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*Original Article*

# Thermal Comfort Assessment of Refugee Shelters in Desert Camp Environments: Field-Based Analysis and Implications for Enhancing Resilience in Azraq and Zaatari Camps, Jordan

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***Abstract*** - *This research aims to present important insights into shelter occupants' preferences by reporting and developing equations that provide relationships regarding the thermal comfort parameters of refugees in Jordan by evaluating their current perceptions of indoor shelter environments. To achieve the research objectives, a descriptive-analytical approach is used to evaluate thermal comfort conditions within Zaatari and Azraq camps in Jordan, based on ASHRAE Standard 55. The sample consists of 336 participants, and the data includes physical indicators of the indoor environment, such as temperature and relative humidity, in addition to personal variables and self-assessments of thermal comfort. The results indicate that the thermal performance of the temporary shelters in the two camps fails to provide acceptable thermal comfort conditions according to ASHRAE 55 (Adaptive Comfort Model) standards in both seasons, albeit to varying degrees. The results indicate that the thermal insulation values (clo) of the clothing exceed the ASHRAE reference values in both seasons. The results of the linear and quadratic regression analysis show that the relationship between expected thermal comfort and the thermal insulation value of clothing is not a simple linear one, but rather a non-linear one, reflecting complex adaptive behavior among residents of shelters. Based on the findings, the research recommends improving the thermal envelope of dwellings in addition to incorporating passive solutions, such as shading and improved ventilation levels, into design strategies.*

***Keywords*** - *Desert camp environments, Design performance, Thermal comfort, Refugees, Shelters.*

## 1. Introduction

By the end of 2024, the number of forcibly displaced people worldwide had reached over 122 million due to various reasons, including persecution, conflict, and human rights violations [1]. Natural disasters and desertification are also major contributing factors to displacement caused by climate change. Estimates indicate that by 2050, the number of displaced people will exceed one billion as a result of climate change [2].

Refugees are forced to live in camps, specifically in areas with harsh climates, both in summer and winter. Some refugees may live in shelters with basic amenities made of lightweight materials for many years [3]. Research has confirmed that refugees may live in camps lacking even the most basic elements of natural comfort [2, 4]. Indoor air temperatures can reach 39°C, and indoor surface temperatures can reach 46°C [5]. Unfortunately, prolonged exposure to unsuitable thermal environments can lead to numerous health problems, especially given climate change, which poses a significant challenge and exacerbates the already difficult living conditions for refugees in camps. Moran et al. (2021) indicated that areas with high temperatures may experience further increases, leading to higher mortality rates associated with rising temperatures [4].

Thermal comfort is a crucial housing requirement that is often neglected in the design process, resulting in inadequate thermal comfort [3]. In some cultures and religions, covering the female body is important, which can be considered uncomfortable if shelter design standards are not carefully addressed [4]. Issues related to refugee camps have received considerable attention due to the increasing number of current and anticipated refugee populations [6, 7]. It is important to design shelters that are responsive to various cultural, psychological, and physical factors [8]. Environmental factors, including thermal radiation, relative humidity, and ventilation, must also be considered, as they all significantly impact thermal comfort. In harsh environmental conditions, in particular, attention must be paid to preventing thermal stress and temperature loss [9]. Cold temperatures are a real concern for shelters, as a 2016 UNHCR report indicated that 20 refugees died in a single cold night [2, 10].

Most shelter designs do not adequately address harsh climatic conditions, whether in summer or in winter [11]. Shelter designs lack proper ventilation and thermal masses that would allow them to store heat in winter [3]. In Jordan, in particular, which has historically been one of the countries hosting the largest number of refugees and a major destination for asylum seekers, shelter designs disregard many basic requirements for thermal comfort [2]. In winter, the wind blows sand into the shelters through unprotected openings [2]. In summer, inadequate shading contributes to increased solar radiation penetration, leading to high temperatures. Therefore, it became necessary to provide the minimum requirements for thermal comfort that would enable refugees to live inside the shelter and survive [2, 12]. Based on that, this research represents a response to the thermal comfort requirements within shelters.

The current research aims to report and develop equations for thermal comfort parameters of refugees in Jordan through evaluating the current situation of refugees' shelter perceptions for the indoor environment. This will be achieved through field monitoring employing the comfort model ASHRAE standard 55. To ensure the realistic results of the experiment, the monitoring was made based on two samples in AL_Azraq and Al_Zatari. Zaatari and Azraq camps are among the largest refugee camps in Jordan, and Zaatari is even considered one of the largest refugee camps in the world. It peaked at 120,000–150,000 Syrian refugees a year after its establishment, before its population stabilized at around 80,000 [13]. Therefore, the current research is of great importance as it is applied in camps housing large numbers of refugees who require thermal comfort to live peacefully within these camps.

The analysis of this research will include parameter interaction, correlation, and interpretation based on three main concepts, including the environmental characteristics of surveyed shelters, assessing personal parameters, and subjective assessment of indoor thermal environment. The result may evaluate the exceeded observation for the ASHRAE standard. This study could stimulate further research to apply the findings to further designs for refugee-hosting countries such as Jordan.

This research would also improve a good understanding of refugees' sensations towards thermal comfort, particularly to recognize other factors or interactions between factors that might influence refugees' perceptions of thermal comfort conditions. Furthermore, this research would provide a future framework to improve shelters and produce shelters that are more comfortable based on the current situation of shelters and their occupant's thermal comfort analysis.

Although there is a large body of literature on thermal comfort in refugee shelters, there are still many significant gaps in field-based assessments of long-term refugee housing in extremely warm desert camp locations. Many existing studies have primarily been concerned with measuring physical characteristics, conducting simulations to evaluate performance, or making general recommendations for shelter designs. Fewer studies have used measured indoor environmental variables, occupants' subjective thermal responses, clothing insulation behavior, inferential statistics, and predictive modeling together as part of the overall analysis. This study addresses this gap by determining thermal comfort conditions in Azraq and Zaatari refugee camps through field-based environmental measurements and occupant-related thermal comfort measures. It also develops statistical and predictive models that relate indoor environmental factors, occupant personal adaptation behaviors, and the likelihood that an occupant will be dissatisfied with the temperature of their environment. The novelty of this study lies in its simultaneous assessment of ASHRAE 55 applicability, seasonal thermal performance, clothing-related adaptive behavior, regression-based prediction models, and neural network-based variable importance in two major desert refugee campsites in Jordan.

## 2. Literature Review

### *2.1. Temporary Shelters and Thermal Comfort*

During the initial stages of displacement, it is difficult to estimate the approximate duration of stay in camps. These stays are often defined as short-term, leading to adaptation of living conditions to meet basic human needs for limited periods, especially given the constraints and limited resources available [2]. Therefore, refugee camps were designed to enable refugees to find a place to stay, so to speak. A shelter can be defined as a safe environment that provides adequate protection for a family from weather fluctuations (high or low temperatures). A shelter also refers to a living space that ensures thermal comfort for the residents and provides suitable fresh air for refugees [14]. Olgyay (2015, 18) argued that the quality of a shelter is necessarily determined by the thermal environment and the level of thermal comfort, enabling them to live in hot or cold regions [15]. Olgyay (2015, 21) defined thermal comfort as the range within which a shelter occupant is expected to expend the least amount of energy to cope with the surrounding environment and ambient temperatures [15].

