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THE ASSESSMENT OF INDOOR THERMAL COMFORT IN A BUILDING: A CASE STUDY OF LEMAR, SALAMIS ROAD, FAMAGUSTA, CYPRUS

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Abstract: **Due to the large amount of fossil fuel being used up to achieve thermal comfort, the future of a healthy environment looks uncertain. To conserve fossil fuel energy and resources used to enhance indoor thermal comfort and reduce the incidence of global warming, calls for better understanding and application of passive design strategies and use of climate sensitive designs. This study is based on the assessment of the indoor thermal comfort in LEMAR as a case study. Mall design is an important aspect to be considered by many as it environment may influence the health and productivity of its occupants and visitors. Health symptoms like fatigue, headache, tiredness and aggressiveness are common scenario faced by people due to bad thermal comfort condition.**

However, the following objectives should be considered;

- **The thermal comfort level in LEMAR based on an objective and subjective evaluation,**
- **The relationship between the physical characteristics of the spaces and both objective and subjective analysis of the thermal comfort level.**

Keywords: **Thermal Comfort, Passive Design Strategy, Environmental Quality.**

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1. INTRODUCTION

Thermal comfort is often related to the condition of an individual's mind, which expresses satisfaction or dissatisfaction with the thermal environment. Man has, for the most part, strived to create thermally comfortable environment. This is reflected in building traditions around the world – from ancient history to present day. A healthy and comfortable thermal environment of indoor spaces helps the users/ occupants to improve their work efficiency by maintaining various comfort related parameters within the desired range. (Shanu, 2010).

Thermal comfort is considered as a principal requirement that is usually demanded by occupants of accommodation units such as school, malls, houses, etc. A compatible indoor climate design is actually a modification of the external environment system and is designed to provide comfort for occupants. Thermal comfort in LEMAR is an important aspect to be considered by many, as it much influences the health and productivity of its occupant. Karimipanah .T (2012) said "good thermal comfort and indoor air quality can actually have a positive impact not just on people's health but can also improve the quality of the environment.

Thermal comfort varies across climatic zones and as a result, malls and other buildings should be designed in relation to the climatic zone. It is the role of the architect to understand and design buildings with minimum cooling loads (artificial ventilation) while also providing for thermal comfort for the buildings occupants. Due to the climatic change in Cyprus, the project, hence seeks to assess thermal comfort in a mall, focusing on LEMAR as a case study.

The concept of thermal comfort, though theoretically understood, appears to pose a challenge in terms of its implementation in design. This is more so because of the complexity of establishing a common ground answer when carrying out subjective evaluation. For building typology such as a mall which contain various spaces of different use and arrangement, the issue of maintaining an optimum level of thermal comfort is crucial. One of the basic objectives in designing buildings is to ensure the thermal comfort to its occupants.

Thermal comfort is crucial because it influences productivity and health as thermal discomfort has also been known to lead to sick building syndrome (SBS). To face climate problem, architectural parameters such as building orientation, window opening, roof shape, building performance and vegetation planning must be considered seriously. Climate modification is also effective to obtain optimal temperature in building. (Prianto et al, 2000)

The following questions would be answered during the course of this study.

1. What are the physical characteristics of the spaces in a mall?

2. What is the thermal comfort level in a mall in terms of objective and subjective evaluation?

3. What is the relationship between the physical characteristics of the spaces and the objective and subjective evaluation?

In view of the importance of thermal comfort in a mall, the research aim and objectives are as stated below.

The aim of the study is to assess the thermal comfort level in a mall and provide modification suitable for future designs.

The objectives of the study are to:

1. Analyze the thermal comfort level in the mall based on an objective and subjective evaluation.

3. Determine the relationship between the physical characteristics of the spaces and both objective and subjective analysis of the thermal comfort level

The outcome of this study is expected to show the relationship between the building and its immediate environment; the effect of the climate on the building orientation and building components and how the configuration of the building and building materials can be used to achieve maximum thermal comfort in the mall. The importance of this study draws on the need for thermal comfort in a mall. It will identify the problems causing poor thermal comfort. The research will be helpful to improve the said problems identified. It will definitely pave a way for the management to take effective steps in providing better commercial facilities for the area. It would also help the author of this study in acquiring knowledge that will be useful in practice. The mall (LEMAR) was chosen because it is the most popular commercial building which is mostly visited by the residents within Famagusta. It is also more accessible to the author, it is neither the oldest nor the newest of all the malls in Famagusta which makes it the right.
Thermal comfort studies are usually carried out in buildings that are permanent, or semi-permanent, occupied or visited by the same people, such as dwellings, offices, classrooms. (Karyono, 2015)
The study is mainly focused on the thermal comfort in LEMAR due to the amount of people that walk in and out of the mall every day. The research involves the distribution of questionnaires to the people around Famagusta who frequently visit the mall in other to have a view of their perception and level of comfort in their thermal environment, the overall analysis of the mall includes, its orientation, the thermal mass of the mall i.e. the roof, the walls, ceiling and floor material, the windows (fenestration), size of the spaces in relation to the number of occupants and the surrounding landscape.

This study is mostly geared towards the assessment of thermal comfort and the parameters required to carry out this study were limited due to lack of data and restriction codes based on the environment of the place or area in which the study is being carried out.

There was limited time frame due to the difficulties faced in getting access to the software required that would help in carrying out the analysis and findings for the project.

The research is specifically concerned with the assessment of thermal comfort in a building, as a mall, which is located on Salamis Road, Famagusta, North-Cyprus. It is known as one of the popular malls known in the area and accessed by many.

2. LITERATURE REVIEW

When constructing a buildings the indoor environmental quality (IEQ), may determine the success or failure of a project. As a result, many of today's sustainable building designs take the issue of indoor environmental quality that includes comfort. Indoor environmental quality refers to the quality of a building's environment in relation to the health and well-being of those who occupy space within it (NIOSH, 2015). IEQ is important because the air quality inside buildings can be more stuffed than the outside air. It should also be noted that people spend 90% of their time indoors. Indoor environments are highly complex and building occupants may be exposed to a variety of contaminants (in form of gases and particles). Understanding the sources of indoor environmental contaminants and controlling them can often help prevent or resolve building-related symptoms.

The indoor environmental quality of a building can be determined by many factors, some of which are:

- Indoor air quality,
- Lighting, thermal comfort,
- Acoustics quality,
- Visual comfort etc.

Indoor air quality (IAQ); is a balance of proper ventilation rates, managing volatile organic compounds, air temperature, humidity levels, water and light. IAQ requirements are addressed in specific standards that spell out minimum ventilation rates for new construction, as well as information on improving IAQ in existing buildings. They also provide lists of maximum contaminant levels for those spaces to maintain acceptable IAQ, which in turn minimizes the potential for adverse health effects on building occupants (CertainTeed, 2015).

Visual comfort; is part practical and part aesthetic. It employs such strategies as artificial lighting, day lighting and creating visually interesting environments.

Acoustics quality; is another method of enhancing occupant comfort that is currently receiving attention in the design community. Creating superior acoustical environments in open plan office spaces, healthcare facilities, multipurpose halls and schools to improve speech intelligibility and privacy is the primary goal.

