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Thermal Comfort in Different Types of Buildings: A review study

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Abstract—**The paper presents a literature review of thermal comfort on buildings in different sectors. Main factors affecting thermal comfort will be discussed. Heat loss and gain through buildings will be highlighted which is responsible for the state condition of the users in different types of buildings. In addition, focus on the effect of building's function on thermal comfort.**

Index Terms: **thermal comfort, review paper, buildings**

I. INTRODUCTION

Having the right temperature indoors was and still one of the most remarkable things that people concern about in buildings. Thermal comfort is a general term which used to describe people's state and condition. It has many definitions as it has been mentioned by Hensen as "a state in which there are no driving impulses to correct the environment by the behaviour" [1]. However, the most common definition is the one which has been announced by the American Society of Heating, Refighting and Air-Conditioning Engineers (ASHRAE) defined as "the condition of mind in which satisfaction is expressed with thermal environment" [2].

Thermal comfort is mostly a state of mind rather than a state of condition as Kuchen (2009) has found that a person who is staying in the same space, climate and culture could have different state to thermal comfort with another one who is staying identically at the same variables [3]. Similarly, Djongyang (2010) has expressed the same fact which shows that achieving thermal comfort can be affected not only by environmental factors, but also social, culture and other aspects have relative attributions [1].

Moreover, the International Standards "ISO" 7730 (1994) considered that since there is an individual differences, it is not an easy task to specify the thermal comfort, but it is possible to modify the environment to be accepted by certain percentage of the occupants. This percentage has been estimated by 80-90% of the occupants [4].

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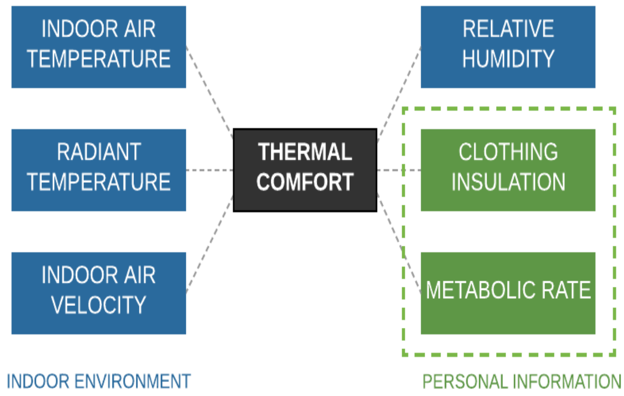

Figure 1 the most important environmental factors affecting thermal comfort

There are many reasons why the society should concern and consider thermal comfort. There is also an international consensus to cut down carbon emissions [5]. Although it might be difficult in some climatic regions to achieve thermal comfort without the use of fossil fuels [6], it is possible to achieve thermal comfort for the most of the year in certain locations with utilizing the use of thermal comfort strategies [7]. Health is one of the most important aspects that are affected by thermal comfort, "Thermal comfort is not just about ensuring a sensation of a satisfaction with ambient temperature, it is inextricably linked to health" [8] Sakka (2012) has pointed out that if the outdoor temperature was not appropriate to the core temperature (37 degree), the body whether will sweat to cool the skin in the case of hot environment, or will be shivering in the case of cold which is an indication of warning [9]. In addition, Parsons (2003) has reported that if the temperature goes higher than 30 degree in classrooms, this could affect student's ability and work [10]. Furthermore, Cheong (2003) has noted that the most important aim of conditioning indoors is to provide a comfortable and healthy environment for the users [11]. Furthermore, Atmaca (2007) has indicates that good building design has to provide health and safety to the occupants [12]. Based on what have been discussed, thermal comfort should receive more attention from researchers as Hall (1999) has reported Fanger's state in his most important book in thermal comfort that there is no enough knowledge about it for practice application [13].

II. THERMAL COMFORT ESTIMATION APPROACHES

Currently, there are two main approaches to estimate human thermal comfort Predicted mean vote (PMV) and the percentage of dissatisfied (PPD) [14, 15]. These approaches based on Fanger's work which take into account some environmental aspects such as dry bulb temperature, humidity, air velocity and mean radiant temperature (see Fig 2) as well as human factors such as thermal resistance and metabolic rate [16]. Thermal balance is derived when the internal heat production in the body is equal to the heat loss to the surrounding environment [4]. There is abounding papers that have been published to investigate and validate these methods as standards that can be applied worldwide. However, there were many results which against them, but they still have a good contribution to be the most commonly used approaches for thermal comfort arithmetic as Jang (2007) has pointed out that they are a suitable method which have the ability to describe the user's reaction about their comfort [16].

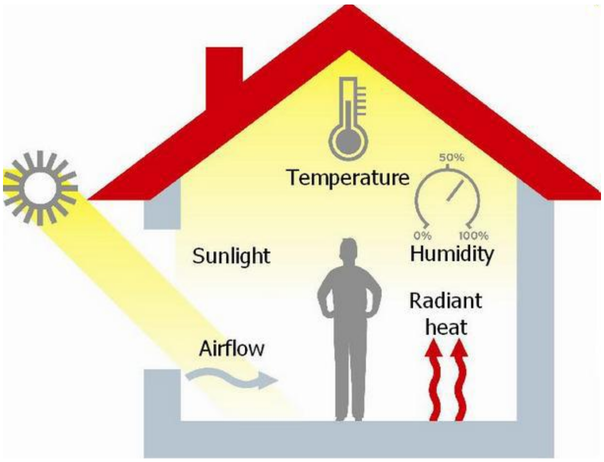

Figure 2 aspects affecting the assumption of thermal comfort in the two approaches (PMV and PPD)
Source: Atjenese (2012)