### *2.2. Thermal Comfort under Shelter Constraints and Related Imperatives*

Rondinel-Oviedo et al. (2019) argued that sudden refugee influxes necessitate immediate intervention to provide adequate shelter, given the limited material and financial resources available to refugees [16]. Maynard et al. (2017) emphasized that political constraints prevent states from authorizing the construction of permanent refugee housing, leading to emergency responses to the pressing needs of refugees, which often do not provide optimal thermal conditions [5, 17]. In some cases, certain health complications can lead to death. Within the refugee environment, there are numerous constraints that limit the possibility of improving indoor temperature and thermal comfort standards, including cost, lack of available materials, and limited local resources. In this regard, Domínguez-Amarillo et al. (2021) argued that the presence of climate control in shelter design does not mean neglecting thermal comfort standards in extremely hot or extremely cold environments [2].

### *2.3. Thermal Comfort Methodological Approaches in Thermal Comfort Studies*

Albadra et al. (2018, 120) argued that neglecting thermal comfort leads to refugee discontent and various serious illnesses, which can sometimes be fatal. Several previous studies have demonstrated the impact of indoor temperatures on morbidity rates among refugees [4, 5, 16]. Consequently, the approach of designing appropriate solutions is prioritized over optimal ones. Domínguez-Amarillo et al. (2021) added that it is crucial to consider harsh climatic conditions when designing shelters to ensure a healthy and safe life for refugees. In this regard, the UNHCR/REACH (2016) report highlighted an information gap in refugee camps in Jordan concerning thermal comfort. The report called for design measures to ensure thermal comfort for refugees, reduce temperatures in hot environments, and maintain internal temperature in cold environments [2, 10]. In this regard, Rondinel-Oviedo et al. (2019) emphasized the potential for improving thermal conditions in shelters and considering them, particularly during the initial design phases. Therefore, improving the shelters where refugees live becomes the only solution to enable them to remain in refugee camps for longer periods [16].

Ying Yu et al. (2016, 175) noted that most studies investigating the thermal performance of refugee camps have focused primarily on cold climates, while Albadra et al. (2017, 461) and Saleh & Gadi (2016) indicated that studies conducted in hot climates specifically surveyed residents of these areas [18, 19, 20] . In hot environments, Moran et al. (2021) suggested that roof insulation and night time ventilation are interventions that can reduce temperatures and thus improve thermal comfort within shelters [4]. However, Moran et al. (2021, 32) emphasized that these interventions have not been subjected to realistic, model-based experimental studies to verify their effectiveness [4]. Moreover, Nguyen and Reiter (2014) highlighted the importance of using thermal simulations in the design of new shelters to improve thermal comfort. Ma'arof et al. (2019) emphasized the importance of using air catchers to reduce indoor temperatures in summer [21]. Lai Lee (2019, 11) supported the use of air catchers and confirmed their effectiveness in providing thermal comfort in hot environments [22].

Furthermore, Domínguez-Amarillo et al. (2021) clarified that several methods can be used to improve thermal comfort, including thermal modelling and the application of architectural capabilities to design high-performance shelters using minimal resources [2]. Furthermore, insulating materials can also be used in the covering, and a moisture-permeable polyester lining can be used to reduce heating requirements and maintain internal temperatures [2]. Domínguez-Amarillo et al. (2021) pointed out that at the end of 2019, the world witnessed the largest wave of displacement as a result of the prevailing political conditions at that time [2]. Despite the high number of refugees, shelters lacked even the most basic suitable thermal conditions, especially considering that many refugee camps were located in harsh and difficult climatic conditions. The available shelters were unable to maintain temperatures within acceptable human tolerance levels. In this regard, Domínguez-Amarillo et al. (2021) assessed the climatic conditions available in shelters and evaluated the thermal performance in three regions that host the most refugees: Jordan, Afghanistan, and South Sudan. Computer simulations were used to compare the thermal performance of refugee camps in these three regions. The results showed that the UNHCR-type shelter ‘A’ was the most suitable in terms of humidity levels, while the ‘C-type’ shelter was the most suitable in terms of thermal stability [2].

Asfour (2019) relied on thermal modeling of building physics to improve thermal comfort in cold and hot climates [23]. A study by Albadra et al. (2018) evaluated thermal comfort in summer and winter within the Zaatari and Azraq refugee camps in Jordan [5]. The study concluded that these camps offer suitable thermal ranges for refugees that can serve as models for the design of various refugee camps.

Moran et al. (2021) investigated the improvement of thermal comfort within refugee camps based on specific variables [4]. The results of thermal modelling were compared with field results. The findings confirmed that the Prototyping modelling yielded better results than the thermal modelling, improving temperature by approximately 6°C, particularly as it reflects the experience of optimizing thermal conditions that cannot be determined using thermal modelling.

### *2.4. Thermal Comfort Assessment in Azraq and Zaatari Refugee Camps*

Alshawawreh (2021) and Scott-Smith and Breeze (2020, 21) argued that although numerous studies have examined the characteristics of refugee camps, they have not adequately addressed the fundamental objectives of providing shelter [24, 25]. While thermal comfort is a key criterion in shelter design, it is not considered a primary objective during the design process. Furthermore, although numerous strategies and interventions can be implemented to ensure adequate thermal comfort, they are not widely adopted in shelter design. Therefore, this study assesses the impact of a range of measures on thermal comfort levels in two refugee camps that host large numbers of refugees in the Arab world and globally, which are Azraq and Zaatari camps, both established specifically in response to the Syrian crisis. Azraq camp was established in 2014 with a capacity of up to 100,000 people [26]. By 2019, it had received approximately 36,000 refugees [10, 26]. According to the REACH report (2015), 90% of shelter occupants in the Azraq area reported poor thermal comfort levels, expressing their complete dissatisfaction with the high temperatures, particularly due to the hot and dry climate of the Azraq region [27]. Zaatari camp, located south of the Syrian-Jordanian border, was built in a hot, high-altitude desert environment. It is considered the largest Syrian refugee camp in the world [28]. This camp faces numerous environmental challenges due to its location in a hot, desert environment [28]. Therefore, the quality of shelter design is a major factor contributing to the challenges faced by refugees in the Zaatari camp.

### *2.5. Comparative Literature Synthesis and Emerging Shelter-Design Approaches*

In contrast to previous studies about shelters for refugees in arid and desert environments, which mainly focused on measuring and understanding thermal comfort using solely physical measurement techniques, researchers have recently begun to explore the possibility of combining social surveys with thermal comfort questionnaires and physical measurements in order to better understand how occupants perceive their environment and adapt their behavior as a result. Albadra et al. [19], used such an approach to analyze the thermal comfort of Syrian refugee camps in Jordan; similarly, Moran et al. [4] showed that passive and low-cost shelter interventions (e.g., roof insulation, shading, increased ventilation, and thermal mass) could lead to improvements in indoor thermal conditions in desert refugee shelters. Recently, new studies on designing shelters have highlighted the need for incremental, thermally optimized and low-carbon shelter solutions that can address both the resources available and habitability issues in extreme climates. Studies in addition to those conducted in Jordan regarding emergency and temporary shelters in other arid or climate-stressed regions found that passive cooling, high reflectance of envelope materials, phase-change materials, increased ventilation pathways and shaded transitional areas can reduce the risk of overheating and improve indoor environmental quality. The results of these studies are applicable to refugee camps in the Middle East, North Africa, South Asia, etc. where lightweight shelters receive high levels of solar radiation, undergo large daily temperature variations, and do not provide adequate mechanical cooling options. Further, environmental psychologists and humanitarian engineers propose that a comprehensive evaluation of shelter performance is necessary and should include factors beyond thermal indices (i.e., residents' sense of control, residents' privacy, residents' cultural practices, residents' clothing behaviors and participation in shelter adaptations). Studies on participatory design methods applied within refugee camps show that residents who are involved in assessing and improving shelters may identify needs that were not assessed by standard engineering models. Therefore, this current study provides additional evidence to the growing body of literature linking objective measures of the indoor environment with subjective perceptions of thermal comfort and adaptive clothing behavior in two large refugee camps situated in a hot desert climate.

