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Estimation of Thermal Comfort Parameters of Building Occupants Based on Comfort Index, Predicted Mean Vote and Predicted Percent of Dissatisfied People in the North-West Zone of Nigeria

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ABSTRACT: Thermal comfort varies significantly between individuals and regions depending on factors such as activity level, clothing, space temperature and relative humidity. This study considers the estimation of thermal comfort parameters such as air temperature, mean radiant temperature, air velocity, emissivity of space, metabolic rates, and heat transfer coefficients to determine comfort index, predicted mean vote, and predicted percent of dissatisfied people. Several equipment were employed to measure thermal comfort parameters indoor of the buildings considered. Results show that Katsina state recorded the least overall comfort index when compared to the remaining states which was attributed to reduced air temperature and relative humidity recorded. Majority of the buildings considered have high mean radiant temperatures and high space diameters which suggests that occupants in this environment are most likely to experience some sort of discomfort especially during summer. Comparing all the thermal comfort of occupants based on Fanger theory, 33.3% felt hot, 26.7% felt warm, 20% felt slightly warm, 13.33% felt slightly cool, 6.7% felt cool, and 0% felt cold which indicates that occupants in this region and Geopolitical zone contend with more of heat than coldness.

KEYWORDS: Thermal comfort, North-west zone, building occupants, heat

I. INTRODUCTION

The human body can be seen as a warmth motor [1] where food is the info vitality. This human body will deliver surplus heat into the earth [2], so the body can keep on working. This warmth is known to be corresponding to temperature difference [3]. In cool areas, the body loses more warmth to the earth and in hot regions [4], the body doesn't deliver enough warmth. Both the hot and cold conditions can lead to distress. Keeping up this norm of thermal comfort for occupants of structures or other enclosures is one of the basic objectives of HVAC (warming, ventilation, and cooling) design engineers [5]. Thermal impartiality is hence kept up when the warmth produced by human digestion is permitted to disseminate, in this way keeping up warm harmony with the environments. The key factors that impact thermal comfort are those that decide heat increase and loss [6], [7], in particular metabolic rate [8], garments protection [9], air temperature [10], mean radiant temperature [11], [12], air velocity [13], and relative humidity [14]. Psychological parameters, for example, individual prospects, likewise influence thermal comfort [15]. Thermal comfort may as well vary significantly between individuals and depending on factors such as activity level [16], clothing, and humidity. At the point when individuals are disappointed with their warm condition, in addition to the fact that it is a potential risk to well-being, it additionally impacts their capacity [17] to work effectively, their satisfaction at work, the probability they will stay as client, etc. It is therefore dependent on a great number of criteria and can be different from one person to another within the same space or building

Thermal comfort deterioration in the North-western Nigeria has become a major concern in residential buildings [18], commercial buildings [19], and construction industries [20]. Building occupants [21] complain more often than not, as to the weather situations [22] that region. Many people in these hot regions experience various health hazards [23], [24], [25], [26] such as blood pressure deficiencies [27], [28], heart pulse rate deficiencies [29], [30], lungs diseases [31], [32], skin irritations [33], [34], and visual impairments [35]. [36].

Research has also proven that productivities [37], [38], [39], [40], [41] in construction industries were lowered due to deficiencies in thermal comfort in the region considered in the study. It is imperative to establish that thermal comfort measurements on regular basis is highly needed to ascertain the level of discomfort penetration among building residents [42], [43]. Various devices and instruments [44], [45] such as transducers, thermocouple, thermopile, thermistor, anemometer well calibrated are popularly known to be able to ascertain the level of comfort in any location-both indoor [46], [47] and outdoor [48], [49]. Builders, engineers [50], architects, town planners, and other professionals [51] in the built industry are of the opinion that the involvement of quacks [52] and non-skilled individuals in building constructions are the major militating factors against adequate thermal comfort in buildings. Power instability and failure [53] are pertinent to the application of thermal systems like chillers, heat recovery systems, air conditioners to effectively enhance thermal comfort in homes and public buildings.

Thermal comfort is vital for health and well-being as well as productivity for both residential and public building users. An absence of Thermal comfort at last causes worry and distress among building inhabitants. At the point when they are excessively warm, they can feel tired; when excessively chilly, they will be fretful and distracted. Various examinations have been directed on gender differences concerning thermal comfort. A lab study demonstrated that ladies felt more awkward than men at high and low-temperature boundaries [54], [55], [56], and ladies revealed they feel colder than men at low temperatures [57]. Comfortable room temperatures according to the environmental protection agency (EPA) are generally considered to be between 62◦F and 74◦F for optimal sleep while humidity stays between 35% and 65% [58]. For little children and babies, the ideal room temperature falls somewhere in the range of 60 and 75◦F [59]. People commonly feel good between temperatures of 23 °C to 27 °C and relative humidity of 45% to 65% [60]. The age of an individual significantly influences the temperature of a room; more established individuals emit less warmth than more youthful individuals. Gender is also a factor that affects the temperature given off by people, females give off less heat than males, and they give off 87% of what the male body gives off [61]. It does as such by coursing blood close to the outside of the skin, by breathing out warm, humidified air, and by dissipating sweat. These cycles work best when the surrounding temperature is around 75◦F where we feel generally good, and they serve to keep up centred internal heat level around 95◦F [62]. The model stickiness for rest is somewhere in the range of 35% and 55% [63]. Anything higher (which is regular throughout the mid-year in numerous pieces of the nation) can make it hard to rest for two reasons: solace and blockage [64]. High dampness keeps dampness from vanishing off your body, which can make you hot and sweat-soaked. The Health and Safety Executive (HSE) proposes that a domain can be said to accomplish 'sensible warmth' when in any event 82% of its occupants are thermally friendly [65], [66]. This implies that thermal comfort can be evaluated by looking over occupants to see if they are disappointed with their warmth circumstance or not.