Thermal comfort: Thermal comfort is defined in the ISO 7730 (1994) and ASHRAE standards 55-66 as "the condition of the mind that which expresses satisfaction with the thermal environment". Cheung (2003) states that, thermal comfort occurs when there is a thermal equilibrium in the absence of regulatory sweating and the heat exchange between the human body and the environment. The human thermal environment is not straightforward and cannot be expressed in degrees, Nor can acceptable temperature ranges satisfactorily define it. It is a personal experience dependent on a great number of criteria and can be different from one person to another within the same space. The Health and Safety Executive suggest that an environment can be said to achieve 'reasonable comfort' when at least 80% of its occupants are thermally comfortable. This means that thermal comfort can be assessed simply by surveying occupants to find out whether they are dissatisfied with their thermal environment.

Thermal comfort is influenced by environmental and personal factors as well as the building's design parameters. The most commonly used indicator of thermal comfort is air temperature because it is the most easy to use and people can rate it without any difficulty. Although it has vital importance, however, it is not the only parameter that can be used to define thermal comfort very accurately. According to (Khaliq, 2009), air temperature should always be considered in relation to other environmental and design factors. Temperature and relative humidity are the two local climatic factors that affect indoor comfort while building envelop, orientation, shading, glazing type and size, vegetation, thermal mass are the design dependent parameters that contribute to the thermal comfort condition in residential buildings such as hostels. Although these factors are independent to each other, they have collectively a great impact.

According to (Gut paul, 1993) the main climatic and environmental factors affecting human comfort, which is relevant to construction, are:

1. Air temperature, its extremes and the difference between day and night, and between summer and winter.
2. Humidity and precipitation.

3. Incoming and outgoing radiation.

4. The influence of the sky condition, air movements and winds.

Air Temperature : This is a dominant environmental factor. It is the temperature of the air surrounding the body and it determines how much indoor temperature would be in a space. Its unit is given in degree Celsius (˚c). It is measured by using a dry bulb thermometer. Bodies in contact or bodies in environment facilitate it. Its conductivity depends on the materials used as different materials have different conductivity level and determines how much heat is dissipated in a space

Relative Humidity (RH) : The ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature, expressed as a percentage. It is simply the amount of moisture content in the atmosphere. It is often compared with temperature whether high or low, and may be increased to cater for thermal comfort. The higher the relative humidity, the more difficult it is to lose heat through evaporative cooling (sweating).

Radiant Temperature : The temperature of a man's surrounding including surfaces, heat generating equipment, the sun and the sky, is commonly communicated as mean radiant temperature (MRT), a weighted average of the temperature of the surfaces encompassing a man, which can be estimated by a globe thermometer) and any solid mono-directional radiation, for example, radiation from the sun (Buildings, 2015) Radiation is just the exchange of warmth from a warmed surface or body to another body or surface. The bodies don't need to be in contact for this exchange to happen.

Air Velocity: The velocity or speed of the air that a person is in contact with is measured in m/s. the faster the air movement, the greater the exchange of heat between the body and the air. It is important because it accelerates convection. It changes the skin and clothing surface heat transfer coefficient (reduces surfaces resistance), as well as increases evaporation from the skin. Thus, producing a physiological cooling effect.

Personal Factors: Another set of factors affecting thermal comfort are known as the human thermo-regulatory or personal factors. They are:

1. Metabolic rate.

2. Clothing.

3. Acclimatization (this can be more difficult where there is a high outdoor-indoor temperature gradient).

4. Body physique and shape.

5. Age, gender and health etc.

Of the afore mentioned, metabolic rate and clothing are the most commonly adopted personal factors used in determining thermal comfort.

Clothing: Clothes insulate a person from exchanging heat with the surrounding air and surfaces as well as affecting the loss of heat through the evaporation of sweat. A person can directly control clothing whereas environmental factors may be beyond their control (Buildings, 2015). Thermal comfort is very much dependent on the insulating effect of the clothing on the person. Wearing too much cloth or personal protective equipment (PPE) may be a primary cause of heat stress even if the environment is not considered warm or hot. Clothing is both a potential cause of thermal discomfort as well as a control for it, as we adapt to the climate in which we are. Clothing is measured in a scale called clo value. 1 clo = 0.155m2k/w insulation to the body. table

Typical values vary from 1 – 4 clo.

Table 1: Showing Typical Clothing Values Proposed by Kenneth Bowazi (2013)

Clo Value	Clothing	Typical comfort temperature when sitting
0 clo	Swimwear	29˚c
0.5 clo	Light clothing	25˚c
1 clo	Suit, jumper	22˚c
2 clo	Coats, gloves, hats	14˚c

Metabolic/ Work Rate: The more physical work we do the more heat we produce. The more heat we produce, the more heat needs to be lost so we do not overheat. The impact of metabolic rate on thermal comfort is critical (Health, 2014). Note that metabolic rate is a function of activity level.

Typical Heat Output of an Adult Male

Table 2: Showing Typical Heat Output Proposed by Kenneth Bowazi (2013)

ACTIVITY	EXAMPLE	HEAT OUTPUT
Immobile	Sleeping	70W
Seated	Watching Tv	155W
Light work	Office	140W
Medium work	Factory work	265W
Heavy work	Lifting	440W

COMFORT ZONE: According to Çakir (2006), thermal comfort in an interior space is defined as the sum total of heat or cold sensations experienced by occupants. Further, if the interior space has neither excessive heat nor cold conditions, it is then considered thermally comfortable. This reveals that the space is within an occupant’s comfort zone. Thus, the comfort zone may be considered as a thermal condition in which little or no effort is required by occupants to adjust their bodies to surrounding environmental conditions. Notice that most people are comfortable at higher temperatures if there is lower humidity. As the temperature drops, higher humidity levels are still within the comfort zone. Occupational safety and health services (1997) OSAHS, provided a thermal comfort standard for sedentary occupations applicable in any climatic zone. According to the standard, most people will be thermally comfortable in the following conditions;

1. Air temperature: heat periods (19ºC-24ºC) cold periods (18ºC-22ºC).
2. Relative humidity: 40%RH-70%RH.
3. Air speed: 0.1-0.2 m/s, without creating draught.
4. Radiant heat: no direct exposure to radiant heat source.

BUILDING DESIGN PRINCIPLES: Generally the tropical zone is defined as the area of land and water between the tropic of cancer (latitude 23.5° N) and the Tropic of Capricorn (latitude 23.5° S). Occupying approximately forty percent of the land surface of the earth, the tropics are the home to almost half of the world’s population (Dilshan R.O, 2008). There are variations in climate within the tropic. However ninety percent of the tropical zones embody hot and humid climatic regions, whether permanent or seasonal. The remaining ten percent is dessert like and characterized as hot and dry climate (Baish, 1987). Several different climatic types can be distinguished within the tropical belt, since latitude is only one of the many factors determining climate in the tropics. Distance from the ocean, prevailing wind conditions, and elevation are all contributing elements. Since the entire tropical zone receives the rays of the sun more directly than areas in higher latitudes, the average annual temperature of the tropics is higher and the seasonal change of temperature is lesser than in other zones (Cleveland, 1999).