## 3. Materials and Methods

To achieve the research objectives, a descriptive-analytical approach will be used. This approach is considered the most suitable for evaluating thermal comfort conditions within Zaatari and Azraq camps in Jordan, based on ASHRAE Standard 55. The study will be conducted through field measurements of indoor environmental variables, along with self-assessment questionnaires to measure residents' thermal comfort.

The sample consisted of 336 participants, and the data included physical indicators of the indoor environment, such as temperature and relative humidity, in addition to personal variables and self-assessments of thermal comfort.

This research utilized secondary field data that has been placed into the University of Bath Research Data Archive as part of a publicly accessible data source. The data contained in the dataset consists of thermal comfort survey information and environmental data taken at Azraq and Zaatari refugee camps over both summer and winter periods. The total number of shelter occupants involved in this study is 336 (enough to support comparative and regression based analyses of the thermal comfort variables among the shelters of the two camps and seasons). As this study relies upon anonymized secondary data, there was no personal contact with vulnerable individuals, nor any type of recruitment or intervention performed directly by the authors of this document.

Because the analysis was restricted to valid measurements, which consisted of all possible thermal comfort and environmental measures, representativeness and the possibility of bias were addressed. The two camps were chosen as they are the largest long term refugee settlement areas in Jordan and are both in desert climates. Therefore, while seasonal heating and cold temperatures can cause discomfort, overheating issues are major concerns in these climates. While the sample provided valuable field data supporting this research, it should be noted that the results may need to be interpreted within the limitations associated with secondary data analysis, camp specific types of shelters and the sampling strategies employed in the original study.

Air temperature, globe temperature, relative humidity, wet-bulb temperature, air velocity, operative temperature, metabolic rate, clothing insulation, thermal sensation vote, thermal preference vote, predicted mean vote and predicted percentage dissatisfied are some examples of the field data that were analyzed using ASHRAE Standard 55 and compared against each other to identify differences between summer and winter conditions. It should also be noted that since sensor calibration, measurement location and frequency of data collection followed the same protocol used by the creators of the original dataset, due to utilizing secondary data analysis, authors had access to very little technical metadata regarding how the original data was collected.

Because this study used secondary field data obtained from a publicly available dataset and the protocol for sensor calibration procedures, sensor placement and measurement intervals was based on that of the original investigators; technical metadata within the archived dataset did not provide enough information to recreate the details of these calibration records or deployment diagrams for each sensor. Although the standardization of the measurement protocol provided consistent information regarding the collection of all environmental and thermal comfort data within each of the two refugee camps during different seasons and as such provides an adequate basis for comparative analysis.

### *3.1. Data Analysis*

Statistical analyses were performed using IBM SPSS Statistics (version 25). Statistical processing included applying the independent samples t-test (two-way) to compare thermal comfort indices between the two camps, and two-way ANOVA to examine the interaction effect of gender and season on thermal perception.

Stepwise multiple regression was used to identify the most influential variables and develop multiple linear regression models and equations. Additionally, simple linear regression was applied to analyse the relationship between the Expected Dissatisfaction Index (Predicted Percentage Dissatisfied (PPD)) and the influential variables, and Pearson's correlation coefficient was used to determine the strength of the relationships between the variables. The analysis was organised along three main axes: the environmental characteristics of the surveyed shelters, the users' personal parameters, and the subjective assessment of the indoor thermal environment. The aim was to develop explanatory models and statistical equations that reflect the reality of thermal comfort in refugee housing in Jordan.

Beyond using descriptive statistical techniques, we also applied inferential methods to assess potential differences and associations that may exist in thermal comfort variables.

We performed independent samples *t*-tests for comparison of PPD across Azraq camp and Zaatari camp; a two-way ANOVA was employed to assess how gender and season impact upon thermal sensation; Pearson correlations were utilized to evaluate the direction and magnitude of association between each subjectively perceived (i.e., rated) and physically measured thermal comfort variable; and finally, linear regression models were developed to predict relationship between dependent and independent variables. In terms of seasonal variation, we evaluated both summer and winter datasets independently as well as included "season" as one of the independent variables within the ANOVA model.

Finally, we analyzed our findings against those found in the literature based upon ASHRAE 55 guidelines and, when applicable, Fanger's PMV/PPD thermal comfort prediction method.

**Table 1. Means and Standard Deviations of fieldwork physical measurements for summer**

| | TSV- scale | TPV-scale | TA (ºC) | TG (ºC) | RH | WBT (ºC) | AV (m/s) | TO (ºC) | Met | Clo.v | PMV | PPD (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Al_Azraq** | | | | | | | | | | | | |
| **Mean** | 1.6 | -1.4 | 32.3 | 33.2 | 24.6 | 22.6 | 0.1 | 32.9 | 1.0 | 0.7 | 2.2 | 78.0 |
| **N** | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 63.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 |
| **SD** | 1.2 | 0.7 | 2.4 | 2.6 | 5.7 | 1.5 | 0.2 | 2.4 | 0.0 | 0.2 | 0.7 | 25.7 |
| **Min.** | 0.0 | -2.0 | 26.8 | 28.2 | 12.0 | 19.6 | 0.0 | 28.2 | 1.0 | 0.4 | 0.4 | 7.6 |
| **Max.** | 3.0 | 0.0 | 36.4 | 38.2 | 39.0 | 24.9 | 0.6 | 36.8 | 1.2 | 1.0 | 3.7 | 100 |
| **Al_Zaatri** | | | | | | | | | | | | |
| **Mean** | 1.1 | -1.2 | 30.4 | 31.4 | 39.6 | 23.3 | 0.2 | 30.9 | 1.0 | 0.7 | -0.5 | 63.9 |
| **N** | 72.0 | 72.0 | 72.0 | 72.0 | 72.0 | 71.0 | 72.0 | 72.0 | 72.0 | 72.0 | 72.0 | 72.0 |
| **SD** | 1.2 | 0.7 | 2.1 | 2.3 | 9.2 | 1.3 | 0.3 | 2.3 | 0.1 | 0.2 | 0.8 | 28.9 |
| **Min.** | -1.0 | -2.0 | 25.7 | 25.4 | 12.0 | 21.2 | 0.0 | 25.8 | 1.0 | 0.4 | -1.9 | 5.1 |
| **Max.** | 3.0 | 0.0 | 33.1 | 36.4 | 57.0 | 26.2 | 1.2 | 35.4 | 2.0 | 1.0 | 3.6 | 99.5 |
| **Total** | | | | | | | | | | | | |
| **Mean** | 1.3 | -1.3 | 31.4 | 32.3 | 31.6 | 23.0 | 0.2 | 32.0 | 1.0 | 0.7 | 1.0 | 71.5 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **N** | 155 | 155 | 155 | 155 | 155 | 134 | 155 | 155 | 155 | 155. | 155.0 | 155. |
| **SD** | 1.2 | 0.7 | 2.4 | 2.6 | 10.6 | 1.4 | 0.2 | 2.6 | 0.1 | 0.2 | 1.5 | 28.0 |
| **Min.** | -1.0 | -2.0 | 25.7 | 25.4 | 12.0 | 19.6 | 0.0 | 25.8 | 1.0 | 0.4 | -1.9 | 5.1 |
| **Max.** | 3.0 | 0.0 | 36.4 | 38.2 | 57.0 | 26.2 | 1.2 | 36.8 | 2.0 | 1.0 | 3.7 | 100 |