1.1 The study area

The study area involves Sokoto, Kano, Kaduna, Kebbi, Zanfara, Katsina, and Jigawa, and depicted in Figure 1. Jigawa State is one of the 36 states that comprise the Federal Republic of Nigeria. It is situated in the north-western aspect of the nation between latitudes 11.00°N to 13.00°N and longitudes 8.00°E to 10.15°E [66]. Kano State and Katsina State fringe Jigawa toward the west, Bauchi State toward the east, and Yobe State toward the upper east. Toward the north, Jigawa shares a global fringe with the Zinder Region in the Republic of Niger, which is a remarkable open door for cross-outskirt exchanging trading activities. The legislature promptly exploited this by starting and setting up a streamlined commerce zone at the border town of Maigatari in Niger.

Kaduna State is the eighteenth state of the Federal Republic of Nigeria situated in the northwest zone of the nation. The Latitude and longitude coordinates are 10° 36' 33.5484" N, 7° 25' 46.2144" E [66]. Kano State is a state situated in northern Nigeria. Kano was made on May 27, 1967, from part of the Northern Region, and outskirts Katsina State toward the northwest, Jigawa State toward the upper east, Bauchi State toward the southeast, and Kaduna State toward the southwest. Latitude and longitude coordinates are: 12° 0' 0.0000" N, 8° 31' 0.0012" E [66].

Katsina, is a state in the northwest zone of Nigeria. The Latitude and longitude coordinates are 12°59'26.95" N 7°36'6.37" E. Kebbi State is circumscribed by Sokoto State, Niger State, Zamfara State, Dosso Region in the Republic of Niger and the country of Benin. The Latitude and longitude coordinates are 12°27'14.00" N, 4°11'51.00" E [66]. It has a complete area of 36,800 km².

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Sokoto generally referred to as Sokoto State to recognize it from the city of Sokoto, is situated in the extraordinary northwest of Nigeria, close to the confluence of the Sokoto River and the Rima River. Starting from 2005, it has an expected populace of more than 4.2 million. Sokoto City is the current capital of Sokoto State. The Latitude and longitude coordinates are: 13° 0' 21.1428" N and 5° 14' 51.1872" E [66].

Zamfara is populated with the Hausa and Fulani people groups. The Latitude and longitude coordinates are: 12°10'0.01" N, 6°15'0.00" E [66]. The individuals of Zamfara have throughout the years battled for self-sufficiency, it was not until 1996 that the then military organization of the Late General Sani Abacha disconnected the Zamfara State from Sokoto State. With a zone of 38,418 square kilometres [66], it is circumscribed in the North by the Niger Republic, toward the South by Kaduna State. In the east, it is flanked by Katsina State and toward the West by Sokoto and Niger States. It has a populace of 3,278,873 as per the 2006 evaluation and contains fourteen nearby government regions. The aim of this study is to estimate thermal comfort parameters in the northwest Zones of Nigeria while the specific objectives are to determine comfort index, predicted mean vote and predicted percent of dissatisfied eople.

Figure 1: North-west Nigeria

II. METHODOLOGY

Buildings in the North-western Geo-Political zone of Nigeria were considered where 10 buildings and a Geographical positioning system were adopted to ascertain the locations of each building for consequent selection. The occupants' thermal comforts were assessed in the dry season (summer) to ascertain the level of risks and possible proffer solutions

Table 1: Gender for Occupants

Gender	Frequency	Percentage
Male	620	40%
Female	930	60%
Total	1550	100%

Table 1 indicates that 60% of the occupants were female, while 40% of the occupants were male. This shows that the female occupants dominated the study with one and a half times their male counterparts.

Table 2 shows that 12.9% of the occupants have their ages less than 10 years and 21.0% have their ages from 10 to 19 years. Furthermore, 25.8% of the occupants have their ages from 20 to 29 years, 18.1% have 30 to 39 years of age and 22.2% are 40 years and above. The highest percentage (25.8%) comes from 20 to 29 years occupants which is an indication that the majority are youths.

Several climatic parameters were measured using Smart meters EM-840, EM-880, and EM-900. The measurements were carried on various building occupants from 8 a.m. to 6 p.m. each day in a two-hour interval for three months during the dry season. The parameters considered in assessing thermal comforts in the buildings are humidity, light intensity, temperature, wind speed, air velocity, the emissivity of the area, the diameter of the area, and the heat transfer coefficient. It is a common experience that air movement, be it a natural wind, or generated by a fan, has a cooling effect. This largely depends on the velocity of that air movement. Under everyday conditions the average subjective reactions to various velocities are: < 0.25 m/s unnoticed 0.25-0.50 pleasant 0.50-1.00 awareness of air movement 1.00-1.50 draughty > 1.50 annoyingly draughty.

Analysis for each building in all the states considered was done based on the comfort index (CI), predicted mean vote (PMV), predicted percent of dissatisfied people (PPD), and thermal sensation. The human thermal response was determined based on results obtained from the surrounding environments. The internal temperatures at which the buildings are exposed to the environments are obtained. These temperatures help to validate a kind of balance between heat loss and the heat gained by radiation and convection. Equation (1) helps to compute the comfort index where t is the air temperature (◦C) while rh is the relative humidity (%). This thermal comfort index was observed from the biological comfort, comfort based on the neighbouring natural environment. The mean radiant temperature M_{rt} in Equation (2), was computed based on the following variables: diameter of the space (d), air velocity (v), the emissivity of the space (ε), Stephan-Boltzmann constant (5.679 $*10^{8}W/m^{2}K^{4}$), space temperature (t_s), air temperature (t_a).