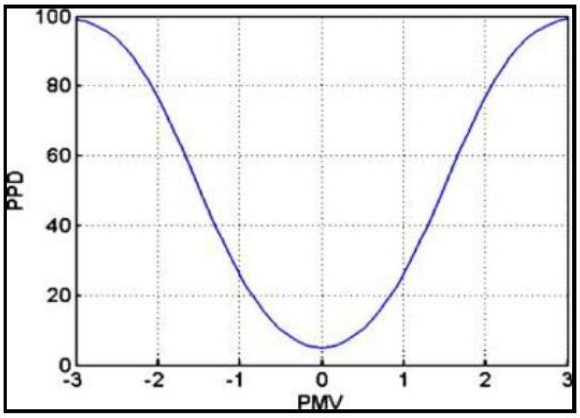

Figure 3 Relationship PMV versus PPD. Source: Peetrs (2009)

In terms of PMV it can be defined as it has been mentioned in [4] "PMV is an index that predicts the mean value of votes of a large group of persons on the 7-point thermal sensation scale" where the range of the scale as follow: +3 is too hot, +2 is warm, +1 is slightly warm, 0 is neutral, -1 is slightly cool, -2 is cool and -3 is cold. In addition to that PMV model uses heat balance methods to combine the six factors to calculate the state of thermal comfort for the users [2].

As far as PPD is concerned, it has been defined by ISO-7730 (2005) as "The PPD predicts the mean value of the thermal of a large people" it is related to the PMV model [4], but it is expressed by those who feel discomfort (+2 and +3 or -3 and -2) [2]. It has been established to determine the percentage of thermally dissatisfied people who is feeling to hot or too cool.

III. FACTORS AFFECTING THERMAL COMFORT

Part from the individual elements that have relative influence on thermal comfort, there are several factors that have the major impact on the satisfaction or dissatisfaction of the occupants. The most affective factors on human thermal comfort are the environmental factors which cover many aspects which have to be taken into account. However, the consideration of each one has received certain concern. [10,2] have pointed out the following factors as the most important when addressing thermal comfort air temperature, humidity, radiant and air movement which are considered as environmental factors. In addition to that are metabolic rate which is generated by human activity and body insulation which is clothing. However, some sources are expressing extra factors in group's format showing priority for some of the factors. This is as it has been pointed out by Gadi in Hall (2010) [17]. Gadi has divided the factors in two different groups the first one contain metabolic rate, mean radiant temperature, air velocity, clothing thermal resistance, air temperature and vapour pressure whereas the second group contains sweat rate, skin wittiness, clothing fit, skin temperature, clothing wittedness and clothing surface.

IV. HEAT LOSS AND GAIN

Heat loss and gain has a strong relationship with thermal comfort as it contributes to the actual state of the user. Just as the human body exchange heat with the surrounding environment, the building also exchange heat between indoor and outdoor (CLEAR n, a). The fabric, however, is the main element which comes in the form of walls, floors, roofs and so on. The following are the factors that affecting heat loss and gain in buildings.

a. Heat loss through glazing (QG)

It has a remarkable influence on buildings, especially, where there is a large amount of glazing. In fact, the point is not only with regard to heat loss from glazing, but also with the whole other aspects which has a relationship with outdoor. One of the most affective aspects that influence heat loss and gain is the area of glazing as well as the U-Value. It has to be highlighted that the size of the window has a huge influence on the sum of heat loss and gain. In addition, if there was not enough consideration on selecting and designing the U-value could be cheaper, but the fluctuation of the heat loss and gain will be larger. As a result, more afford has to be undertaken to improve the performance of the buildings, especially, in location such as Saudi Arabia where there is a massive differences between the temperatures indoors and outdoors. In order to calculate this heat, the following equation has to be done for each window in the building:

QG = (UG * AG * TD), where:

UG is the U-Value of the glazing which has a major affect as it has been mentioned before.
AG is the area of the glazing which also affects the amount of heat that could loss from the building.
TD which id indicating the temperatures difference between inside and outside the building.

b. Heat gain through glazing (QS)

This is the form of heat that enters the building through the glazing in the case of cooling load. It has some variables that influence the gain which will be considered in the formula that can be used to calculate the amount of heat gain through this window. The equation is giving as following:

QS = (SRW * SHG * AG * STG), where:

SRW is the amount of solar radiation that is hitting the window at the specific time.
SHG is shading coefficient of this window.
AG is the area of the glazing.
Finally, STG is solar transmittance of glazing.

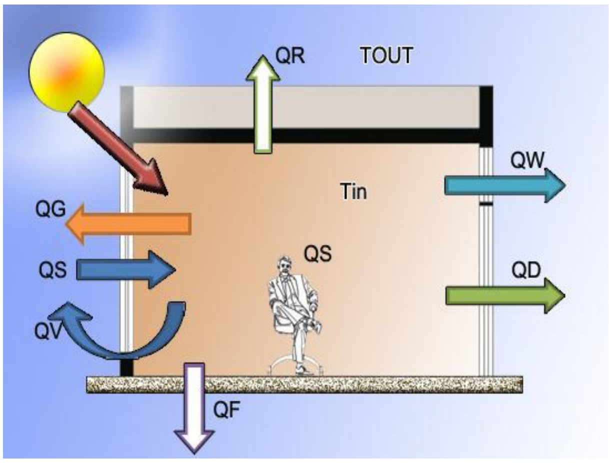

Figure. 4 Different aspects that influence the transferred heat loss and gain from and into the building where:
(QG) is heat loss through glazing
(QS) is heat gain through glazing
(QW) is heat loss and gain through fabric
(QR) is heat loss and gain through roofs
(QF) is heat loss and gain through floors
(QC) is heat gain by the occupants
(QV) is heat loss and gain by ventilation
TOUT is outdoor temperature
Tin is the internal optimum temperature
Source (Reproduced) from MSc lecture in Renewable Research

c. Heat Loss and Gain through Fabric (QW)