**Table 2. Means and Standard Deviations of fieldwork physical measurements for winter**

| | **TSV-scale** | **TPV-scale** | **TA (°C)** | **TG (°C)** | **RH** | **WBT (°C)** | **AV (m/s)** | **TO (°C)** | **Met** | **Clo.v** | **PMV** | **PPD (%)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Al_Azraqz** | | | | | | | | | | | | |
| Mean | -0.3 | 0.6 | 18.9 | 19.3 | 37.1 | 13.8 | 0.0 | 19.3 | 1.0 | 1.4 | -0.8 | 17.8 |
| N | 89.0 | 89.0 | 89.0 | 89.0 | 89.0 | 89.0 | 89.0 | 89.0 | 89.0 | 89.0 | 89.0 | 89.0 |
| SD | 0.8 | 0.7 | 1.4 | 2.1 | 7.4 | 1.4 | 0.0 | 2.1 | 0.0 | 0.3 | 0.9 | 17.2 |
| Min. | -3.0 | -1.0 | 15.8 | 13.9 | 24.0 | 10.4 | 0.0 | 13.9 | 1.0 | 0.7 | -3.9 | 5.0 |
| Max. | 2.0 | 2.0 | 21.5 | 23.1 | 53.0 | 16.7 | 0.0 | 23.1 | 1.2 | 2.1 | 2.3 | 73.8 |
| **Al_Zaatri** | | | | | | | | | | | | |
| Mean | -0.7 | 0.7 | 18.2 | 18.0 | 38.8 | 12.7 | 0.1 | 18.1 | 1.0 | 1.3 | 1.3 | 28.6 |
| N | 87.0 | 85.0 | 87.0 | 87.0 | 87.0 | 87.0 | 87.0 | 87.0 | 87.0 | 87.0 | 87.0 | 87.0 |
| SD | 1.1 | 0.7 | 2.3 | 2.7 | 6.5 | 1.8 | 0.2 | 2.3 | 0.2 | 0.4 | 1.2 | 25.4 |
| Min. | -3.0 | -1.0 | 10.4 | 12.0 | 28.0 | 7.8 | 0.0 | 11.7 | 1.0 | 0.5 | -1.9 | 5.0 |
| Max. | 2.0 | 2.0 | 22.2 | 23.6 | 53.0 | 16.2 | 1.0 | 23.2 | 1.7 | 2.0 | 3.1 | 100.0 |
| **Total** | | | | | | | | | | | | |
| Mean | -0.5 | 0.6 | 18.5 | 18.6 | 37.9 | 13.2 | 0.0 | 18.7 | 1.0 | 1.4 | 0.2 | 23.2 |
| N | 176.0 | 174. | 176. | 176. | 176. | 176. | 176 | 176 | 176 | 176 | 176 | 176 |
| SD | 1.0 | 0.7 | 1.9 | 2.5 | 7.0 | 1.7 | 0.1 | 2.3 | 0.1 | 0.3 | 1.5 | 22.2 |
| Min. | -3.0 | -1.0 | 10.4 | 12.0 | 24.0 | 7.8 | 0.0 | 11.7 | 1.0 | 0.5 | -3.9 | 5.0 |
| Max. | 2.0 | 2.0 | 22.2 | 23.6 | 53.0 | 16.7 | 1.0 | 23.2 | 1.7 | 2.1 | 3.1 | 100.0 |

Where: TSV = Thermal Sensation Vote, TPV = Thermal Preference Vote, TA = Air Temperature (°C), TG = Globe Temperature (°C), RH = Relative Humidity (%), WBT = Wet Bulb Temperature (°C), AV = Air Velocity, TO = Operative Temperature, Met = Metabolic Rate (met), Clo.v = Clothing Value (clo), PMV = Predicted Mean Vote, PPD = Predicted Percentage Dissatisfied.

### *3.2. Assessing Environmental Characteristics of Surveyed Shelters*

Assessing environmental characteristics will be based on two major contrasts. Firstly, the environmental characteristics of the surveyed shelters will be based on descriptive summaries for summer and winter. Second, a comparison and correlation between environmental characteristics for summer and winter, depending on box plots showing the percentage, the mode, median, standard deviation, and normality for all of the measures, will then be provided.

#### *3.2.1. Descriptive Summary of Environmental characteristics for Summer and Winter*

Table 1 presents a descriptive statistical summary of indoor environmental parameters in shelters during summer, whereas Table 2 provides a similar summary for winter, encompassing mean, standard deviation, and range of total averages by camp location for the surveyed shelters.Based on the findings in Tables 1 and 2, the mean daily outdoor temperature for each survey day (TA) and the mean daily co-operative temperature (TO) were determined. However, there were no evident variations in the outdoor temperatures among all shelters. The mean daily outdoor temperatures during summer ranged from 25.7 to 36.4°C, with an overall mean of 31.4°C. Additionally, as shown in Table 1 and Table 2, the indoor Operative Temperatures (TO) for winter ranged from 10.4 – 22.2°C, with an average of 18.5°C. As seen in Table 1 and Table 2, the indoor operative temperatures during summer ranged from 25.7 – 36.4°C, with an average of 32.3°C.

According to Tables 1 and 2, the indoor Relative Humidity (RH) during summer ranged from 12 % – 57 %, with a mean of 31.6 %. In contrast, the RH values for winter ranged from 24 % – 53 %, with a mean of 37.9 %. The highest mean RH was recorded by Al Azraq at 53.0 % and it also had a standard deviation of 7.4 in the winter months, whereas the maximum RH recorded by Al Zatari in the summer was 57%.

#### *3.2.2. Comparison and Correlation between Environmental Characteristics for Summer and Winter*

Figure 1 presents the relationship between indoor operative temperatures and outdoor air temperatures during summer and winter within the caravans in both camps. Each data point represents an individual survey conducted in a single shelter.

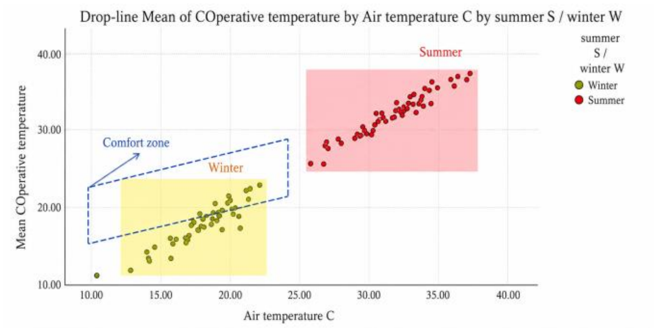


**Fig. 1 Indoor operative and outdoor temperatures for summer and winter in the surveyed shelters**

*Source: Authors*

The anticipated ASHRAE 55 adaptive comfort zone is represented by the blue square superimposed on the measured data in Figure 1. During winter trips to both camps, only 10% of the calculated operating temperatures fall inside the comfort zone; the remaining values are outside of it. The correlation between seasonal variation and outdoor air temperature shows that the shelters inside operating temperatures regularly surpass the bounds of thermal comfort. Figure 1, which shows that interior conditions consistently remain above the adaptive comfort zone across the majority of measurements, effectively illustrates this trend. The estimated operating temperatures for the Al Azraq and Zaatari camps throughout the winter fall outside the ASHRAE 55 adaptable comfort zone, which corresponds to mean outdoor temperatures above 24°C, as further shown in Tables 1 and 2. All operational temperature values are higher than the upper bounds of the thermal comfort range during the summer.

### *3.3. Assessing Personal Parameters*

Assessing Personal Parameters relies on a Cultural and environmental effect on standard bands of total clothing value. The method used for analysing results was One-way ANOVA for comparing the effect of total clothing value and predicted percentage of dissatisfaction. Then it was followed by regression analysis for comparing the estimated range of ASHRAE Clo.v and the negative relationship with PPD.