The heat transfer coefficient is given in Equation (12) and dependent on variables space diameter and air velocity. The transducers employed to measure these parameters are air temperature transducer, air velocity transducer, humidity transducer, and space temperature transducer. The air temperature was measured using a high precision thermistor and thermocouple in the different locations under consideration. The devices were calibrated such that the detecting elements were protected from radiation by a cylindrical metal screen. The air velocity was measured using Omni-directional anemometers based on the constant temperature principle. The anemometer elements are sustained at a constant temperature by an electrical heating element that compensates for the heat lost to the surrounding air stream. The amount of current required to keep the element at a constant temperature is connected to the amount of air flowing past the element per unit time

$$CI = 0.8t + \frac{(t * rh)}{500} \quad [66] \qquad (1)$$

$$M_{rt} = \left\{ \frac{6.38v^{0.5}}{\sigma\varepsilon d^{0.4}}(t_s - t_a) + t_a{}^{4} \right\}^{\frac{1}{4}} \quad [66] \qquad (2)$$

2.1 Thermal comfort models

2.1.1. Thermal environment

This describes a person's psychological state of mind and is usually referred to in terms of whether someone is feeling too hot or too cold. It is important to note that one needs to take into account a range of environmental and personal factors when deciding what will make people feel comfortable. $E_{metabolism}$ based on Equation (3) is the heat produced by metabolism, $E_{radiant}$ is the radiant heat lost at the exterior surface of clothing, $E_{environment}$ is the heat lost through evaporation of perspiration, E_{latent} is the latent heat of evaporation of the perspiration, $E_{evaporation}$ is the heat lost through evaporation of perspiration, and $E_{diffusion}$ is the lost heat through the diffusion of water vapours through the skin.

2.1.2. Fanger theory

Fanger proposed a strategy by which the genuine thermal sensation could be projected. His assumption for this was the sensation experienced by an individual was a component of the physiological strain forced on him by nature. This he characterized as "the contrast between the internal heat production and the heat loss to the actual environment for a man kept at comfort values for skin temperature and sweat production at the actual activity level" [66]. He determined this additional load for individuals associated with atmosphere chamber explores and plotted their comfort vote against it. Accordingly he had the option to anticipate what comfort vote would emerge from a given arrangement of natural conditions for given apparel protection and metabolic rate. Fanger understood that the vote predicted was only the mean value to be expected from a group of people, and he extended the predicted mean vote (PMV) to predict the proportion of any population who will be dissatisfied with the environment [66]. An individual's dissatisfaction was characterized as far as his/her comfort vote. The individuals who casted a ballot outside the focal three scaling focuses on the ASHRAE scale were considered disappointed. The PMV as built up by Fanger states that hot (+3), warm (+2), slightly warm (+1), neutral (0), slightly cool (- 1), cool (- 2), cold (- 3). The PMV is given in Equation (11) where $t\alpha$ is the air temperature, t_r is the mean radiant temperature, var. is the relative speed of air, $\rho\alpha$ is the partial pressure of water vapour, and t_{cl} is the temperature at the surface of the cloth. Equations (4)-(9) represent variables considered to determine Equation (10)-the predicted mean vote

Where, 1metabolic rate (M)=58.2W/m^2, W=work done/m^2, 1 cloth index (cl)= $0.155\frac{°Cm^2}{W}$, and f_{cl} is the ratio between the dressed surface of the human body and the undressed surface of the human

2.2 Metabolic rates

Our living bodies produce heat since we are Homoeothermic (warm-blooded) animals. The rate at which warmth is delivered relies fundamentally upon our metabolic rate. The metabolic rate is our capacity to produce warmth and it is generally an element of our degree of strong action. A portion of the vitality created by solid movement will be straightforwardly converted into Work (Force x Distance) and the overabundance vitality will be scattered as Heat [66]. Since heat trade with our condition is fundamentally by means of the skin, the met unit is characterized regarding both Heat vitality and surface territory. The unit of the metabolic rate is known as "Met" which is comparable to 58.2W/m^2. Table 1 delineates different exercises and their metabolic rates while Table 2 shows protection esteems for various sorts of Clothing.

$$E_{metabolism} = E_{radiant} + E_{environment} + E_{latent} + E_{evaporation} + E_{diffusion} \text{ [66]} \quad (3)$$

$$\alpha = (0.303 * \ell^{-0.036M} + 0.028) \quad (4)$$

$$\beta = (M-W) - 3.05 * \ell^{-3} * [5733 - 6.99 * (M-W) - \rho\alpha] - 0.42 * [(M-W) - 58.15] \quad (5)$$

$$\chi = 3.05 * \ell^{-3} * [5733 - 6.99 * (M-W) - \rho\alpha] - 0.42 * [(M-W) - 58.15] \quad (6)$$

$$\delta = 1.7 * \ell^{-5} * M * (5867 - \rho\alpha - 0.0014 * M * (34 - t\alpha) \quad (7)$$

$$\gamma = 3.96 * \ell^{-8} * f_{cl} * \left[(t_{cl} + 273)^4 - (t_r + 273)^4\right] \quad (8)$$

$$\eta = f_{cl} * h_c * (t_{cl} - t_\alpha) \quad (9)$$

$$PMV = \alpha * \{\beta - \chi - \delta - \gamma - \eta\} \text{ [66]} \quad (10)$$

Table 2: Age range of occupants

Age Range	Male	Female	Frequency	Percentage (%)
Less than 10 years	75	125	200	12.9
10 – 19 years	140	185	325	21.0
20 – 29 years	140	260	400	25.8
30 – 39 years	130	150	280	18.1
40 and above	135	210	345	22.2
Total	620	930	1550	100%

Table 3: Metabolic rates [29]

Activity	Work was done (W/m^2)	Metabolic rates (met)
Resting	48	0.85
Settled and calm	60	1.0625
Clock mender	67	1.186458
Standing relaxed	72	1.275
Vehicle driving	82	1.452083

Standing, slight activity	95	1.682292
Trekking, 25 km/h	115	2.036458
Medium activity (home chores)	119	2.107292
Laundry activity	149	2.638542
Trekking, 10 km/h	206	3.647917
Construction work	279	4.940625
Athletics - sprinting at 20 km/h	557	9.863542

Table 4: Insulation values for clothing [29]