In different way it can be called heat loss and gain through external walls. This aspect is calculating the amount of heat loss and gain for the inter external walls in the building and there are some variables that influence the result which is listed in the following formula:

QW1 = (UW1 * AW1 * TDW1), where

UW is the U-Value of the wall which shows how well this wall has been designed in terms of materials used and layer's thickness.
AW is the area of the wall. This could influence the final result significantly.
TDW which is referring to the temperature differential between indoors and out.
Heat loss and gain through roofs (QR)
To calculate the amount of heat loss and gain through roofs the following formula has to be used:

QR = (UR1 * AR1 * TDR1), where:

UR is the U-Value of the roof.
AR is the area of the roof.
Finally, TDR is the temperature differential between inside and out.

d. Heat loss and gain through floors (QF)

This is indicating the amount of heat loss and gain through the floor which can be calculated by the following equation:

QF = (UF * AF * TDF) where :

UF is the U-Value of the floor.

AF is the area of the floor.

TDF is the temperature differential between indoor and outdoor.

e. Heat gain by the occupants (QC)

This is just to calculate the sum of heat that could be generated by the occupants with the given formula:

QC = (QP + QE) where:

QP is the number of people, and it is obvious that the more people is mean more heat would produce.
QE is the amount of heat that is producing from the equipment.

f. Heat loss and gain by ventilation (QV)

The final aspect that has an attribution toward the amount of heat that could be calculated is the effect of natural ventilation which can be calculated by the following formula:

QV = ((ARC * V) * TD) / 3 where:

ARC is ventilation rate.
This factor can be controlled by adjusting the openings of the building such as windows weather it is located on the external walls of the building or on courtyards or even on roof lights. V which is referring to the volume of the whole building and that has to take the inter volume of the house into account including roof lights and courtyards. TD which is the temperature differential between indoor and outdoor [36].

V. EFFECT OF BUILDING FUNCTION ON ADAPTIVE THERMAL COMFORT

The function and use of a building can make a massive difference in terms of the opportunity of adaptive thermal comfort for occupancy. Four main buildings types will be taken into consideration:

- **Residential buildings**
- **Office building**
- **Healthcare buildings**
- **Educational buildings**

Each one of these buildings has its own use, activity and variety of zones which all will have certain effect on chance of adaptation.

a. *Residential buildings*

It is one of the most energy consumption comparing with the other types of buildings [48]. This might be because of the amount of time that people spend in their homes [14]. In addition, Djongyany (2010), has drawn attention to the fact that residential buildings consist of several kind of spaces such as living room, bedroom and kitchen, and each one of them require its own thermal comfort level [1].

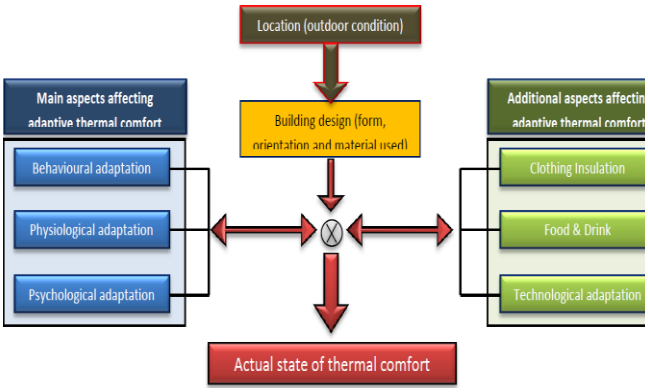

Figure 5. the main aspects effecting thermal comfort, and other additional common aspects that leading to the actual state of thermal comfort

In a study done by Peeters (2009) which express that thermal comfort in residential buildings rely heavily on local weather [45]. There are three explanations for this. The first one is because most of people in developing countries live in rural areas [45]. The second justification is that many people live in detach house which leave all the external walls and ceiling expose to the fluctuation of the weather. The third one as it has been considered by (Ghisi 2007) which indicates the importance of dwelling thermal performance which leads to increase in energy consumption. As a result, it has to be highlighted that the energy consumption of domestic buildings has to be reduced, especially, in the rapid rise of residential buildings [46].

In a work done by Peeters (2009), where he has divided residential building into three main zones; each one has different requirement of thermal comfort, and these as following: Bathroom, bedroom and other rooms such as kitchen, living room, study room and etc. Furthermore, Peeters has pointed out the reason of such classifications which based on physical activity level and more individual factors that will be discussed later within the paper [45]. For instance, in bathroom there are air temperature of the water of the bath, air temperature of the bathroom and humidity of air [47]. Moreover, peeters (2009) has observed that bathrooms have a very critical lower limit temperature due to the condition of the body (nude) and wetness (humidity). He has state the comfort in the bathroom in the range from (21 degree to 30.5) [45]. There is a far more published papers have been done on bathrooms when considering variety of zones in residential building. As a result, more attention will be given to it.