#### *3.3.1. Culture and Environmental Effect on Protector Bands of Total Clothing Value*

The clo values for the occupants in the sample (Abaya, Thoub) ranged from 0.4 to 1 in summer. It was far from the clothing insulation estimates assumed by ASHRAE 0.5 for summer. The interpretation for these high values for clothes is related to a religious and cultural aspect that forces occupants to be fully covered inside the caravans.

However, in winter, the clo values ranged from 0.5 to 2.1. It is far from the clothing insulation estimates assumed by ASHRAE 1.0 winter. The interpretation for these high values for clothes related to wearing jackets also includes the cultural aspect to be fully covered inside the caravans by the occupants to feel more comfortable, as seen in Figure 2.


**Fig. 2 Occupants (refugees) dress across all shelters**

*Source: Authors*

According to the survey data, the overall mean clothing insulation was 0.7 clo in summer and approximately 1.4 clo in winter. The winter mean was 1.4 clo in Al-Azraq and 1.3 clo in Al-Zaatari. The jacket-related clothing range illustrated in Figure 2 was approximately 1.5–1.8 clo, whereas the observed total winter clothing-insulation values ranged from 0.5 to 2.1 clo. Thus, values approaching 2.1 clo represent the total clothing ensemble rather than the jacket alone. These findings indicate that clothing adaptation reflects both environmental conditions and shared cultural and behavioral practices among shelter occupants.

#### *3.3.2. One-way ANOVA Comparing the Effect of CLO.v and PPD*

A One-way ANOVA was conducted to compare the effect of total clothing value on the predicted percentage of dissatisfaction, see Tables 3 and 4.

**Table 3. One-Way Analyses of Variance**

| Model | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Regression** | 30.778 | 2 | 15.389 | 160 | 0 |
| **Residual** | 32.08 | 333 | 0.096 | | |
| **Total** | 62.858 | 335 | | | |

The analysis of variance showed that the effect of total clothing value on predicted percentage of dissatisfaction was significant, $F(2,333) = 160$, $p = .000$, see Table 4.

**Table 4. One-way ANOVA model summary**

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| 0.7 | 0.49 | 0.487 | 0.31 |
| The independent variable is the predicted percentage dissatisfied. | | | |

#### *3.3.3. Regression Analysis Comparing the Estimated Range Of ASHRAE Clo.v and the Negative Relationship with PPD*

A simple linear regression was calculated to predict a percentage of dissatisfaction based on total clothing value.

Investigating the degree to which total clothing value predicts the percentage of dissatisfaction as an effect on thermal comfort for occupants.

The Predicted Mean Vote (PMV) and a Predicted Percentage of Dissatisfied (PPD) are the most widely used thermal comfort indices. A significant regression equation was found ($F(2,333) = 160$, $p < 0.05$), with an $R^2$ of 0.490, see Tables 3 and 4. The Unstandardised Coefficients are illustrated in Table 5. Shelter occupants predicted dissatisfaction is equal to 1.556 - 0.017 (Total clothing value) percentage when clothing value is measured in clo.v. Shelter occupant's dissatisfaction percentage increased by 1.556 for each one percentage of the predicted percentage of satisfaction.

Linear Model:

$$Y = 1.500 - 0.009X \qquad (1)$$

X Predicted percentage dissatisfied.
Y Total clothing value.

Quadratic Model:

$$Y = 1.556 - 0.017X + 8.08 \times 10^{-5}X^2 \qquad (2)$$

Simple linear and quadratic regression models were fitted with total clothing insulation as the dependent variable and Predicted Percentage of Dissatisfied (PPD) as the predictor.

In the following equations, Y represents total clothing insulation in clo, and X represents PPD (%).

**Table 5. Coefficients for the quadratic regression model predicting total clothing insulation from PPD**

| Coefficients | | | | | |
|---|---|---|---|---|---|
| | **Unstandardized Coefficients** | | **Standardized Coefficients** | | |
| | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| **Predicted Percentage Dissatisfied** | -.017- | 0.002 | -1.342- | -7.423- | p<.001 |
| **Predicted Percentage Dissatisfied ** 2** | 8.08E-05 | 0 | 0.673 | 3.724 | p<.001 |
| (Constant) | 1.556 | 0.04 | | 38.828 | p<.001 |

**Note:** B represents the unstandardized coefficient expressed in the original measurement units and is therefore used to construct Equation 2. Beta represents the standardized coefficient and is reported to compare the relative contributions of the predictors. The standardized coefficient for the linear PPD term ($\beta = -1.342$) exceeds $-1$ because the inclusion of both PPD and $PPD^2$ produces substantial multicollinearity between the linear and quadratic terms. It should therefore be interpreted jointly with the quadratic term ($\beta = 0.673$), rather than as an independent bivariate effect.

The relationship between the parameters can be concluded from Table 5. As seen in the quadratic regression Equation 2, the predicted percentage dissatisfied as increased for 1%, the clo value decreases by about .017.

This indicates that refugees tend to feel more comfortable when wearing fewer clothes. The linear regression results in Equation 1 show that a 1% increase in the predicted percentage of dissatisfied occupants is associated with a decrease of approximately 0.009 clo in clothing insulation.

Figure 3 also identifies the ASHRAE 55 reference clothing-insulation values of 0.5 clo for summer and 1.0 clo for winter, represented by the purple dashed lines.

These are reference values rather than an estimated regression range. The observed clothing-insulation values ranged from 0.5 to 2.1 clo and frequently exceeded the relevant seasonal reference values.

Figure 3 shows both the negative relationship of a simple linear regression model and a quadratic linear regression model to indicate the significant impact of the predicted percentage of satisfaction on total clothing value. The purple dashed lines represent the ASHRAE 55 seasonal reference clothing-insulation values of 0.5 clo for summer and 1.0 clo for winter. The sample is too small to conclude anything serious. N=336, the results suggest that a curvilinear model fits the surveyed data much better than the linear one. Scientists routinely overlook curvilinear models.

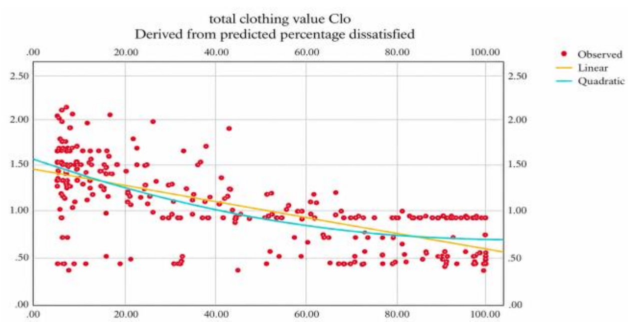


**Fig. 3 The relationship between a simple linear regression model and a quadratic linear regression model**

*Source: Authors*

### *3.4. Subjective Assessment of Indoor Thermal Environment*

The Subjective assessment of the indoor thermal environment for this paper started with analysing thermal sensation votes for occupants in Al_Azraq and Al_Zatari and comparing them.

### *3.4.1. Thermal Sensation Vote for Refugees*

Table 6 illustrates the measured values for the thermal satisfaction vote. Providing a good understanding of the measured thermal environment parameters.

It also indicates that 49% of the sample described their thermal perception as neutral, indicating that approximately half of the population does not experience significant thermal discomfort. Conversely, 44% of the sample reported an uncomfortable thermal perception towards warmth (from slightly warm to hot), while 19% reported thermal discomfort towards cold (from slightly cool to very cold).