(Gut paul, 1993) stated that, the points to take into consideration when designing a tropical responsive building are as follow:

1. Minimize heat gain during daytime and maximize heat loss at night in hot seasons,
2. Minimize internal heat gain in the hot seasons,
3. Select the site according to microclimatic criteria,
4. Optimize the building structure (especially regarding thermal storage and time lag),
5. Control solar radiation,
6. Regulate air circulation.

Any building designed for warm climatic conditions should attempt to exclude loads that bring about high temperature and intensity of solar radiation. The absorption of outdoor temperature by the building is the major source of heat gain inside the building space (Gut paul, 1993). The passive way to reduce, cool and thermally make a building comfortable is to minimize the solar radiation incidence on the building, adequate building orientation, proper layout of the building by taking into cognizance neighbouring buildings and by using proper shading devices to help reduce the incident solar radiation on the building (Dilshan R.O, 2008).

If the ambient temperatures are higher than the room temperature, heat enters into the building by convection due to undesirable ventilation, which needs to be reduced to the minimum possible level (Dilshan R.O, 2008).

However, some design dependent parameters that contribute to the thermal comfort condition of the indoor space such as roof types, wall material, fenestrations, building configuration, etc. are discussed below.

ROOF DESIGN FOR PASSIVE COOLING STRATEGY: A near vertical sun during the hottest hours of the day causes the roof to bear the greatest intensity of heat (Plumbe, 1987). The roofing should be tightly fixed and the material should insulate the building from both excessive heat and humidity. Eaves are recommended as they create plenty of shade around the building and protect the outer walls from getting soaked (Duchein, 1988; Schüller, 2000). Pitched or sloping roofs are recommended, specially designed to stand the many and sudden tropical showers as well as the violent winds, from gusty to cyclonic. Metal roofs made from aluminium, zinc, copper or stainless steel have the disadvantage of being very effective heat conductors, as well as possibly suffering from corrosion caused by contact with Sulphur dioxide in the atmosphere (Duchein, 1988). The construction of secondary roofs and facades, with a gap of several inches between the primary and secondary surfaces, to allow for ample airflow around the primary building, is very important. This prevents sunlight from shining on and directly heating the outside surfaces (Schüller, 2000). Thermal insulation or the construction of false ceilings will have a similar positive effect.

According to Agrawal (1974) a light roof colour to reflect unwanted summer heat may reduce heat transmission into the building. The reflectance of a surface is a measure of the energy that is neither absorbed nor transmitted and is expressed as the ratio of the reflected energy to the total incident radiation energy.

Roof Solar Shade: Appropriate external shading devices can control the amount of solar radiation admitted into the room, which could largely reduce cooling loads and improve indoor thermal comfort and day lighting quality. The geometry of window shading device system can influence the thermal performance. Façade designs can improve indoor thermal comfort for naturally ventilated buildings, especially for hot-humid climate. In addition, it is noticed that there are very few guidelines for facade designers of naturally ventilated buildings or for occupants with operation of individual control over their thermal environment for the hot-humid climate (Jamiu, 2014).

Roof Solar Reflection: According to Sharma (2003) if the external surfaces of the building are painted with such colours that reflect solar radiation (in order to have minimum absorption), but the emission in the long wave region is high, then the heat flux transmitted into the building is reduced considerably. For highly absorptive (low solar reflectance) roofs, the difference between the surface and ambient air temperatures may be as high as 50°C (90°F), while for less absorptive (high-solar reflectance) roofs, such as white paint, the difference is only about 10°C (18°F). For this reason, "cool" roofs (which absorb little "insolation") are effective in reducing cooling energy use (Dilshan R.O, 2008).

An alternative method is to provide a cover of deciduous plants or creepers. Because of the evaporation from the leaf surfaces, the temperature of such a cover will be lower than the daytime air temperature and at night it may even be lower than the sky temperature.

From the aforementioned, it can be deduced that roofs should be tightly fixed and the materials used should insulate the building. It is recommended to use eaves to create shade and the eaves should have opening to let out accumulated heat. The use of a light roof colour, reflective foil or green roof can reflect unwanted summer heat thereby reducing the heat transmission into the building and improving thermal comfort.

Thermal comfort in buildings nowadays is paramount as it tends to stabilize the interior temperature and relative humidity and not affected by fluctuation of exterior condition (Jamiu, 2014). Wall design is a logical means for passive control of a building’s indoor conditions by managing the transference of outdoor temperature. Construction materials such as concrete, brick, cement block and other solid masonry materials used in the tropics are considered as having high thermal mass and are considered very effective against rapid heat transfer, which is due to their abilities to absorb heat from solar radiation at a much slower rate than lightweight materials.

There are four designs factor for wall. They are wall solar shade and reflection, wall material and wall thickness (Dilshan R.O, 2008)

Wall Solar Shade: The impact of solar protection of walls is of less importance than the solar protection of windows. Therefore, if a project is too expensive, the preferred initial source of economy is the wall protection. (Garde, 2004) Highlighted that an overheating of 2ºC was observed in rooms with coloured concrete walls exposed to the solar radiation compared to rooms with no walls exposed. The most important surfaces to treat therefore are those most exposed to the sun that is to the east and south, and to a lesser extent, the northern and western surfaces. The other surfaces could be granted dispensations, or else given less requirements (Garde, 2004). Heat gain through exterior walls of a building should be minimized where appropriate using various shading devices designed as part of the structure or through the use of selected vegetation such as creeping plants on walls to give off a green façade.

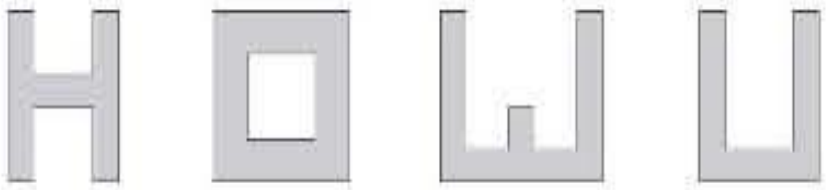
Wall Solar Reflection: When it comes to solar responsive design, perhaps the lowest-hanging fruit is choosing white. The use of reflective surfaces to avoid solar gains and the use of reflective insulation are the most effective means of improving attic performance. A white wall will reflect most of the sun’s energy back into space, while a black wall absorbs most of the sunlight and turns it to heat. Also, the differences in wall types were almost equalized when white surfaces were tested. For the solar protection of the dark coloured house wall of reflectance, it was recommended to put 10 cm insulation instead of the 6cm. white ceilings and interior walls make electric lighting more efficient, and white roofs and exterior walls can make daylighting more efficient. No insulation was planned for the solar protection of medium coloured walls. A dispensation was granted over this point as well (Garde, 2004). The amount of solar radiation absorbed by a surface is referred to as the absorptivity and is dependent on the colour of the surface (Ogunsote and Prucnal-Ogunsote, 2004). The absorption factor and reflectance factor are two different ways to describe the same phenomenon. Either can tell how much sunlight is absorbed and how much is reflected. Since it has been established that white has a very high reflectance factor, the absorption factor is very low.