Bedrooms as a most used place in residential block

People spend one-third of their life sleeping [1]. This includes every single human being. Furthermore, to surpass tiredness, sleeping might be a good solution. Consequently, there should be abundance in research on this field. However, as Djongyang has pointed out that there are quite limited publications. One of the most important factors in sleeping thermal adaptation that should be taken into consideration is that behavioural adaptation is limited during sleep [45]. Traditional matters might have an effect on sleepwear. For instance, the traditional style bed of Chinese which called “Zonghang” provide less insulation [49]a. In addition to that people may prefer sitting or sleeping on floor rather than sofas or beds, respectively (as it is the case in Eastern style). This could raise certain limitations [50].

In a paper conducted by Lin (2008) where values of the bedding system has been divided into the following: bed, bedding (its percentage covering over human body), and sleepwear. The overall thermal insulation value of the bedding has a major impact on thermal comfort [51]. Furthermore, another study done by Lin (2006) is supporting this fact where a survey has been conducted. It shows that most of people prefer cooler indoor temperatures at sleeping time (below 24 degree) [52]. It has to be highlighted that bedding system has to be taken into consideration in energy balance to provide thermal comfort in different indoor environments [53].

Figure 6. examples of experiment of sleeping conditions with different level of clothing insulation. Source: Lin (2008)

b. *Office buildings*

Deep plan in office buildings started to appear since 1960s with fully glazed façade that would increase the need for artificial lights. Moreover, in 1980s personal computers compensated pen as well as typewriter which added extra heat. Even though in moderate climates, these extra loads would not be easily removed by natural ventilation [54]. As a result, energy consumption in office buildings is mainly used for creating and maintaining comfort conditions in the internal environment [46]. In addition, Hens (2009) has expressed that air conditioning in office building is on operation in North Western Europe as a result of high internal loads created by personal computers as well as solar gain [54].

Many researchers have expressed the fact that office buildings experience maximum energy consumption as they rely usually on mechanical methods to achieve thermal comfort. In a study conducted by Chen (2012), which observes that over-cooling, is typical in office buildings this is due to adaptation and design of air conditioning system [56]. However, Barlow (2007) is against this in a paper done in UK's offices where a group of people has voted for opening windows as their favourite method for achieving thermal comfort. However, this contrast might have some additional aspects involved such as local location; location like the UK dose not experience extreme summer like other locations does, with exception of some heat-waves that take place in summer [57].

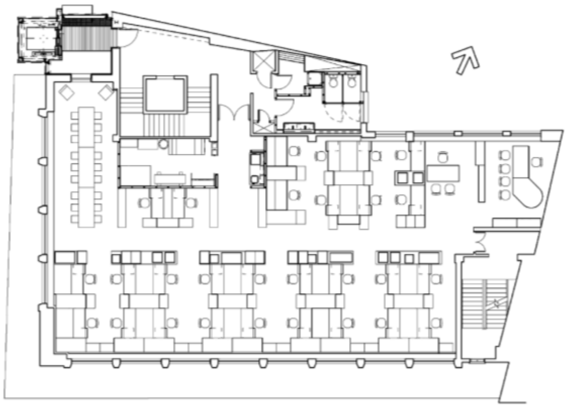

Figure 7. Typical office floor plan. Source: Barlow (2007)

One of the most elements that make it difficult for workers in office buildings to achieve thermal comfort is that they do not change their clothing during the day. Such method which considered as one of the active thermal adaptation is quite important to reduce energy consumption in office buildings [57]. Furthermore, Ricciardi (2012) has shared the same opinion. He mentioned that in hot and arid climate, clothing insulation has a significant impact on thermal comfort on office workers [58].

There are several active approaches that may result a massive reduction in energy consumption in office buildings:

- Temporal and spatial control (workers changing their time to avoid inconvenience working conditions).
- Adding or removing cloths based on the current condition.
- Solar shading control (to reduce solar gain)
- Switching off the lights which it is not needed.
- Natural ventilation control (opening and closing windows) [57].

It has to be mentioned that adaptive approaches will always give different results due to the variation of subjective behaviour of the workers, and their background [58].

c. Health care buildings

Healthcare is a wide term that covers any building which its main purpose is to take care of people's health including hospitals, GPs and etc. Since hospitals are the most common destination for patients, it will be highlighted only representing health care buildings. Hospitals have been classified as one of the most complex internal environment with wide range of facilities and numerous different users. Furthermore, it has the most demanding indoor zones. Maintaining a fixed internal condition in hospitals is very critical which has to be in operation 24 hours every day. These statistics are making it the highest energy consumption per unit floor area in the entire buildings sector [57]. Observing a patient's illness does not only know his or her body temperature as a result of weakness, but it rather understands that creating comfort environment would be beneficial to stabilize moods of patients [59]. Although there has been a various publications on thermal comfort, but most of them did not take hospitals into consideration [60].

As far as the difficulties of adaptive thermal comfort in hospitals are concerned, there is a significant difference between patient and staff in their conception among thermal comfort due to the differential in range of activities, cloths and medical condition. On the top of that physical, social and individual needs of each one of the two groups vary to far extent. Moreover, patients usually have lower activities when comparing with staff, because they have to remain on bed as long as they are in the hospitals in many cases. As a result, all these variables make it quite hard to optimize and achieve thermal comfort for both of them [61]. Operation room in hospitals is the most critical zone where indoor air temperature, humidity and air velocity has to be kept within a certain range. Consequently, it requires a sufficient HVAC installed to provide very high demand indoor environment [62].