Clothing	Depiction	Insulation clothing	Cloth index($0.155\frac{°Cm^2}{W}$)
	Pantyhose	0.029	0.004495
	Briefs	0.049	0.007595
	Pants	0.108	0.01674
	Bra	0.018	0.00279
	T-shirts	0.099	0.015345
	Nylon	0.148	0.02294
Shirts	Tube top	0.067	0.010385
	Short sleeves	0.096	0.01488
	Long sleeves	0.257	0.039835
Trousers	Shorts	0.068	0.01054
	Normal trousers	0.254	0.03937
	overalls	0.285	0.044175
Insulated cover-alls	Multi-component filling	1.036	0.16058
	Fibre-pelt	1.137	0.176235
Sweaters	Thin sweaters	0.208	0.03224
	Normal sweaters	0.289	0.044795
	Thick sweaters	0.357	0.055335

$$f_{cl} = \begin{cases} 1.00 + 1.290 * I_{cl} + ... for ... I_{cl} \leq 0.078 \frac{m^2 \, ^\circ c}{w} \\ 1.05 + 0.645 * I_{cl} + ... for ... I_{cl} > 0.078 \frac{m^2 \, ^\circ c}{w} \end{cases} \quad (11)$$

$$h_c = \begin{cases} 2.38 * (t_{cl} - t_a)^{0.25} \; for 2.38 * (t_{cl} - t_a)^{0.25} > 12.1\sqrt{\text{var}} \\ 12.1\sqrt{\text{var}} \; for 2.38 * (t_{cl} - t_a)^{0.25} > 12.1\sqrt{\text{var}} \end{cases} \quad (12)$$

$$t_{cl} = 35.7 - 0.028 * (M - W) - I_{cl} \quad (13)$$

$$PPD = 100 - 95 * \ell^{-(0.03353 * PMV^4 + 0.2179 * PMV^2)} \quad (14)$$

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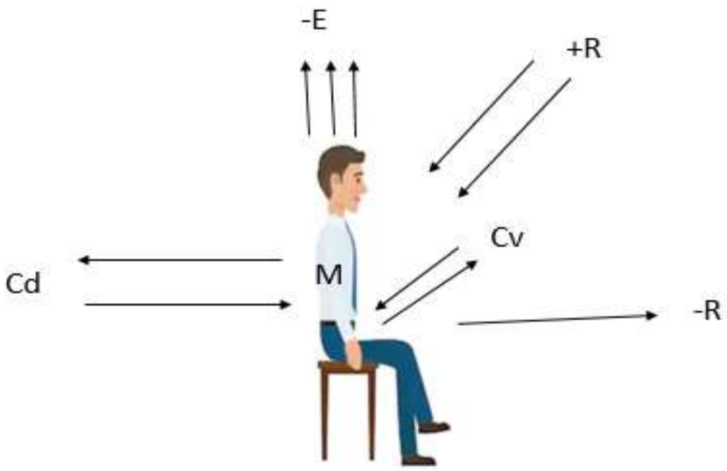


Figure 2: Heat exchanges of the body

The ratio between the dressed surface of the human body and the undressed surface of the human body is a factor that has predefined values function to the cloth index and given by: f_{cl} The heat transfer coefficient for convection is h_c , Predicted percent of dissatisfied people, PPD.Cv= convection, R= net radiation, Cd = conduction, E = evaporation heat loss

III. RESULTS AND CONCLUSION

Table 5: Air temperature, relative humidity, and Comfort index for Jigawa State

buildings	average air temperature	average relative humidity	Comfort index
B1	30	0.48	24.0288
B2	33	0.5	26.433
B3	37	0.52	29.63848
B4	39	0.59	31.24602
B5	38	0.55	30.4418
B6	34	0.51	27.23468
B7	32	0.55	25.6352
B8	36	0.58	28.84176
B9	33	0.53	26.43498
B10	35	0.56	28.0392

Table 6: Air temperature, relative humidity, and Comfort index for Kano State

buildings	average air temperature	average relative humidity	Coomfort index
B11	36	0.58	28.84176
B12	37	0.58	29.64292
B13	38	0.57	30.44332
B14	38	0.56	30.44256
B15	39	0.59	31.24602
B16	39	0.59	31.24602
B17	35	0.58	28.0406
B18	37	0.55	29.6407
B19	38	0.57	30.44332
B20	38	0.58	30.44408

Table 7: Air temperature, relative humidity, and Comfort index for Zamfara State

buildings	average air temperature	average relative humidity	Comfort index
B21	31	0.51	24.83162
B22	33	0.53	26.43498
B23	32	0.5	25.632
B24	30	0.54	24.0324
B25	29	0.55	23.2319
B26	28	0.49	22.42744
B27	31	0.48	24.82976
B28	27	0.52	21.62808
B29	32	0.47	25.63008
B30	30	0.54	24.0324

Table 8: Air temperature, relative humidity, and Comfort index for Kaduna State

buildings	average air temperature	average relative humidity	Comfort index
B31	33	0.48	26.43168
B32	36	0.56	28.84032
B33	35	0.58	28.0406
B34	38	0.51	30.43876
B35	37	0.58	29.64292
B36	35	0.46	28.0322
B37	34	0.45	27.2306
B38	33	0.56	26.43696
B39	38	0.49	30.43724
B40	36	0.53	28.83816

Table 9: Air temperature, relative humidity, and Comfort index for Katsina State

buildings	average air temperature	average relative humidity	Comfort index
B41	23	0.45	18.4207
B42	26	0.53	20.82756
B43	30	0.56	24.0336
B44	28	0.52	22.42912
B45	27	0.48	21.62592
B46	31	0.49	24.83038
B47	24	0.47	19.22256
B48	32	0.52	25.63328
B49	29	0.48	23.22784
B50	25	0.51	20.0255

Table 10: Air temperature, relative humidity, and Comfort index for Sokoto State

buildings	average air temperature	average relative humidity	Comfort index
B51	25	0.55	20.0275
B52	29	0.58	23.23364
B53	31	0.46	24.82852
B54	24	0.42	19.22016
B55	26	0.49	20.82548
B56	30	0.57	24.0342
B57	26	0.56	20.82912
B58	29	0.42	23.22436
B59	33	0.56	26.43696
B60	34	0.58	27.23944