This result reflects a clear thermal polarisation. Despite the high percentage of neutral perceptions, a significant proportion of the population experiences thermal polarization, particularly towards warmth. This aligns with operating temperatures exceeding the comfort range and the poor thermal envelope efficiency of the dwellings.

**Table 6. The number of occupants and the percentage of the sample responses of TSV describing what they feel**

| Thermal sensation vote | Score | N | Percentage |
|---|---|---|---|
| Neutral | 0 | 164 | 49% |
| Slightly warm | 1 | 36 | 11% |
| Warm | 2 | 33 | 10% |
| Hot | 3 | 43 | 13% |
| Slightly cool | -1 | 32 | 10% |
| Cool | -2 | 19 | 6% |
| Cold | -3 | 9 | 3% |
| | | 336 | 100% |

### *3.4.2. Thermal Sensation Vote for Shelter Occupants in Al_Azraq*

Figure 4 displays the frequency distributions of Thermal Sensation Votes (TSV) of occupants of Al_Zatari and Al_Azraq buildings for each case of both seasons. The TSVs were mainly concentrated around the middle three categories of the thermal sensation scales: "slightly cool," "neutral," and "slightly warm."-1, 0, +1.

The overall mean thermal sensation scale value for Total occupants is -0.5 in winter and +1.3 in summer. For Al_Azraq building, the mean thermal sensation scale values are -0.3 in winter and +1.6 in summer. The mean thermal sensation scale values for Al_Zatari building are -0.7 in winter and +1.1 in summer.

The quoted uncertainties correspond to one standard deviation. A total of 49% of shelter occupants in both camps reported a neutral thermal sensation across both seasons. The remaining responses were distributed as follows: 11% slightly warm, 10% warm, and 13% hot, compared to 10% slightly cool, 6% cool, and 3% cold.

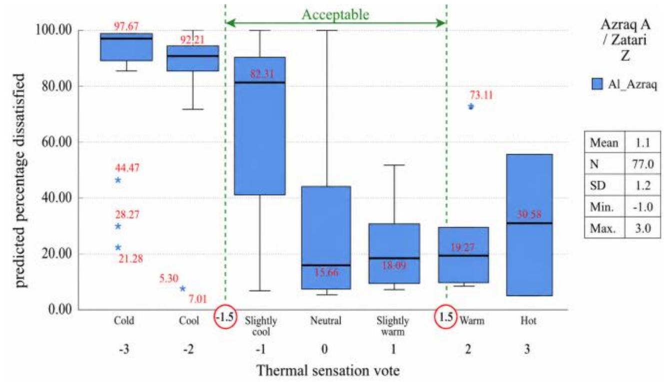


**Fig. 4 Clustered box plot of predicted percentage dissatisfied by Thermal Sensation Vote by Al_Azraq**

*Source: Authors*

### *3.4.3. Thermal Sensation Vote for Shelter Occupants in Al_Azraq*

As illustrated in Figure 5, the middle three categories (i.e., -1, 0 and +1), on a seven-point thermal sensation scale, as per the Predicted Percentage Dissatisfied (PPD) Thermal Comfort Index by Fanger (1970), indicate that individuals will generally find an appropriate level of satisfaction with respect to their thermal comfort conditions. On the other hand, the two most extreme categories of the thermal sensation scale, which represent the extremes of the cold side (-3, -2) and the warm side (+3, +2), are representative of dissatisfaction.

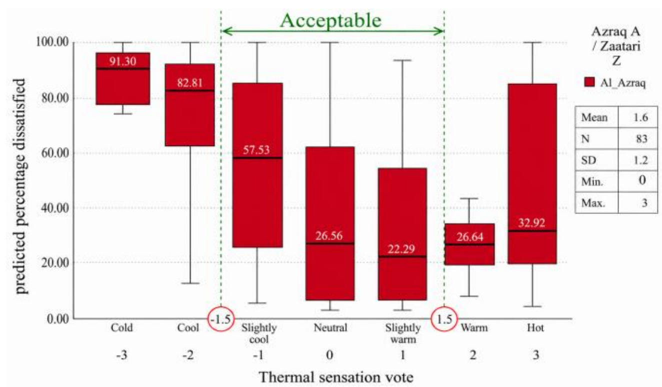


**Fig. 5 Clustered boxplot of predicted percentage dissatisfied by Thermal Sensation Vote by AL_Zaatri**

*Source: Authors*

ASHRAE states that an acceptable level for thermal comfort is at least 80%, but only about 69% of male and female refugees occupied by all the surveyed shelters experienced thermal sensation ratings that would be classified as "middle" on the Thermal Sensation Scale (Table 6), while approximately 31% failed to achieve the required 80% thermal acceptability rate established by ASHRAE. The percentage of occupants who did not feel comfortable due to temperature in Al-Azraq Camp was higher than in Al-Zaatari Camp because of the colder ambient conditions. As such, thermal sensations in Al-Azraq were rated lower than those in Al-Zaatari Camp in Figures 4 and 5.

*3.4.4. Comparison between Two Samples*

Figure 6 presents box plots illustrating the distribution of Thermal Sensation Votes (TSV) for Al-Zaatari and Al-Azraq camps across both seasons. Both camps exhibit a relatively large variance in TSV values within the box plots of the predicted percentage of dissatisfied occupants by thermal sensation vote.

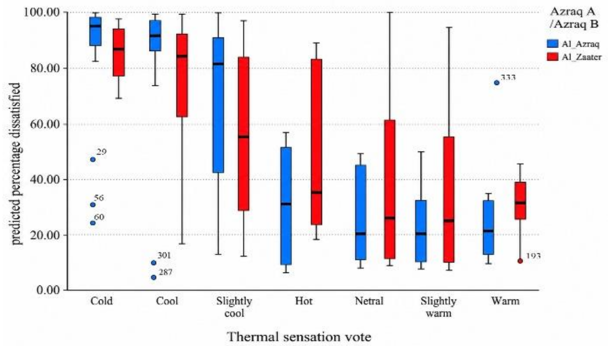


**Fig. 6 The distribution of Thermal Sensation Votes for all refugees, Al-Zatari, and Al-Azraq**

*Source: Authors*

The majority of the voters in both camps have a tendency to be on the right hand side of the temperature scale. The medians for each camp are in the middle of the seven-point temperature scale. The interquartile ranges account for 49%, 10% and 11% of the responses and they all exist within three middle points of the temperature scales. In total 69% of the total number of responses (69% of 336 = 232) were located in those middle three points on the seven-point scale; slightly cool, neutral, and slightly warm which indicate an acceptable thermal sensation range based upon ASHRAE Standard 55. Acceptable thermal sensations would be those that meet the definition of acceptability or satisfied occupants where there is a percentage of satisfactory responses on the seven point Thermal Sensation Vote (TSV) scale with a response value less than +1.5 and greater than -1.5 (the green lines).

### *3.5. Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD)*

The Predicted Percent Dissatisfied (PPD) Index is a numerical measurement of the degree to which the thermal comfort of a population in an indoor space has been affected by thermal conditions. A linear equation that represents how a change in the independent variable affects the dependent variable is used to determine the relationship between these two variables. Therefore, it is hypothesized that the slope of this linear equation will represent a statistically significant relationship between both the independent and dependent variables.

Y = Predicted Percentage Dissatisfied (PPD) Independent

X = Predicted Mean Vote (PMV). Dependent variables are affected

The curve line in Figure 7 illustrates the relationship between Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD).