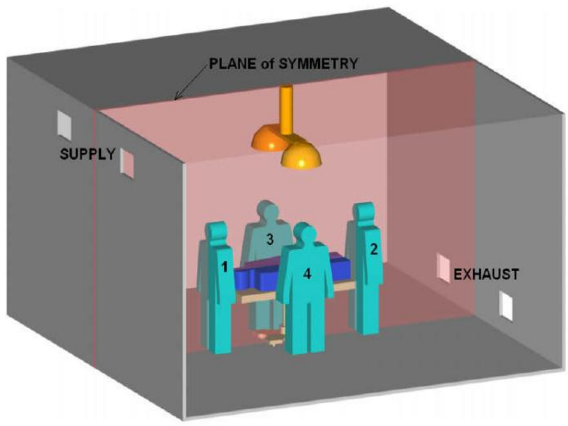

Figure 8. model of an operation room in a hospital

Patient in an operation room has very serious case where many variables are affecting his comfort. Ho (2009) has listed these points as follows:

- Patient has to lie on an operation table
- Several surgical staff members standing (usually four)
- Surgical lights above the patient's head

Ho found that it is more effective placing the supply grilles closer to the vertical centreline of the wall. In addition, in such zones, there is still the need for natural ventilation even in winter time when the mean of natural ventilation become very limited [63]. Adamu (2012) has revealed that 25% ducts ventilation opening fraction is needed to achieve required air flow rates and convenience thermal comfort in winter [64]. Hashiguchi (2008) has expressed the need for increase the humidity in winter which caused by the use of central heating systems. In fact, low relative humidity could have an effect not only on comfort, but also on health. Furthermore, humidifiers in hospitals during winter time can have a major impact in increasing humidity, with exception to large open space such as nurse-station [65]. Finally, peak times should receive enough consideration, in terms of hospitals; it was found that morning time is the issue in winter, and noon in summer [66].

d. Educational buildings

Thermal comfort has a significant impact on student's performance (67, 68, and 59). The importance of insuring acceptable indoor air quality in class rooms is distinguished as contributed factor to the learning performance of students [68]. Moreover, providing healthy and comfortable environment is crucial for every single type of buildings, particularly, in schools where a high level of indoor condition quality is important to enable them to spend many time of listening and understanding their lessons without any moment from the desks [67]. As a result, the condition in class rooms should be improved in an urgent educational preference [68], as it is the case for the improvement of indoor air quality in class rooms [56]. The most affected categories in schools are children in the range of age from 7 to 11. Those have very limited chance for thermal adaptation for many explanations [70]. For this reason, more focus will be on them. Two main problems face children to adapt properly:

- Cloths
- Activity level

In terms of cloths, some of young students go to school in the early morning wearing thicker cloth because of the cool air at that time. However, they get warmer in the noon time because they usually do not remove any of these cloths [71]. Furthermore, Teli (2012) and Humphreys (1977) have drawn attention to the same factors which lead to different perceived optimal conditions, hence would have a warmer thermal sensation than adults [70 and 71] respectively. With regard to activity level, students have to remain settled during lessons. Consequently, adjusting and modifying their activity level will be limited. This kind of freedom may also include adding or taking off some cloths, opening or closing windows or even modifying sun-shading devices [67]. The integration between natural ventilation and thermal comfort level in school building should receive certain consideration since it may result noise that derives from internal environment. For instance, Mumovic (2009) stated that in many cases, proper ventilated school building often result an increase of negative impact on students. He observed that there is a serious challenge to integrate thermal comfort, ventilation and acoustics which, perhaps, make it more difficult for the designers to pay more attention toward this matter [68].

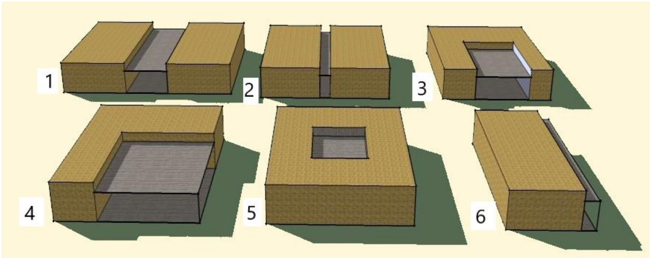

Figure 9. Classification of most common school building forms (reproduced with some modifications from Graca 2007). 3D views of each form of school building
1.Two sets sequence of classrooms with corridor
2.Double loaded corridor plane
3."U" shape of classrooms around semi closed courtyard
4."L" shape of classrooms
5.Classrooms opened on a fully closed courtyard
6.Row of classrooms along a single corridor

VI. CONCLUSION

This paper presents a literature review on thermal comfort. There was more focus on buildings and the properties of it such as zones available and types of users. Thermal comfort estimation approaches have been taken into consideration where two main methods were demonstrated PMV and PPD. It has been mentioned that these are the most common and accepted methods to predict the state of user in terms of thermal comfort. Moreover, both of them rely heavily on six main aspects. Some of which could be considered as environmental elements such as air temperature, radiant temperature, humidity whereas the other two can be classified as personal elements such as metabolic rate (activity) and clothing insulation. These factors have a considerable impact on the actual state of thermal comfort for the users. However, there are some other personal aspects that could have certain contribution as well. For instance, two users could be setting in the same internal condition, at the same time, but they might have completely different thermal comfort.

In general, environmental aspects seem to have the most effective points that could influence the state of thermal comfort for individuals. Moreover, air temperature is the most effective one among the rest. It is the key factor that concern people when considering a new place. However, people can accept wider range of temperature even above the optimum that suggested by Fanger which is 25.6 when addressing adaptation which can bring the average to higher or lower levels. It also has to be highlighted that there is a very strong relationship between air temperature, relative humidity and air speed to allow the skin to loss heat in by sweating in the case of higher temperature. Furthermore, activity which is known by metabolic rate also could have a massive influence on human thermal comfort, particularly; in the case of addressing different types of building since each building has its own purpose (function), and also its own required activity. For instance, there is a clear difference in the activity level between school where student usually remain seated, and between their teachers who has to be standing and moving most of the time.