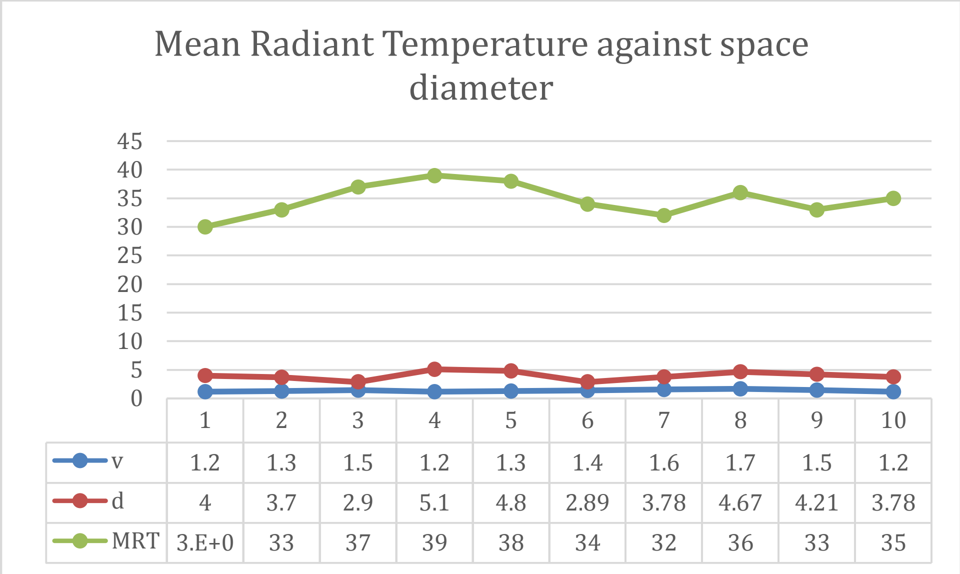


Figure 2: Mean Radiant Temperature against space diameter (Jigawa State)

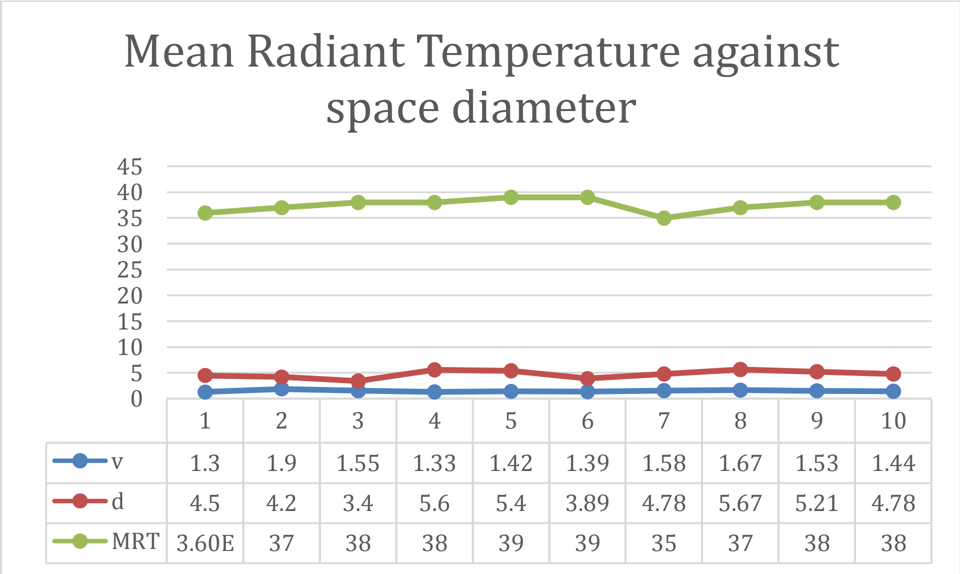


Figure 3: Mean Radiant Temperature against space diameter (Kano State)

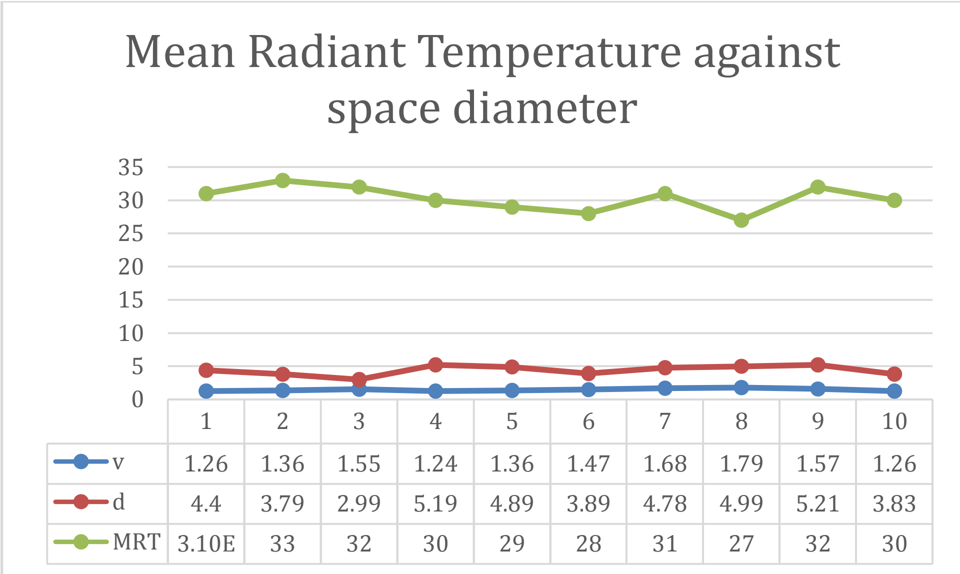


Figure 4: Mean Radiant Temperature against space diameter (Zamfara State)