Wall Thickness: The variation in wall thickness makes a significant difference in the comfort performance of houses (Mallick, 1996). Indicated rooms with thicker walls tend to be more comfortable. Comparison of temperature measurements in houses that have wall thicknesses ranging between 125 and 500 mm shows that rooms with thicker walls tend to be more comfortable, particularly in hot and dry period between March and June in Bangladesh. Houses with thick walls on lower floors can be comfortable all year round as opposed to ones that are on top floors (Mallick, 1996). Thermal transmission in a certain material depends upon the thermal property (in this case the thermal conductivity) and the thickness of that material. The lower value thermal conductivity will have less thermal transmission. Similarly, the thicker insulation material will create less thermal transmission (Mahlia, 2007). From traditional knowledge, low-mass materials such as wood is considered appropriate for free-running operation in hot humid climates as their indoor temperature drops rapidly in the evening, when the winds usually subside. High-mass buildings cool down more slowly during the night, which is a feature to cause discomfort during sleep. High-mass buildings can have more cumulative degree hours of discomfort over a 24 hours period, but on a daytime basis only they have far more advantages. The conclusion is that for free-running operation, if there is assisted ventilation at night, for most of the time high mass buildings can be more comfortable than low mass ones (Rosangela, 2002).

Wall Materials: The choice of building materials is essentially determined by their local availability, their economy, durability and suitability for the particular climate (Wolfgang, 2011). Construction materials such as concrete, brick, cement block and other solid masonry materials are considered as having high thermal mass. However, high thermal mass materials are considered very effective against rapid heat transfer, which is mainly due to their properties to absorb heat from solar radiation at a much slower rate than lightweight materials with a low thermal mass. Lightweight materials of timber, steel and the various building wall materials absorb heat quickly and conversely cool down quickly. A composite construction wall may be a compromise solution ideally suited to the local climatic conditions (Dilshan R.O, 2008).

BUILDING OPENING DESIGN STRATEGY: In traditional buildings, designers place windows at certain points to create a current of air. Further, opening windows can reduce heat and humidity, but on the other hand the existence of windows can increase inside temperatures with solar penetration. East and west-facing walls and windows are the most important to shade, as solar heating is most intense on these orientations. Reduce unwanted morning and afternoon solar heat gain by minimizing or protecting extent of walls and windows facing east or west (Dilshan R.O, 2008). Breezes in high humidity allow people to feel cooler because of evaporation from their skin. This is why ceiling fans make people feel cooler. Breezes also replace indoor air with fresh air, keeping humidity levels from building up as people exhale both moisture and heat. But when the temperature of air is higher than skin temperature, the cooling effect by evaporation is not possible even though the relative humidity is less than 100% (Koch-Nielsen & Holger, 2002). Buildings that rely on natural qualities for comfort need to be planned thoughtfully. Their location, orientation, and surrounding landscape matter a great deal. As they need to be shaped to avoid direct sunlight and catch breezes (Stouter P., 2008).

Long and narrow footprints are better than square ones for daylighting and adequate ventilation. Although square buildings have lower heating load, lighting and ventilating the interior is difficult and the imbalance between perimeter heating loads and interior cooling loads necessitates a complex HVAC system.



Source: Weidt Group - Iowa DNR Sustainable Design Initiative

Fig 1: Showing Examples of Building Footprints with High Daylight and Ventilation Access

According to Neilson and Brown 2001, Buildings that use the following strategies can be seen as comfortable based on the following parameters;

- **Catch the breeze:** Locate on a hill or raise above the ground, at a 20- 40° angle to the prevailing breezes.
- **Do not block the breeze:** Spaces buildings out, and add breezeways in them. Build 18m downwind from a 3m height building to allow breezes in.
- **Make rooms breezy:** Each room needs two exterior walls, with many windows or vents, including low openings. Verandas with outside stairs obstruct breezes much less than interior halls.
- **Make outdoor areas breezy:** Keep them open to warmer season breezes, and if possible protected from storm and cool season winds.
- **Use vents as well as windows:** If possible, use mosquito-netting curtains inside walls of open work or vent blocks. Windows or shutter on one or two sides can block breeze on cool evenings.
- Screen porches or verandas to allow openings to unscreened windows in the centre of the building.
- Pull breezes in with wing-walls, and shutters or casement windows that open outward. Although jalousie windows allow ventilation by keeping rain out while they are open, casements under an overhang can be helpful to catch breezes. A sturdy adjustable shutter that pivots vertically in the centre of the windowsill may be able to secure a building and catch breezes too.

A climate conscious building can be achieved by the exploration of shading potentials to reduce the total heat gain through the wall openings in two ways, which are: natural devices and sun control devices. The natural shading strategies are the means of shading the building with orientation of the sun and by the use of vegetation. Sun control devices are used to exclude the unwanted solar radiation penetration into the building. The design, fixing location, effectiveness in terminating the direct sun and operational systems are attributes of the sun control devices and as such, are divided into the internal and external devices

1. Internal devices to control solar radiation can be categorized into two types:
2. Solar shading using blinds, louvers, drapers and screens which are other than the window-glazing pane.
3. The use of special glazing, without the use of internal or external shading devices. The internal solar shading devices are less effective, as they allow solar radiation to strike on the vertical surface of the building. They also permit the heat into the building.
4. External devices are projections attached to the building skin or an extension of the skin to eliminate unwanted solar heat. They are more effective as they intercept the solar radiation before it reaches the vertical surface of the building envelope. The obstructed heat is dissipated to the outside air. Thus, heat reduction is best achieved by excluding unwanted heat rather than removing it later.

The horizontal (overhang) and vertical (fins) devices are the two basic forms of external shading devices. The egg crate devices are combinations of the horizontal and vertical devices. Based on these basic forms, configuration of the external shading devices varies from structural projections in the form of cantilevered floor, recessed walls and shading devices using lightweight materials. The form of horizontal and vertical fins and light shelves perform a similar function. Use of lightweight materials enabled to give more flexibility in operating solar shading. Configurations of operable shading device were able to change or adjusted to the changing patterns of sun's motion and the shading needs. Therefore, the performance of an operable device in eliminating the unwanted heat is better than a fixed device (Givoni, 1998).

Cross ventilation is of high importance in creating a thermally comfortable indoor space in the tropical region (Dilshan R.O, 2008). Natural ventilation of dwellings is efficient during the hot and humid season. This is quite a good result because the main objective of the building design in tropical climates is to avoid the overheating of the indoor temperature by keeping it at least below the outdoor temperature (Prianto, 2003). Actually, for heavyweight construction types smaller opening areas provided better performance also for free-running operation. Based on these simulations, a 50% value was set as a maximum window opening area in terms of wall area for dual mode operation (Rosangela, 2002).

However, cover openings on west and east ends. Use few windows and doors. For openings use vertical sunscreens, climbing vines, or shrubs to reduce heat gain on western walls. Use of wide horizontal-shading device (such as wide eaves, veranda or pergola) to shade windows on east-west axis, a vertical shading device or the window should be small and placed high on the wall under the eave. Spaces should allow for cross ventilation, on the exterior, both vertical and horizontal shading device should be adopted, as external shading devices are more efficient. Choose window types that offer the best ventilation performance or alternatively look at design combinations that fit the situation. High ceilings let hot air rise above the people so the room feels cooler to its occupants.