Heat loss and gain has also been discussed within the review, and has given certain consideration. Heat loss and gain is the incident of heat exchange with the surrounding environment through the envelope of the building which could be walls, floors, roofs, glazing and so on. It has a strong relationship with thermal comfort as it affects the state of the users directly. In can be agreed that such knowledge can serve to predict the influence if the outdoor environment as well as the envelope of the building to cop which will have a significant impact on users. It has to be mentioned that heat loss and gain through glazing has a remarkable influence on the incident of change heat with outdoor environment, and that rely on three main aspects the size of the window, the direction and the U-value of the glazing.

The effect of building function on adaptive thermal comfort has been discussed with reference to residential, office, healthcare and educational buildings. It has to be considered that there is a noticeable effect on the different types of building in terms of its impact on the users.

Residential building, for instance, is consist of four main zones living room, bedroom, kitchen and bathroom, and each one has its own requirement of thermal comfort in terms of needed indoor temperature, humidity and air velocity. In bedrooms there is an additional insulation aspect which is the sleepwear. This makes most of the users prefer lower indoor temperature in bedrooms. On the other hand, high indoor temperature is preferred in bathroom where the user wear there less cloth, or even to be naked. Moreover, in the kitchen there is extra heat that derived from the mechanical equipment there.

The characteristics of modern office building design has been introduced which has deep plans, glazed façade and personal computers which is responsible of the extra heat that is common in office buildings todays. All these make it quite difficult to cool the space with minimum reliance on mechanical equipment such as heating or cooling.

In hospitals there are serious challenges. The combination of the users which represented in patients and staff make it very difficult to achieve thermal comfort. Each of them has different activities and also different clothing. Hospitals classified as the highest energy consumption sector by meter squire when comparing with other types of buildings as there are many equipment and facilities which have to be in operation 24 hours. In addition, operation rooms are one of the most critical zones in the list. It requires more attention and research to maintain a fixed indoor condition in the existing of much equipment.

The importance of insuring acceptable indoor air quality in classrooms is distinguished as contributed factor to the learning performance of students. It quite essential to clarify that the most affected categories in school buildings are children in the age of (7 to 11). Children in such age found with limited chance for thermal adaptation such as changing cloth and activity level where students have to remain seated on their chairs. The integration between natural ventilation and thermal comfort level in school buildings has been found very complicated since the "noise" is essential in such buildings. More research and investigation is required to address this issue which can help to provide more sustainable and comfortable environment for students.

REFERENCES

[1] Djongyang, N., Tchinda, R., Njomo, D. (2010) „Thermal comfort: A review paper" Journal of Renewable and Sustainable Energy Reviews 14, 2626-2640

[2] ASHRAE standard-55 (2004) „Thermal environment conditions for human occupancy" ASHARAE

[3] Kuchen, E., Frsch, M. (2009) „Spot monitoring: thermal comfort evaluation in 25 office buildings in winter" Journal of Building and Environment 44, 839-847

[4] ISO-7730 (2005) „Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria" ISO

[5] Tian, L., Lin, Z., Liu, J., T., Wang, Q. (2011) „The impact of temperature on mean local air age and thermal comfort in a stratum ventilated office" Journal of Building and Environment 46, 501-510

[6] Talyor, P., Fuller, R., Luther, M. (2008) „Energy use and thermal comfort in a rammed earth office building" Journal of Energy and Building 40, 793-800

[7] Memon, R., Chirarattananon, S., Vangtook, P. (2008) „Thermal comfort assessment and application of radiant cooling: A case study" Journal of Building and Environemnt 43, 1185-1196

[8] Ormandy, D., Ezratty, V. (2012) „Health and thermal comfort: from WHO guidance housing strategies" Journal of Energy Policy 49, 116-121

[9] Sakka, A., Santamourise, M., Livada, L., Noicol, F, Wilson, M. (2012) „On thermal performance of low income housing during heat waves" Journal of Energy and Buildings 49, 96-77

[10] Parsons, K. (2002) „The effect of gender, acclimation state, the opportunity to adjust clothing and physical disability on requirements for thermal comfort „Journal of Energy and Buildings 34, 593-599

[11] Cheong, K., Djunaedy, E., Chya, Y., Tham, K., Sekhar, S., Wong, N., Ullah, M. (2003) „Thermal comfort study of an air-conditioned lecture theatre in the tropics" Journal of Building and Environment 38, 63-73

[12] Atmaca, I., Kaynkli, O., Yigit, A. (2007) „Effect of radiant temperature on thermal comfort" Journal of Building and Environment 42, 3210-3220

[13] Hall, D., Walker, S., Spanton, A. (1999) „Dispersion from courtyards and other enclosed spaces" Journal of Atmospheric Environment 33, 1187-1203

[14] Backer, R., Paciuk, M. (2009) „Thermal comfort in residential buildings – Faiure to predict by standard model" Journal of Building and Environment 44, 948-960

[15] Homod, R., Sahari, K., Almurib, H., Nagi, F. (2012) „RLF and TS fuzzy model identification of indoor thermal comfort based on OMV/PPD" Journal of Built and Environment 49, 141-153