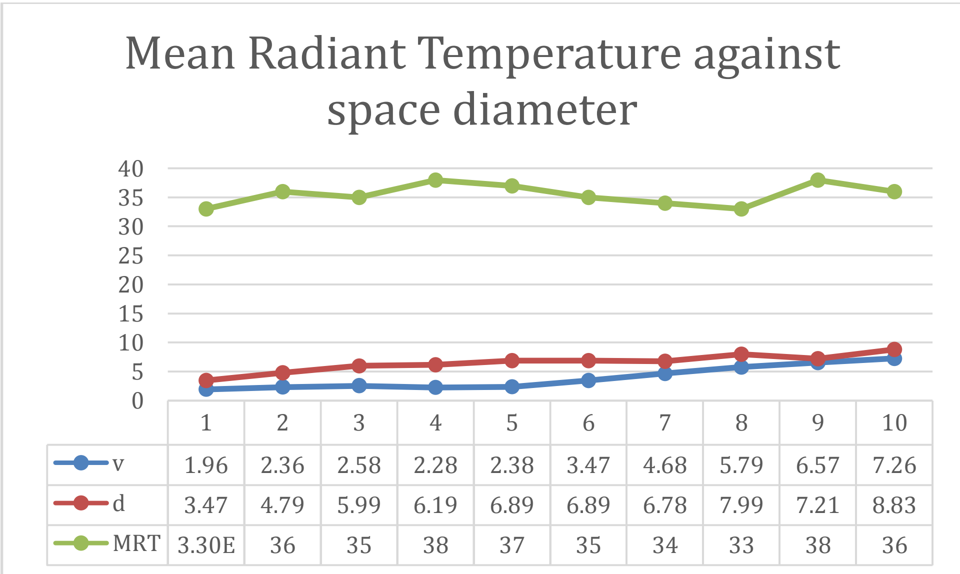
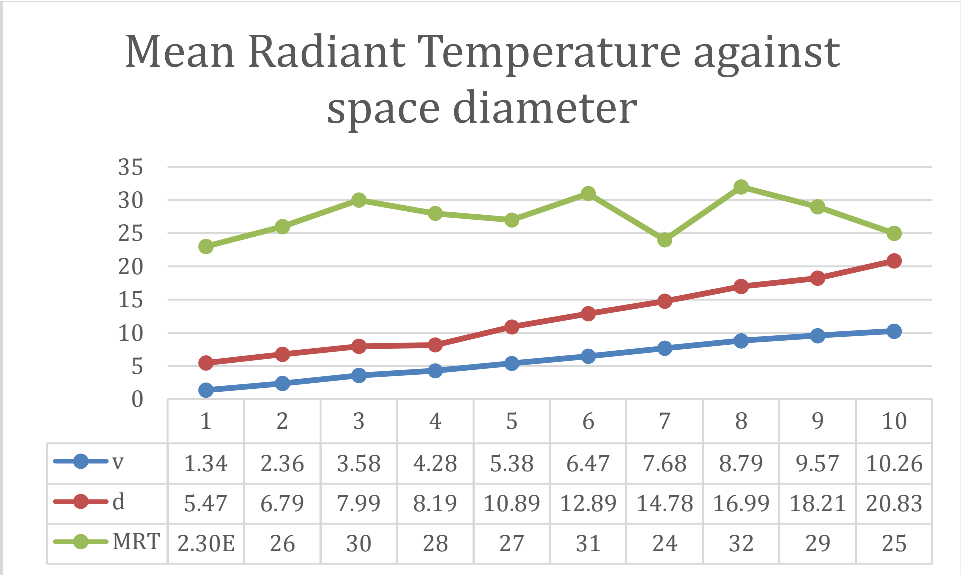
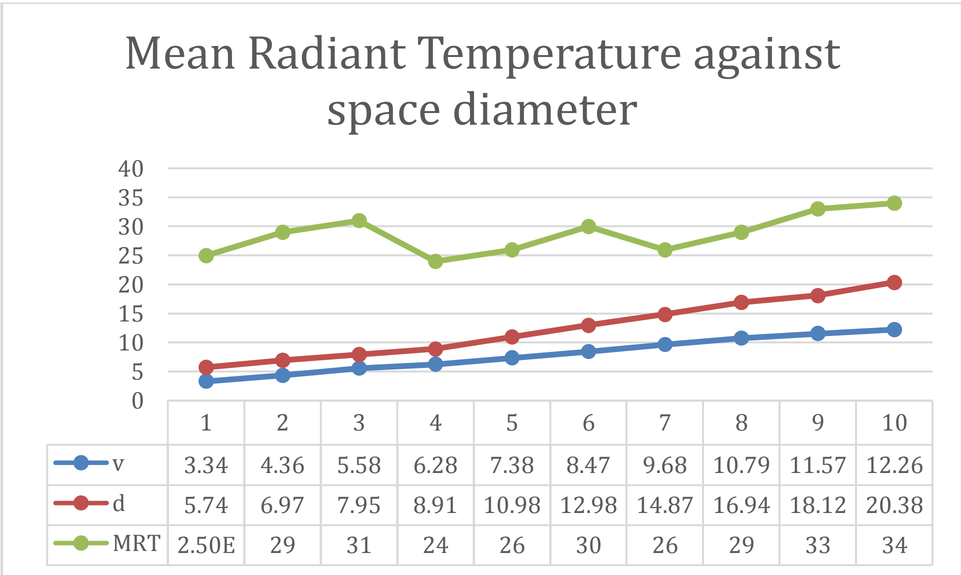


Figure 5: Mean Radiant Temperature against space diameter (Kaduna State)



	1	2	3	4	5	6	7	8	9	10
v	1.34	2.36	3.58	4.28	5.38	6.47	7.68	8.79	9.57	10.26
d	5.47	6.79	7.99	8.19	10.89	12.89	14.78	16.99	18.21	20.83
MRT	2.30E	26	30	28	27	31	24	32	29	25