3. METHODOLOGY

The study adopts the use of both qualitative and quantitative data gathered mainly through field survey, computer model and the use of content approach to analyze the information's gathered via other people's documentation (as secondary source). In the course of this study, the data analysis and findings gathered are vital as they serve as key element to understand the thermal environmental condition in a room. The study also proposes the use of the SPSS statistical software as a means to stimulate, generate and evaluate data that would be acquired and necessary in the course of the research.

However, Computer simulation helps to indicate the efficiency degree in terms of comfort indoor environment, exploring thermal performance of the building, and examining the potential effects of proposed materials. It is also necessary to study articles, journal, etc. relating to the subject matter and then develop strategies by which the comfortability level of the chosen building or space can be maximized. The objective of this research is focused on the design dependent elements and parameters such as; Air temperature, relative humidity, radiant temperature, air velocity that will be valuable in determining the assessment of thermal comfort in a room.

4. RESULTS AND DISCUSSION

To get the assessment of the indoor thermal comfort of Lemar, questionnaires were distributed among its users. Selection of people used in the study was random. Comprising of students, workers and locals, within the area. 50 questionnaires were distributed and retrieved. These questionnaires were analyzed with the use of SPSS statistical software.

Gender of Respondent

From the 50 questionnaires that were shared and retrieved, it can be deduced that 27 people where male, while the remaining 23 people where female.

Table 3: Indoor Thermal Comfort Parameter (Gender of Respondents)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	27	54.0	54.0	54.0
	Female	23	46.0	46.0	100.0
	Total	50	100.0	100.0	

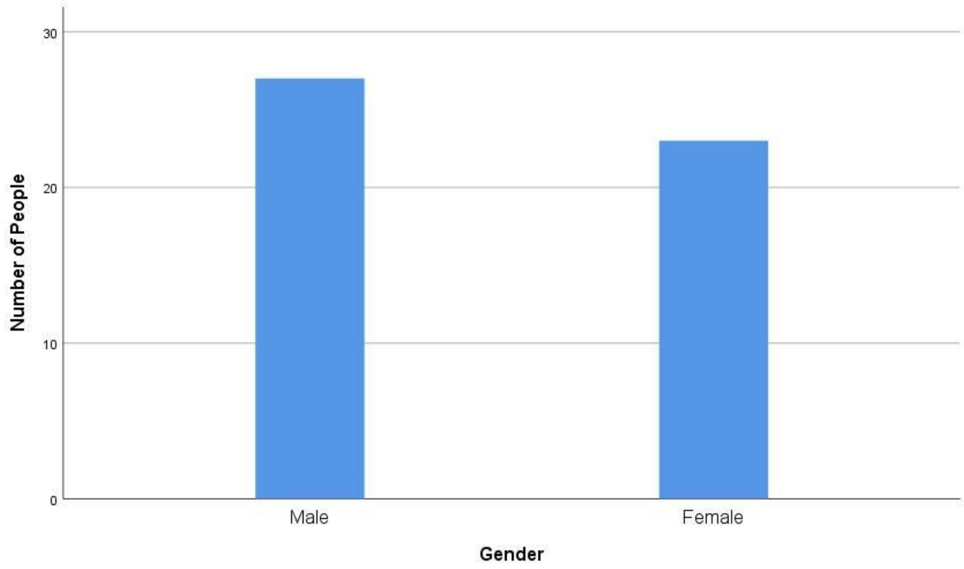


Fig 2: Indoor Thermal Comfort Parameter (Gender of Respondents)

Physical Stature of Respondent

From the 50 questionnaires that were shared and retrieved, it can be deduced that 26 people had ticked slim as their stature, 19 people ticked average, 2 people ticked fat, while 3 people where indecisive of which option to tick.

Table 4: Indoor Thermal Comfort Parameter (Stature of Respondents)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Slim	26	52.0	52.0	52.0
	Average	19	38.0	38.0	90.0
	Fat	2	4.0	4.0	94.0
	Indecisive	3	6.0	6.0	100.0
	Total	50	100.0	100.0	

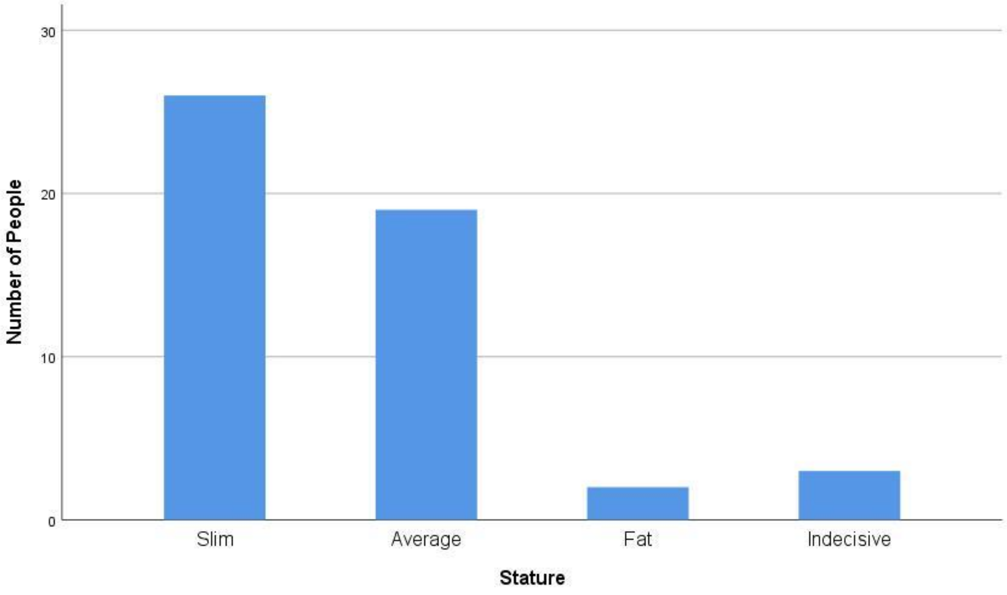


Fig 3: Indoor Thermal Comfort Parameter (Stature of Respondents)

Age of Respondent

From the 50 questionnaires that were shared and retrieved, it was deduced that a total of 18 people fell within the age of 18-21 years, 11 people fell within 22-25 years, 18 people fell within the age of 26-30, while the remaining 3 people fell within 30 years and above.