[16] Jang, M., Kol, C., Moon, I. (2007) „Review of thermal comfort design based on PMV/PPD in cabins of Korean maritime patrol vessels" Journal of Building and Environment 42, 55-61

[17] Hall, R. (2010) Materials for energy efficiency and thermal comfort in buildings. The UK: CRC

[18] Health and safety executive (HSE) (n,a) The six basic factors [online] available from <http://www.hse.gov.uk/temperature/thermal/factors.htm#radiant> [Accessed on 24 Mar 2012]

[19] Hanqing, W., Chunhue, H., Zhiqiang, L., Guangfa, T. (2006) „Dynamic evaluation of thermal comfort environment of air-conditioned buildings" Journal of Buildings and Environment 41, 1522-1529

[20] Metje, N., Sterling, M., Baker, C. (2008) „Pedestrian comfort using clothing values and body temperatures" Journal of Wind Engineering and Industrial Aerodynamics 96, 412-435

[21] Hoof, J., Hensen, J. (2007) „Quantifying the relevance of adaptive thermal comfort models in moderate thermal climate zones" Journal of Building and Environment 42, 156-170

[22] Wang, Z., Zhang, L., He, Y. (2010) „Thermal comfort for naturally ventilated residential buildings in Harbin" Journal of Energy and Buildings 42, 2406-2415

[23] Candido, C., Dear, R., Lamberts, R., Bittencourt, L. (2010) „Air movement acceptability limits and thermal comfort in Brazil"s hot humid climate zone" Journal of Building and Environments 45, 222-229

[24] Hanqing, W., Chunhue, H., Zhiqiang, L., Guangfa, T. (2006) „Dynamic evaluation of thermal comfort environment of air-conditioned buildings" Journal of Buildings and Environment 41, 1522-1529

[25] Ho, S., Rosario, L., Rahman, M. (2009) „Thermal comfort enhanced by using a ceiling fan" Journal of Applied Thermal Engineering 29, 1648-1656