Figure 6: Mean Radiant Temperature against space diameter (Katsina State)



	1	2	3	4	5	6	7	8	9	10
v	3.34	4.36	5.58	6.28	7.38	8.47	9.68	10.79	11.57	12.26
d	5.74	6.97	7.95	8.91	10.98	12.98	14.87	16.94	18.12	20.38
MRT	2.50E	29	31	24	26	30	26	29	33	34

Figure 7: Mean Radiant Temperature against space diameter (Sokoto State)

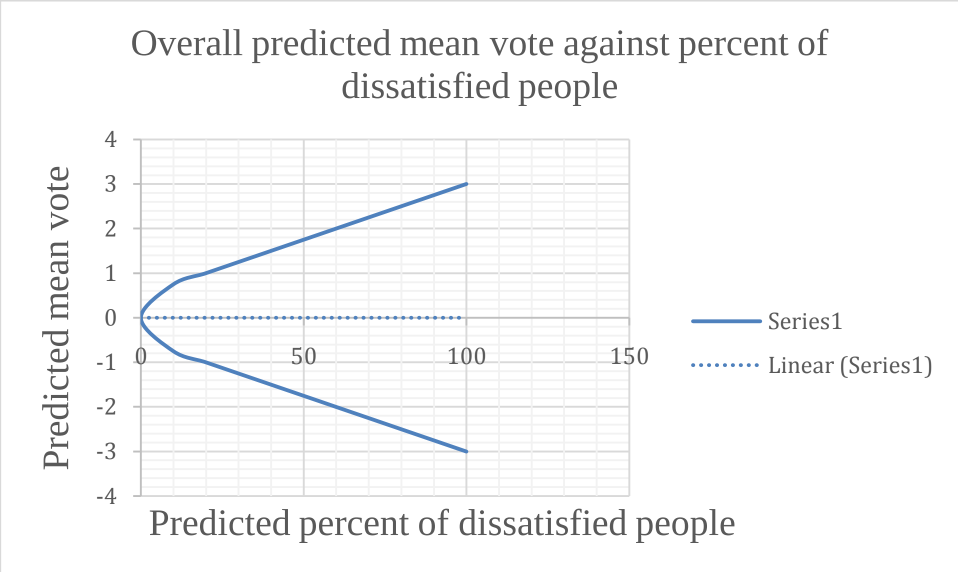


Figure 8: Overall predicted mean vote against percent of dissatisfied people

Table 5 depicts average air temperature, average relative humidity and overall comfort index of building occupants measured indoors of the buildings considered in Jigawa state. The comfort index was computed using Equation (1). Buildings B1, B2, B6, B7, and B9 all have their occupants feeling comfortable during the period of measurements while occupants of buildings B3, B4, B5, B8, and B10 have their occupants feeling uncomfortable at the time of measurements. The reason for the situation felt by the first set of people could be attributed to the low temperature and low humidity experienced.

Table 6 illustrates average air temperature, average relative humidity and overall comfort index of building occupants measured indoors of the buildings considered in Kano state. The comfort index was computed using Equation (1). Residents of buildings B11, B12 and B18 felt comfortable at the time of measurements while occupants of buildings B13, B14, B15, B16, B17, B19, and B20 have their occupants feeling uncomfortable at the time of measurements. The comfort indices of Kano State compared to Jigawa State were much higher, which means the weather conditions in Kano has greater effects.

Table 7 describes average air temperature, average relative humidity and overall comfort index of building occupants measured indoors of the buildings considered in Zamfara state. Residents of buildings B21, B23, B24, B25, B26, B27, B28, B29, and B30 all felt comfortable at the time of measurements while only occupants of building B22 have their occupants feeling uncomfortable at the time of measurements. The comfort indices of Zamfara State compared to Jigawa State and Kano were seen to be much lower, which gives the occupants better health situations.

Table 8 represents average air temperature, average relative humidity and overall comfort index of building occupants measured indoors of the buildings considered in Kaduna state. Residents of buildings B31, B32, B33, B36, B37, B38, and B40 all felt comfortable at the time of measurements while occupants of buildings B34, B35, and B39 have their occupants feeling uncomfortable at the time of measurements. The comfort indices of Kaduna State is higher than Zamfara State which is a reflection that the occupants will likely feel more uncomfortable than those of Zamfara State.

Table 9 signifies average air temperature, average relative humidity and overall comfort index of building occupants measured indoors of the buildings considered in Katsina State. Residents of buildings B41 to B50 all felt comfortable at the time of measurements. This state recorded the least overall comfort index when compared to the remaining states. This could be attributed to reduced air temperature and relative humidity recorded.

Table 10 denotes average air temperature, average relative humidity and overall comfort index of building occupants measured indoors of the buildings considered in Sokoto State. Residents of buildings B51 to B59 all felt comfortable at the time of measurements except for B60. The overall comfort index in this state is the second lowest after Katsina State.

Figure 2 depicts Mean Radiant Temperature (MRT) against space diameter measured indoors of the buildings considered in Jigawa state. The MRT was computed using Equation (2). It was discovered that as the diameter of the space or building increases, the MRT decreases. This is an indication that thermal comfort is achieved when the space within the building is not too wide or too small.

Figure 3 depicts Mean Radiant Temperature (MRT) against space diameter measured indoors of the buildings considered in Kano state. The MRT was computed using Equation (2). Many occupants with high MRT and low space diameters are the major occupants with regular complaints on thermal comfort. Those with large space diameters and low MRT tend to be more comfortable.

Figure 4 depicts Mean Radiant Temperature (MRT) against space diameter measured indoors of the buildings considered in Zamfara state. Majority of the buildings considered has low MRTs and high space diameters. This suggests that occupants in this environment are most likely to benefit from thermal comfort.

Figure 5 depicts Mean Radiant Temperature (MRT) against space diameter measured indoors of the buildings considered in Kaduna State. Majority of the buildings considered has high MRTs and high space diameters. This suggests that occupants in this environment are most likely to experience some sort of discomfort especially during summer.