Table 5: Indoor Thermal Comfort Parameter (Age of Respondents)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-21yrs	18	36.0	36.0	36.0
	22-25yrs	11	22.0	22.0	58.0
	26-30yrs	18	36.0	36.0	94.0
	Above 30yrs	3	6.0	6.0	100.0
	Total	50	100.0	100.0	

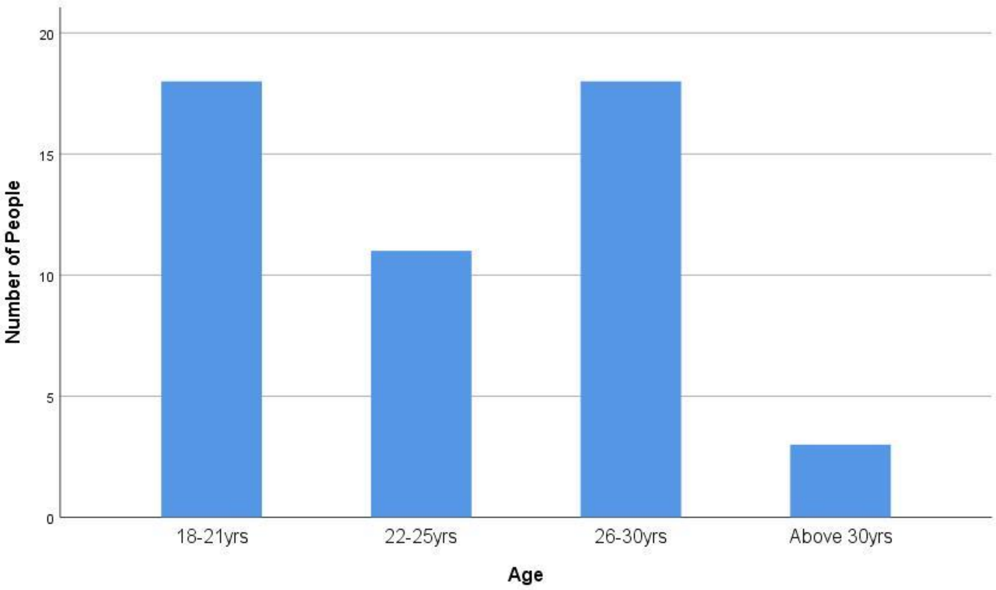


Fig 4: Indoor Thermal Comfort Parameter (Age of Respondents)

Weight of Respondent

From the 50 questionnaires that were shared and retrieved, it was deduced that a total of 8 people weighed 20-55kg, 16 people weighed 56-75kg, 21 people weighed 76-95kg, while the remaining 5 people where indecisive of which option to tick.

Table 6: Indoor Thermal Comfort Parameter (Weight of respondent)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20-55kg	8	16.0	16.0	16.0
	56-75kg	16	32.0	32.0	48.0
	76-95kg	21	42.0	42.0	90.0
	Indecisive	5	10.0	10.0	100.0
	Total	50	100.0	100.0	

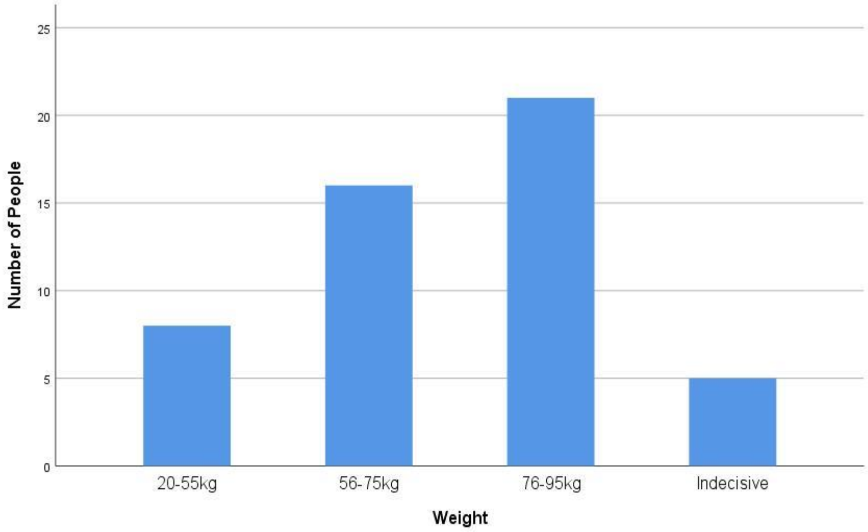


Fig 5: Indoor Thermal Comfort Parameter (weight of respondent)

Air quality

Each respondents was asked to choose the option that best described the air quality of the space. 10% said excellent, 58% said good, 26% said average, while the remaining 6% fell under others which ranges from the combination of 2 or more options.

Table 7: Indoor Thermal Comfort Parameters (Perception of Air Quality)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Excellent	5	10.0	10.0	10.0
	Good	29	58.0	58.0	68.0
	Average	13	26.0	26.0	94.0
	Undefined	3	6.0	6.0	100.0
	Total	50	100.0	100.0	

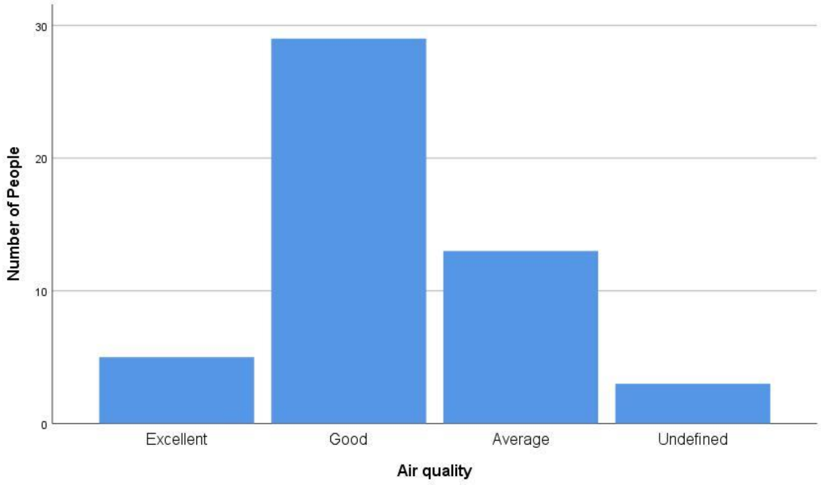


Fig 6: Indoor Thermal Comfort Parameters (Perception of Air Quality)

Comfortability

Each respondents was asked to choose the option that best describes the comfortability of the space without air conditions or heaters. 20% said yes, 48% said no, while the remaining 32% fell under others which where indecisive of how they felt within the space.

Table 8: Indoor Thermal Comfort Parameters (comfortability)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	10	20.0	20.0	20.0
	No	24	48.0	48.0	68.0
	Undefined	16	32.0	32.0	100.0
	Total	50	100.0	100.0	

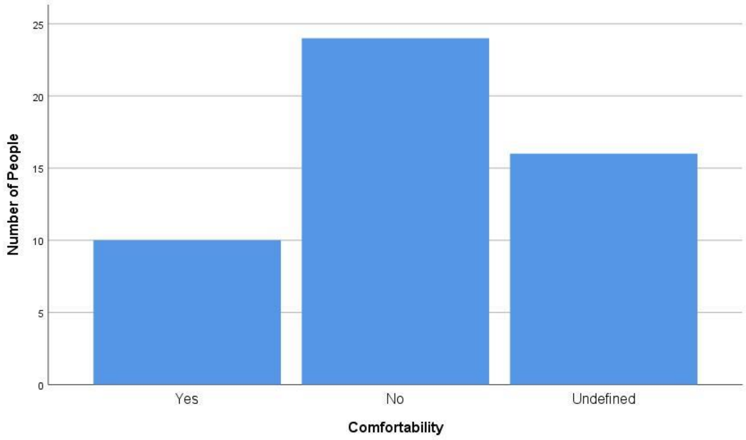


Fig 7: Indoor Thermal Comfort Parameters (comfortability)

Activity Level

Each respondents was asked to choose the option that best described their level of activity when at the mall. 8% said seated, 6% said standing, 50% said light activity, while the remaining 36% said medium activity.