[26] Ghaddar, N., Chehaitly, S. (2011) „Assessing thermal comfort of active people in transitional spaces in presence of air movement" Journal of Energy and Buildings 43, 2832-2842
[27] Rowe, D. (2001) „Activity rates and thermal comfort of office occupants in Sydney" Journal of Thermal Biology 26, 415-418
[28] Caril, M., Olesen, B., Zarrella, A., Zecchim, R. (2007) „People"s clothing behaviour according to external weather and indoor environment" Journal of Building and Environment 42, 3965-3973
[29] Oliveira, A., Gaspar, A., Quintela, D. (2011) „Dynamic clothing insulation. Measurements with a thermal manikin operating under the thermal comfort regulation mode" Journal of Applied Ergonomics, 1-10
[30] Lee, J., Choi, J. (2004) „Influences of clothing types on metabolic, thermal and subjective responses in cool environment" Journal of Thermal Biology 29, 221-229
[31] Al-ajmi, F., Loveday, D., Bedwell, K., Havenith, G. (2008) „Thermal insulation and clothing areas factors for typical Arabian Gulf clothing ensembles for males and females: Measurements using thermal manikins" Journal of Applied Ergonomics 39, 407-414
[32] Bulcao, C., Frank, St., Raja, S., Tran, K. (2000) „Relative contribution of core and skin temperatures to thermal comfort in humans" Journal of Thermal Biology 25, 147-150
[33] Karjalainen, S. (2007)" Gender differences in thermal comfort and use of thermostats in everyday thermal environments" Journal of Built and Environment 42, 1594-1603
[34] Wang, Z. (2006) „A field study of the thermal comfort in residential buildings in Harbin" Journal of Built and Environment 42, 1594-1603
[26] Choi, J., Aziz, A., Loftness, V. (2010) „Investigation on the impacts of different genders and ages on satisfaction with thermal environments in office buildings" Journal of Building and Environment 45, 1529-1535
[36] Alwetaishi, M. (2011) Innovative Wind Tower for Improving Indoor Air Movement and Thermal Comfort. Dissertation for MSc course. The University of Nottingham
[37] MACQUARIE (2004) the adaptive model of thermal comfort [online] available form <http://aws.mq.edu.au/rp-884/ashrae_rp884_home.html> [accessed on 28 April 2012]
[38] Liu, J., Yao, R., McCloy, R. (2012) „A method to weight three categories of adaptive thermal comfort" Journal of Energy and Buildings 47, 312-320
[39] Liu, J., Humphecys, M. (2002) „Adaptive thermal cmfort and sustainable thermal standards for buildings" Journal of Energy and Buildings 34, 563-572
[40] Sing, M., Mahapatra, S., Atreya, S. (2011) „Adaptive thermal comfort model for different climatic zones of North East India" Journal of Applied Energy 88, 2420-2428
[41] Indraganti, M. (2011) „Thermal comfort in apartments in India: Adaptive use of environmental controls and hindrances" Journal of Renewable Energy 36, 1182-1189
[42] Mui, K., Chan, W. (2003) „Adaptive comfort temperature model of air-conditioned building in Hong Kong" Journal of Building and Environment 38, 837-852
[43] Schweiker, M., Brasche, S., Bischof, W., Hawighorst, M., Karsten, V. Wagner, A. (2012) „Development and validiation of a methodology to chalange the adaptive comfort model" Journal of Building and Environment 49, 336-347
[44] Nguyen, A., Sing, M., Reiter, S. (2012) „An adaptive thermal comfort model for hot humid South– East Asia" Journal of Building and Environment 56, 291-300
[45] Peeters, L., Dear, R., Hensen, J., D"haeseleer, W. (2009) „Thermal comfort in residential buildings: comfort values and scales for building energy simulation" Journal of Applied Energy 86, 772-780
[45] Han, J., Zhou, J., Zhang, Q., Moschandreas, D. (2009) „A comparative analysis of urban residential thermal comfort under natural ventilation environment" Journal of Energy and Building 41, 139-145
[46] Ghisi, E., Massignani, R. (2007)"Thermal performance of bedrooms in a multi-storey residential building in Southern Brazil" Journal of Building and Environment 42, 730-742
[47] Zingano, B. (2001) „A discussion on thermal comfort with deduce to bath water temperature to deduce a midpoint of thermal comfort temperature zone" Journal of Renewable Energy 23, 41-47
[48] Griego, D., Krarti, M., Hernandez-Guerrero, A. (2012) „Optimization of energy efficiceny and thermal comfort measures for residential buildings in Salamanca, Mexico" Journal of Energy and Building
[49] Lin, Z., Deng, S. (2008)a „A study on thermal comfort in sleeping environments in the subtropics-Measuring the total insulation value for the bedding systems commonly used in the subtropics" Journal of Building and Environment 43, 905-916
[50]Maerefat, M., Zolfaghari, A., Omidvar, A. (2012) „On the conformity of floor heating systems with sleeping in the eastern-style beds; physiological responses and thermal assessment" Journal of Building and Environment 47, 322-329
[51] Lin, Z., Deng, S. (2008)b „A study on the thermal comfort in sleeping environments in the subtropics-Developing a thermal comfort model for sleeping environments" Journal of Building and Environment 43, 70-81
[52] Lin, Z., Deng, S. (2006) „A questionnaire survey on sleeping thermal environment and bedroom air conditioning in high-rise residences in Hong Kong" Journal of Energy and Building 38, 1302-1307
[53] Djongyang (2012) „Estimation of some comfort parameters for sleeping environments in dry-tropical sub-Saharan Africa region" Journal of Energy Conversion and Management 58, 110-119
[54] Hens, H (2009) „Thermal comfort in office buildings: Two case studies commented" Journal of Building and Environment 44, 1399-1408
[55] Moujalled, B., Cantin, R., Guarracino, G. (2008) „Comparison of thermal comfort algorithms in naturally ventilated office building" Journal of Energy and Building 40, 2215-2223
[56] Chen, A., Chang, V. (2012) „Human health and thermal comfort of office workers in Singapore" Journal of Building and Environment 58, 172-178
[57] Barlow, S., Fiala, D. (2007) „Occupant in UK offices-How adaptive comfort theories might influence suture low energy office refurbishment strategies" Journal of Energy and Building 39, 837-846
[58] Ricciardi, P., Buratti, C. (2012) „Thermal comfort in open plan offices in northern Italy: An adaptive approach" Journal of Building and Environment 56, 314-320
[59] Hwang, R., Lin, T., Cheng, M., Chien, J. (2007) „Patient thermal comfort requirement for hospital environments in Taiwan" Journal of Building and Environment 42, 2980-2987
[60] Khodakarami, J., Nasrollahi, N. (2012) „Thermal comfort in hospitals – A literature review" Journal of Renewable and Sustainable Energy Reviews 16, 4071-4077
[61] Skoog, J., Fransson, N., Jagemar, L. (2005) „Thermal environment in Swedish hospitals summer and winter measurements" Journal of Energy and Buildings 37, 872-877
[62] Balaras, C., Dascalaki, E., Gaglia, A. (2007) „HVAC and indoor thermal conditions in hospital operating rooms" Journal of Energy and Buildings 39, 454-470
[63] Ho, S., Rosario, L., Rahman, M. (2009) „Three-dimensional analysis for hospital operating room thermal comfort and contaminant removal" Journal of Applied of Thermal Engineering 29, 2080-2092
[64] Adamu, Z., Price, A., Cook, M. (2012) „Performance evaluation of natural ventilation strategies for hospital wards – A case study of Great Ormond Street Hospital" Journal of Building and Environment 56, 211-222
[65] Hashiguchi, N., Hirakawa, M., Tochihara, Y., Kaji, Y., Karaki, C. (2008) „Effects of setting up of humidifiers on thermal conditions and subjective responses of patients and staff in a hospital during winter" Journal of Applied Ergonomics 39, 158-165
[66] Pourshaghaghy, A., Omidvari, M. (2012) „Examination of thermal comfort in a hospital using PMV-PPD model" Journal of Applied Ergonomics 43, 1089-1095
[67] Corgnati, S., Filippi, M., Viazzo, S. (2007) „Perception of the thermal environment in high school and university classrooms: Subjective preferences and thermal comfort" Journal of Building and Environment 42, 951-959
[68] Mumovic, D., Palmer, J., Davies, M., Orme, M., Ridley, I., Oreszcyn, T., Judd, C., Critchlow, R., Medina, H., Pilmoor, G., Pearson, C., Way, P. (2009) „Winter indoor air quality, thermal comfort and acoustic performance of newly built secondary schools in England" Journal of Building and Environment 44, 1466-1477
[69] Zeiler, W., Boxem, G. (2009) „Effects of thermal activated building systems in schools on thermal comfort in winter" Journal of Building and Environment 44, 2308-2317
[70] Teli, D., Jentsch, M., James, P. (2012) „Naturally ventilated classrooms an assessment of existing comfort models for predicting the thermal sensation and preference of primary school children" Journal of Energy and Building 53, 166-182
[71] Humphreys, M. (1977) „A study of the thermal comfort of primary children in summer" Journal of Building and Environment 12, 231.

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