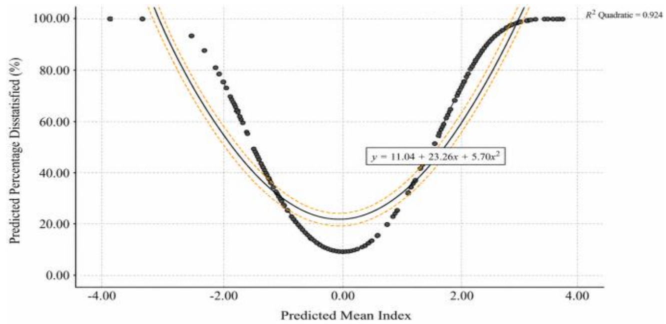


**Fig. 7 The relationship between Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD).**

*Source: Authors*

A quadratic fit was applied with a 95% confidence interval, yielding $R^2 = 0.820$. The fitted model was $Y = 18.8 + 2.5X + 9.2X^2$, where $Y$represents PPD and $X$represents PMV.

Model Fit:

$$Y = 18.8 + 2.5X + 9.2X^2 \quad (3)$$

The quadratic model produced an $R^2$value of 0.820.

*3.5.1. Quadratic regression for Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD)*

A simple linear regression was calculated to predict participants' mean vote based on their Dissatisfaction.

**Table 7. Model summary for quadratic linear regression for PPD and PMV**

| R | R Square | Adjusted R-Square | Std. Error of the Estimate |
|---|---|---|---|
| 0.719 | 0.517 | 0.514 | 1.097 |
| The independent variable is Predicted Percentage Dissatisfied (%). | | | |

**Table 8. Coefficients for quadratic linear regression for PPD and PMV**

| | Unstandardized Coefficients | | Significant |
|---|---|---|---|
| | B | Slandered Error | |
| Predicted Percentage Dissatisfied (%) | -0.031 | 0.008 | 0.000 |
| Predicted Percentage Dissatisfied (%) ** 2 | 0.001 | 0.000 | 0.000 |
| (Constant) | 0.020 | 0.142 | 0.886 |

Tables 7 and 8 show that the quadratic regression model was statistically significant, $F(2,333) = 178.316, p < .001$. The model produced $R = 0.719$, $R^2 = 0.517$, and an adjusted $R^2 = 0.514$. Thus, the linear and quadratic PPD terms jointly explained 51.7% of the variance in PMV. Based on the unstandardized coefficients, the estimated quadratic regression equation is:

$$Y = 0.020 - 0.031X + 0.001X^2 \quad (4)$$

Where Y is PMV, and X is PPD. The relationship is nonlinear; consequently, the effect of a one-percentage-point change in PPD on PMV varies according to the existing PPD level. The quadratic model had a multiple correlation coefficient of $R = 0.719$and explained 51.7% of the variance in PMV ($R^2 = 0.517$), as shown in Figure 8. The R² value indicates that 51.7% of the variability in PMV is explained by PPD.

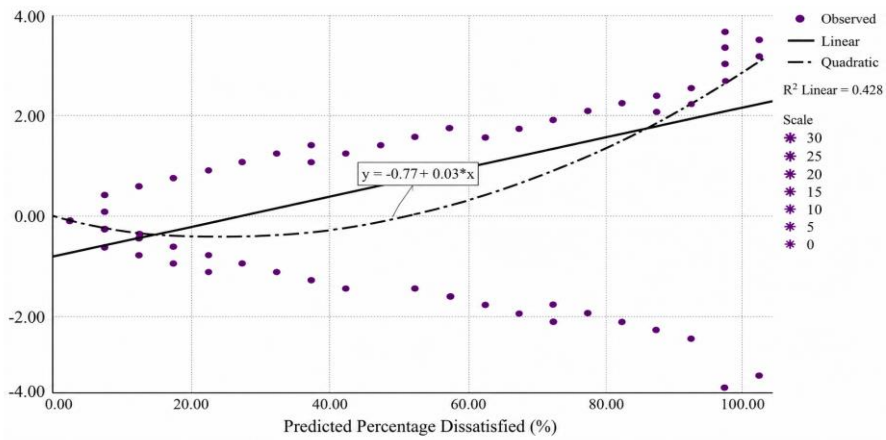


**Fig. 8 Illustrates both quadratic and simple linear regression models of PMV and PPD**

*Source: Authors*

According to Figure 8, the quadratic model produced $R^2 = 0.517$, whereas the linear model produced $R^2 = 0.423$. Perform a two-sample independent t-test (two-tailed t-test) for Al_Zatari and Al_Azraq in SPSS.

*First: The Performed Data Set for the Two-Tailed T-test*

The dataset of Predicted Percentage of Dissatisfied (PPD), which is intended for testing, is a crucial factor when performing any analysis, as it provides the context for the population under study. Information about the occupants, including gender, age, weight, and height, is available. All participants reside in shelters in both Al-Zaatari and Al-Azraq camps. The data represent the satisfaction of the occupants inside the shelter, Figure 9. Some of the data were recorded in summer, and the other in winter.

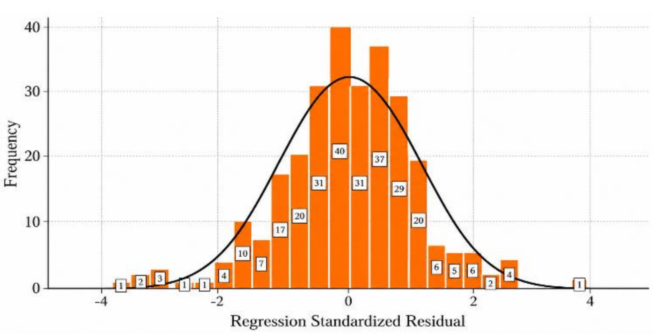


**Fig. 9 Histogram shows the two-tailed observations of the dependent variable, the predicted percentage of dissatisfied.**

*Source: Authors*

*Second: Assumption Two-sample Independent T-test Al_Za'atari and Al_Azraq Samples*

The study aims to investigate how changes in the Predicted Mean Vote (PMV) influence the Predicted Percentage of Dissatisfied (PPD). Additionally, the effects of Global Temperature (TG) and Air Temperature (TA) on PPD are examined. Furthermore, the impact of residence location (Al-Zaatari vs. Al-Azraq) on the differences in PPD among occupants is assessed.

- Grouping variable: Two groups are defined for comparison: Group 0 – Al-Zaatari; Group 1 – Al-Azraq.
- Test variable: The Predicted Percentage of Dissatisfied (PPD) is used as the dependent variable for comparison between the two groups

*Third: Hypotheses for Two-Sample Independent T-Test: Al-Zaatari and Al-Azraq Samples*

The null hypothesis ($H_0$) states that the mean percentage of dissatisfaction for occupants of Al-Zaatari shelters is equal to that of Al-Azraq shelters. Conversely, the alternative hypothesis ($H_1$) posits that the mean percentage of dissatisfaction for Al-Zaatari occupants is not equal to that of Al-Azraq occupants. An independent samples t-test was conducted to analyze and compare the means of the two separate groups of shelter occupants. The alpha level was set at 0.05 for a 95% confidence level. Descriptive statistics indicate that the Al-Zaatari sample includes 159 occupants with a mean PPD of 44.6%, while the Al-Azraq sample includes 172 occupants with a mean PPD of 46.9%. Given the difference in means, a significant difference may exist; the t-test will determine whether the null hypothesis can be rejected.

