall for taken spot measurement. The results revealed that the shoppers prefer high air speed and they are more comfortable with a mean air temperature of 20-24^{0}C, mean relative air humidity of 50-65% and mean air speed of 0.2-0.4 m/s. Chun and Tamura (1998)'s study on the other hand, was focused on the comparison of thermal environment and human responses in underground shopping malls and departmental stores in Japan. The result revealed an unstable thermal condition and unstable users' psychological evaluation in the underground shopping mall compared to the department store. Also, the neutral temperature recorded in the underground shopping mall becomes colder in winter compared to the department store. It was concluded that the difference in the neutral temperature recorded was due to the fact that the temperature range in winter is very different between the two buildings. Eleven (11) respondents were used for the whole study.

Few studies conducted in shopping malls actually put all IEQ factors into consideration. Example includes studies by

Della Crociata et al. (2012), Zhao et al. (2015), Martellotta et al. (2016). For all these studies, both subjective and objective measurement were done on all IEQ factors (thermal comfort, IAQ, visual and acoustic comfort). Della Crociata et al. (2012) discuss the suitability of a proposed data collection method called "on-site measurement procedure" to assess IEQ perception in hypermarket workers. The "On-site measurement procedure" involves allocating a specific fixed location within the retail space for respondents to stay while filling out the questionnaire. While respondents were attending to the questionnaire, the physical measurement was conducted simultaneously within the same location. At the end of the study, they were able to prove that their method of data collection showed minor predictable biases and it is effective in environmental studies as it minimizes interference with workers' activities.

Zhao et al. (2015) studied occupant perceptions and health outcome in 14 retail buildings in Texas and Pennsylvania with the aim of understanding employees' perception of all indoor environmental parameters. The study revealed that the employees' responses had a high correlation with the measured parameters and the air exchange rate is the most influential parameter that affects employees' perceptions and a health outcome. Martellotta *et al.* (2016) used different statistical analysis to the interaction between users' satisfaction and different IEQ contributing factors in a retail building located in Southern Italy. By employing the Kano's satisfaction model, the study revealed that thermal comfort and IAQ were considered "basic factors" (i.e. they cause negative effect on satisfaction when they underperform) while acoustic comfort was considered a "bonus factor" (i.e. cause extreme satisfaction when it performs well but does not cause dissatisfaction when it underperform). At the end of the study, the visual and thermal comfort showed a linear relation with overall satisfaction, therefore, proved to have the highest impact on users' satisfaction.

All the above reviewed literature with the exception of Martellotta et al. (2016), did not consider the occupants/users' satisfaction with regards to the studied buildings overall performance in their studies. Furthermore, the effects of the studied IEQ factors on the overall performance satisfaction level were neglected as well. Although Martellotta et al. (2016) included the evaluation of users' overall satisfaction in their study, the shoppers were not included among the users that were studied. Also, another study by John et al. (2016) did include both retailers and shoppers in their study, their evaluation of users' overall satisfaction with regards to the studied mall was not based on IEQ. The study was focused on users' perception of location, use, aesthetics and security of a mall located in Porto Alegre, Brazil.

Ibiyeye (2017) and Ibiyeye *et al.* (2018) however, did an extensive study on thermal performance of mixed-mode ventilated shopping malls in hot-humid climatic region. Occupants' thermal perception (both shoppers' and retailers') and IEQ performance was investigated in two mixed-mode ventilated malls selected based on their design concept ('open' and 'enclosed'). Both subjective and objective measurements were carried out in accordance with the ASHRAE performance measurement protocol for commercial buildings. Five IEQ factors (indoor air temperature, operative temperature, relative humidity, air speed, and carbon dioxide concentration level) were evaluated in the two malls. The results revealed that both malls fell below the ASHRAE comfort requirement but majority of the occupants still found the indoor thermal performance acceptable despite the high indoor air temperature recorded. For both malls, high air speed and low humidity level were recorded. However, higher air movement was still preferred by the occupants while the recorded mean carbon dioxide (CO2) concentration was within the recommended level. The 'open' concept mixed-mode ventilated mall proved superior compared to the 'enclosed' concept by providing a more thermally tolerance indoor environment for its occupants. Ibiyeye (2017) went further to compare the performances of the two mixed-mode ventilated malls with a fully air-conditioned one. Results revealed that for indoor temperature, the air-conditioned ventilated mall performed better that the two mixed-mode ventilated malls. Yet, thermal acceptance in all three malls was high. However, for air speed and CO_2 concentration, the two mixed-mode ventilated malls performed better than the air-conditioned ventilated mall.

CONCLUSION

This paper has reviewed some of the major studies relating to thermal comfort, acoustic comfort and indoor air quality and how these factors affect building occupants and their perception of their buildings' performance. This paper further reviewed and discusses relevant literature on how adopted ventilation modes in different building types affect occupants' comfort and their perception most especially retail buildings under different climatic conditions. The following conclusions can be drawn from this review:

1. Occupants of any building types desire adequate comfort so much so that occupants displays varying adaptive features (such as opening of windows, reducing the layers of clothing worn, making use of assisted ventilation devices e.g. fan, stepping outside of the uncomfortable space, etc.) whenever the indoor space fails to deliver the expected level of comfort.
2. Ventilation modes adopted within a building affect occupants' comfort and expectations. Though retail buildings have been known for their controlled indoor environment, but retail buildings are now taking advantage of natural ventilation and day lighting to improve comfort within their indoor spaces.
3. Although, concerns have been raised concerning the practicability of natural ventilation to achieve adequate comfort in large retail buildings such as shopping malls, some studies have however revealed that natural ventilation has a great application potential in large retail buildings.
4. Occupants' thermal responses in naturally ventilated spaces depend in part on the outdoor climate and may differ from thermal responses in buildings that are air-conditioned mainly due to the different thermal experiences, availability of control, changes in clothing, and shifts in occupant expectations.

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