Table 9: Indoor Thermal Comfort Parameters (Activity level)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Seated	4	8.0	8.0	8.0
	Standing	3	6.0	6.0	14.0
	Light Activity	25	50.0	50.0	64.0
	Medium Activity	18	36.0	36.0	100.0
	Total	50	100.0	100.0	

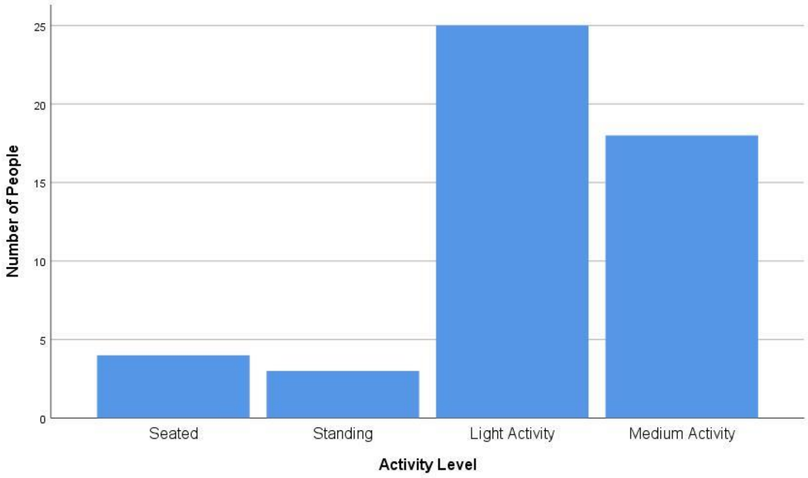


Fig 8: Indoor Thermal Comfort Parameters (Activity level)

Time

From carry out the study it was noticed that 6% of it users visited in the morning, 26% visited in the afternoon, 50% visited towards evening while the remaining 18% visited at night.

Table 10: Indoor Thermal Comfort Parameters (Time)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Morning	3	6.0	6.0	6.0
	Afternoon	13	26.0	26.0	32.0
	Evening	25	50.0	50.0	82.0
	Night	9	18.0	18.0	100.0
	Total	50	100.0	100.0	

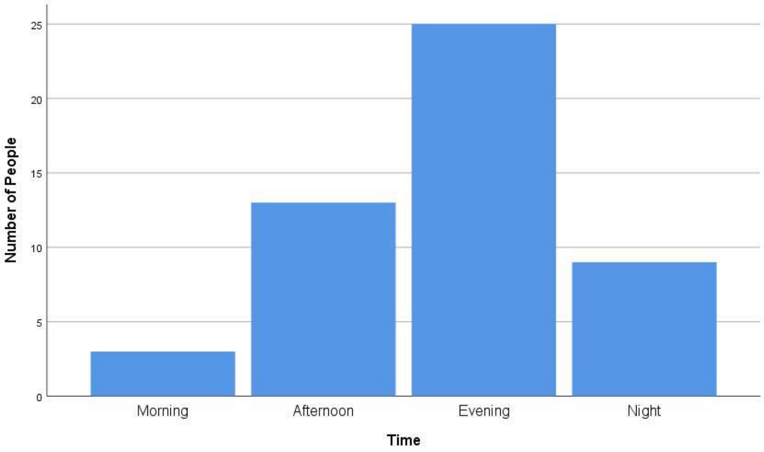


Fig 9: Indoor Thermal Comfort Parameters (Time)

Temperature Satisfaction

When asked how of the temperature satisfaction of the mall, 58% where satisfied, 20% where very satisfied 18% said neutral, 4% where dissatisfied.

Table 11: Indoor Thermal Comfort Parameters (Temperature Satisfaction)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Satisfied	29	58.0	58.0	58.0
	Very Satisfied	10	20.0	20.0	78.0
	Neutral	9	18.0	18.0	96.0
	Dissatisfied	2	4.0	4.0	100.0
	Total	50	100.0	100.0	

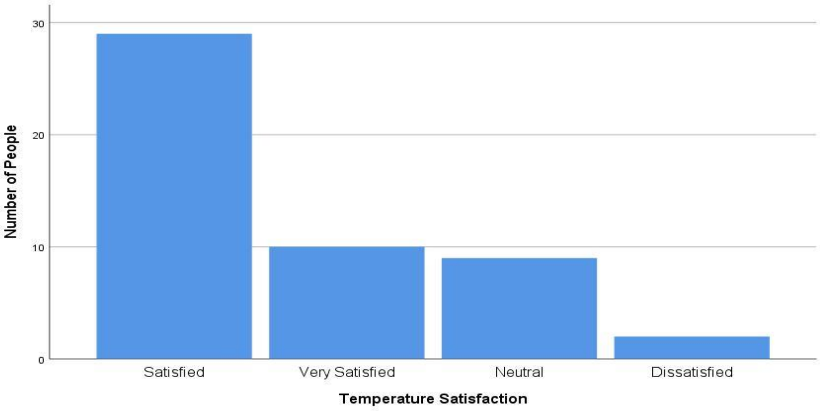


Fig 10: Indoor Thermal Comfort Parameters (Temperature Satisfaction)

Winter

Based on the seasonal analysis of the mall, in winter, 46% said warm, 42% said neutral, while the remaining 12% said cold

Table 12: Indoor Thermal Comfort Parameters (Winter)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Warm	23	46.0	46.0	46.0
	Neutral	21	42.0	42.0	88.0
	Cold	6	12.0	12.0	100.0
	Total	50	100.0	100.0	

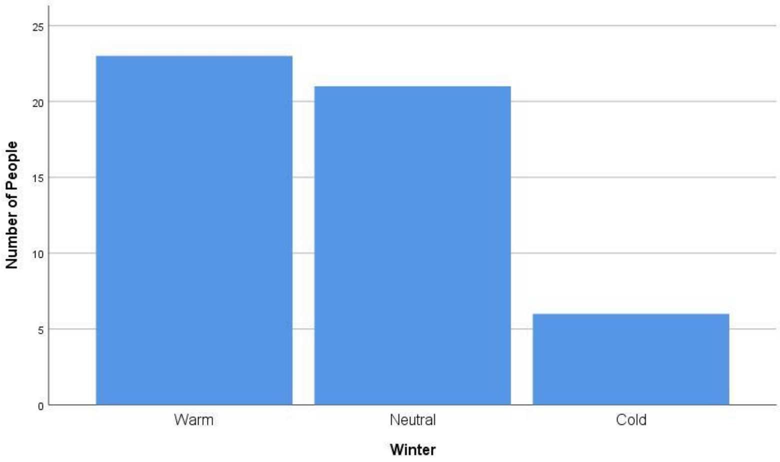


Fig 11: Indoor Thermal Comfort Parameters (Winter)