Figure 6 shows Mean Radiant Temperature (MRT) against space diameter measured indoors of the buildings considered in Katsina State. The MRTs obtained are not evenly distributed, which suggests that weather situations in this state cannot be predicted. Majority of the buildings considered has low MRTs and low space diameters. This suggests that occupants in this environment are most likely to experience some sort of discomfort at one time or the other during the year.

Figure 7 depicts Mean Radiant Temperature (MRT) against space diameter measured indoors of the buildings considered in Sokoto State. . The MRTs obtained are evenly distributed, which suggests that weather situations in this state can be predicted up to an extent. Majority of the buildings considered has low MRTs and low space diameters. This suggests that occupants in this environment are most likely to experience some sort of discomfort at one time or the other during the year.

Figure 8 depicts Overall predicted mean vote against percent of dissatisfied people. This was obtained based on recorded complaints from occupants in all the states. Comparing all the thermal comfort of occupants based on Fanger theory, 33.3% felt hot, 26.7% felt warm, 20% felt slightly warm, 13.33% felt slightly cool, 6.7% felt cool, and 0% felt cold. This results show that occupants in this region and Geopolitical zone contend with more of heat than coldness.

IV. CONCLUSION AND RECOMMENDATIONS

- Use a Heating, Ventilation, and Air Conditioning (HVAC) framework that controls Mean Radiant Temperature (MRT): This is profoundly essential to human Thermal Comfort. Accordingly, utilizing a HVAC framework that measures and controls the Radiant part of usable Temperature goes far to accomplishing Thermal Comfort. The most ideal approach to accomplish this is to introduce a Radiant Cooling/Heating framework with a way to gauge and screen the MRT.
- Minimize spillage: Depending on the open air conditions, your HVAC framework might be heating up and humidifying chilly, dry air, or it could be chilling off and dehumidifying hot, moist air. In any case, the air needs to go through the HVAC hardware for this to happen productively and adequately. In the event that there is spillage in the structure envelope and the air is moving all through the structure other than through the HVAC framework, the exhibition will be brought down.
- Design and work for inhabitant control: Often, individuals will be the most agreeable when they have authority over some part of their framework. Along these lines, permitting admittance to the indoor regulator, or operable windows and blinds, may help apparent thermal comfort. Some portion of this is planning the structure to amplify the possible utilization of regular ventilation and radiation from the sun. These won't just lower the vitality load of the HVAC framework yet, in addition permit inhabitants to all the more accurately control their condition as they want. The test here is that in spaces involved by different individuals, permitting singular control can bring down execution for most of individuals and cause clashes. Accordingly, while structuring for the likely joining of client control and the utilization of common radiation and ventilation may be a possibility for some development plans, it isn't prudent for every one of them. What is regularly better for

thermal comfort is essentially permitting individuals to wear thermally agreeable garments, and control their comfort by either eliminating an external coat or putting on something hotter. This may demonstrate a superior way to give fine changes in accordance with the individual thermal condition, as opposed to adjusting the general heating and ventilation of the space.

- Maintain the thermal condition, and make changes as fundamental: Good support is critical to appropriately working HVAC hardware. In such manner, introducing a brilliant cooling/heating framework is indeed valuable, as support expenses and exertion are a lot of lower than all-air frameworks. Upkeep may likewise require monitoring, and responding to, occasional changes.
- Replace hot air with cold, or supplant cold air with hot, as required humidify or dehumidify the air as required increment air development by ventilation or cooling
- Reduce draft inconvenience by coordinating the ventilation or air development with the goal that it doesn't blow legitimately onto the representatives, e.g. utilizing bewilders Separate the wellspring of thermal or cold from the worker
- Erect hindrances that shield or protect the work region or limit get to and overhaul occupations to eliminate the representative from the region
- Restrict the time span that representatives are presented to hot or cold conditions control the measure of work and pace of work workers are required to do present mechanical guides (e.g. lifting helps or force devices) to help truly requesting positions in thermal and hot situations or when workers are wearing a ton of dress Control the attire. On the off chance that PPE is worn, ensure that workers are not wearing more PPE than is fitting
- If regalia are worn, assess elective plans, new materials, and so on to improve the thermal comfort of garments assess clothing regulation and permit representatives to adjust their dress where conceivable numerous layers of garments empower workers to make sensible acclimations to their attire dependent on their individual needs
- Allow the representative to make social transformations. Where conceivable, eliminate all limitations that may keep representatives from making minor acclimations to their garments or work rate give thermal-up or chill off territories give individual radiators or fans permit representatives to modify indoor regulators or open windows as fitting
- Provide fitting management and preparing acquire clinical guidance from a word related wellbeing proficient for representatives who are pregnant, have an ailment or incapacity, or are taking drugs your danger appraisal should as of now address dangers to pregnant workers, however you may decide to survey it when a worker discloses to you she is pregnant, to assist you with choosing if you have to do anything else to control the dangers
- Administrative controls incorporate arranging and rescheduling work times and practices and rest plans, for instance, planning 'hot' work for cooler times or permitting representatives to have adaptable hours to help stay away from the most noticeably terrible impacts of working in high temperatures.
- Administrative controls are for the most part of a present moment, impermanent nature. Albeit some can be perpetual, for instance, crisis techniques and the arrangement of suitable government assistance offices, for example, skilful first aiders with extra information in the administration and acknowledgment of thermal related ailments and wounds just as guaranteeing the accessibility of proper emergency treatment hardware.
- The more physical work we do, the more thermal we produce. The more thermal we produce, the more thermal should be lost so we don't overheat. The effect of metabolic rate on thermal comfort is basic. An individual's physical qualities ought to consistently be borne as a main priority while thinking about their thermal comfort, as components, for example, their size and weight, age, wellness level, and sex would all be able to affect how they feel, regardless of whether different factors, for example, air temperature, moistness, and air speed are altogether steady.

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