Spring

in spring, 40% said warm, 54% said neutral, while the remaining 6% said cold

Table 13: Indoor Thermal Comfort Parameters (Spring)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Warm	20	40.0	40.0	40.0
	Neutral	27	54.0	54.0	94.0
	Cold	3	6.0	6.0	100.0
	Total	50	100.0	100.0	

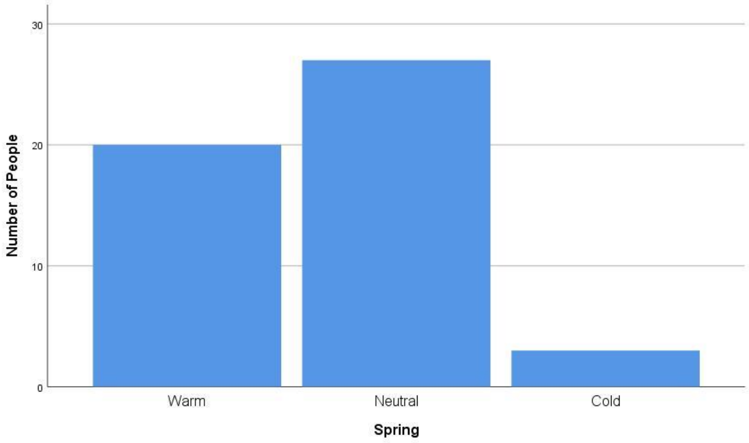


Fig 12: Indoor Thermal Comfort Parameters (Spring)

Summer

In summer, 12% said hot, 10% said warm, 50% said neutral, while the remaining 28% said cold

Table 14: Indoor Thermal Comfort Parameters (Summer)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Hot	6	12.0	12.0	12.0
	Warm	5	10.0	10.0	22.0
	Neutral	25	50.0	50.0	72.0
	Cold	14	28.0	28.0	100.0
	Total	50	100.0	100.0	

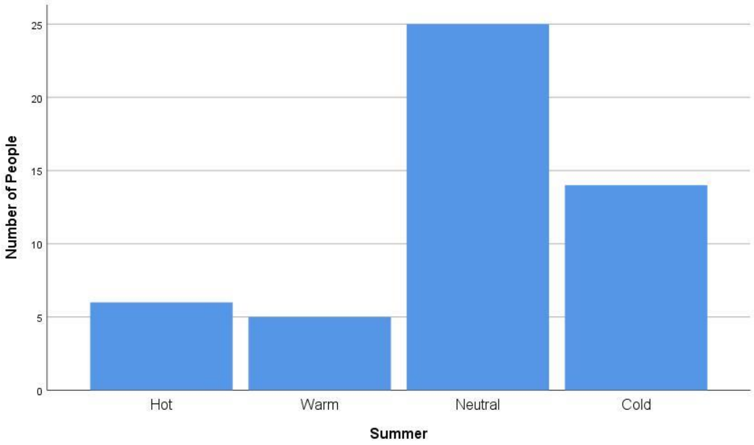


Fig 13: Indoor Thermal Comfort Parameters (Summer)

Fall

In fall, 4% said hot, 14% said warm, 50% said neutral, while the remaining 32% said cold

Table 15: Indoor Thermal Comfort Parameters (Fall)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Hot	2	4.0	4.0	4.0
	Warm	7	14.0	14.0	18.0
	Neutral	25	50.0	50.0	68.0
	Cold	16	32.0	32.0	100.0
	Total	50	100.0	100.0	

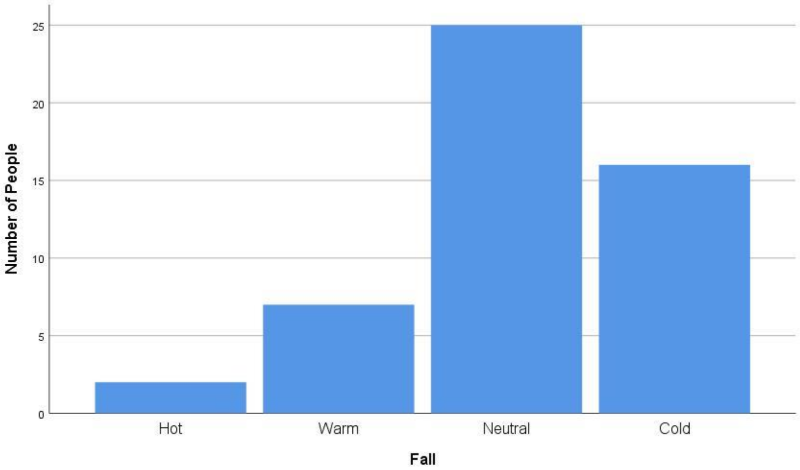


Fig 14: Indoor Thermal Comfort Parameters (Fall)

5. CONCLUSION

This study examined various factors to be considered when putting into thought the indoor thermal comfort of a building. The study also reviewed various literatures on the topic and related topic to gain more knowledge on the assessment of thermal comfort in buildings.

The use of both primary and secondary data for the analysis was employed. Primary data being field survey and distribution of questionnaire and the secondary data that entails the study of journal, articles etc.

The building features and their materials, spaces and the personal data of the respondents where carefully analyzed after the retrieval of the questionnaires and the results examined are as follows:

Based on the thermal comfort and seasonal analysis of the questionnaire, note that:

- 58% of the people agreed with the fact that the indoor air quality of the building is good,
- 50% of the people who visits the mall often engage themselves in light weight activities,
- 58% of the people were satisfied with the indoor temperature of the building,
- 48% of the people feel more comfortable in the space when heaters are on in winter and air condition being used in summer to regulate the indoor temperature.
- In winter, 46% of the people described the indoor thermal comfort of the building as warm, which makes it favourable to be in at that time of the year.
- In fall, 50% of the people described the indoor thermal comfort of the building as neutral,
- In summer, 50% of the people also described the indoor thermal comfort of the building as neutral, meaning it was never too hot or too cold but adequately comfortable for one to visit.
- In spring, 50% of the people described the indoor thermal comfort of the building as neutral,

Other analysis based on the physical appearance/characteristics of the building are as follows;

- The surrounding soft scape is minimal, not adequate and not well positioned enough to shield the building from solar radiation.
- It has an effective headroom of about 3000 to 4500mm for each floor that allows hot air to rise clear of human height.
- Use of insulating materials and HVAC systems within the building to facilitate a thermally comfortable internal environment.

Fig 15: Showing the interior view of Lemar

fig 16: Showingvertical circulation of Lemar

Fig 17: Showing the exterior view of Lemar **Fig 18: Showing the exterior view of Lemar**

Fig 19: Showing the parking lot of Lemar **Fig 20: Showing the entrance view of Lemar**

Based on the analysis gotten from the result and discussions in the project, it can be said that the mall is moderately comfortable in terms of indoor thermal comfort assessment.

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