*Fourth: Determining Equality of Variances*

No significant difference was found in the Predicted Percentage of Dissatisfied (PPD) between the two groups. The Al-Zaatari group had a mean of 44.6 (SD = 2.55), while the Al-Azraq group had a mean of 46.9 (SD = 2.8), as shown in Table 9 (t(329) = 0.595, p = 0.55); see Table 10. The Levene's test for equality of variances indicated F = 0.001, which is less than the alpha level of 0.05. Therefore, equal variances cannot be assumed, suggesting that the two groups are not necessarily drawn from populations with equal variability. Despite this, the overall analysis indicates that the two groups can be considered from the same population, and there is no significant evidence that residence in Al-Zaatari or Al-Azraq affects the PPD. Consequently, the null hypothesis is accepted. Interaction between gender, season, and its effect on thermal Sensation by using a two-way ANOVA test.

**Table 9. Group statistics for T-test**

| Independent Samples Test | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| PPD | Equal variances assumed | 12.21 | 0.00 | -0.59 | 329.00 | 0.55 | -2.28 | 3.83 | -9.82 | 5.26 |
| | Equal variances not assumed | | | -0.60 | 327.64 | 0.55 | -2.28 | 3.81 | -9.78 | 5.22 |

**Table 10. Levene's test for equality of variances for the T_test**

| Group Statistics | | | | | |
|---|---|---|---|---|---|
| Camp | | N | Mean | Std. Deviation | Std. Error Mean |
| PPD | Za'atri | 159 | 44.6000 | 32.17225 | 2.55143 |
| | Azraq | 172 | 46.8805 | 37.13552 | 2.83156 |

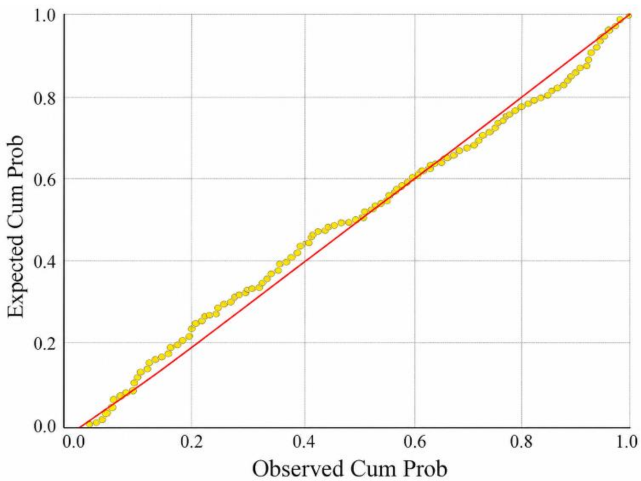


**Fig. 10 Normal P_P plot for regression standardized residual for the dependent variable, predicted percentage of dissatisfaction. Show the normality of the data**

*Source: Authors*

### *3.6. Normality Test*

Figure 10 illustrates the testing of linearity using the standardized residuals of the dependent variable. A two-way ANOVA was conducted with Thermal Sensation Vote (TSV) as the dependent variable, which followed a normal distribution. Gender (female = 1, male = 0) and season (summer = 1, winter = 0) were included as the two independent variables.

The hypothesis tests examine the effect of each independent variable while controlling for the effects of the other independent variables.

Results in Table 11 are reported using a two-way ANOVA to examine the influence of two independent variables, gender and season, on the number of occupants in a single session. Gender consists of two categories (female = 1, male = 0), and measurements were conducted across two seasons (summer = 1, winter = 0).

**Table 11. Two-way ANOVA test. Descriptive statistics show the variance between variables to understand the effect of the interaction between gender and season on thermal sensation**

| Dependent Variable: Thermal sensation vote | | | | |
|---|---|---|---|---|
| summer S / winter W | | Mean | Std. Deviation | N |
| Winter | Male | -0.31 | 0.86 | 65 |
| | Female | -0.57 | 1.01 | 111 |
| | Total | -0.47 | 0.97 | 176 |
| Summer | Male | 1.16 | 1.23 | 75 |

| | | | | |
|---|---|---|---|---|
| | Female | 1.48 | 1.25 | 81 |
| | Total | 1.33 | 1.25 | 156 |
| Total | Male | 0.48 | 1.30 | 140 |
| | Female | 0.30 | 1.51 | 192 |
| | Total | 0.37 | 1.42 | 332 |

From Table 12 all effects were statistically significant at the .05 significance level. The main effect for season yielded an F ratio of F (1, 328) = 203.862, p < .05. From Table 11 indicating a significant difference between winter (M = -0.4716, SD = 0.96764) and summer (M = 1.3269, SD =1.24519).

**Table 12. Two-way ANOVA test. Tests of between-subjects effects show the significance of the model and the significance of the impact of gender with season in the Thermal Sensation Vote**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 274.295[a] | 3 | 91.432 | 75.466 | 0.000 |
| Intercept | 62.300 | 1 | 62.300 | 51.422 | 0.000 |
| Sex | 0.076 | 1 | 0.076 | 0.063 | 0.803 |
| Season | 246.991 | 1 | 246.991 | 203.862 | 0.000 |
| Sex × Season | 6.750 | 1 | 6.750 | 5.571 | 0.019 |
| Error | 397.392 | 328 | 1.212 | — | — |
| Total | 718.000 | 332 | — | — | — |
| Corrected Total | 671.687 | 331 | — | — | — |

Dependent Variable: Thermal Sensation Vote
Note. [a] $R^2 = 0.408$ (Adjusted $R^2 = 0.403$).

Figure 11 shows the interaction point that occurred because of the interaction of the two independent variables, gender and season. The main effect for gender yielded an F ratio of F (1, 328) = 0.063, p > .05, indicating that the effect for age was not significant, male (M = 0.4786, SD = 1.31) and female (M = 0.3735, SD = 1.50753) the interaction effect was significant, F (1, 328) = 5.571, p < .01, as seen bellow in Figure 12.

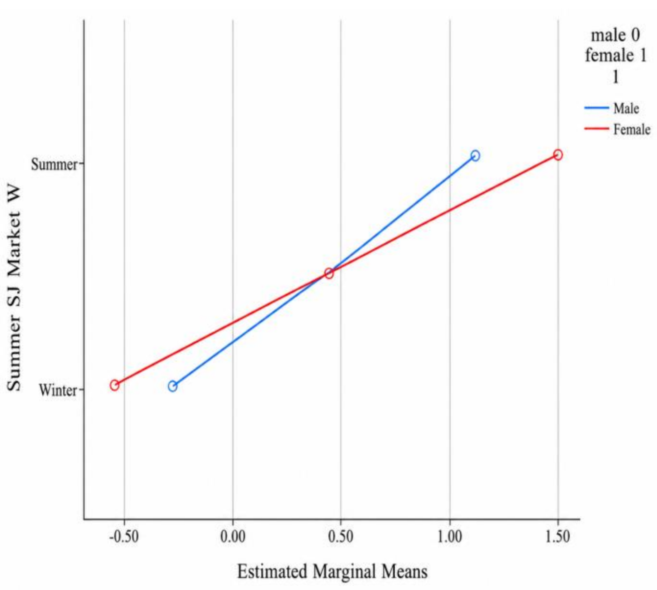


**Fig. 11 Estimated Marginal Means of Thermal Sensation Vote**

### *3.7. Stepwise Regression*

*3.7.1. Descriptive*

Identifying the best set of predictors when accounting for variation and an outcome variable in the context of multiple regression. The slandered approach to multiple regression involves having a single dependent variable and one or more than predicted variable.

*3.7.2. Measured Variables*

TSV = Thermal Sensation Vote
TPV=Thermal Preference Vote
TA= Air Temperature C
TG= Globe Temperature C
RH=Relative Humidity %
WBT= Wet bulb temperature C
AV= Air Velocity
TO = Cooperative's Temperature
Met= Metabolic Rate met
Clo.v=Total Clothing Value Clo
PMV = Predicted Mean Vote
Ppd = Predicted Percentage Dissatisfied

*3.7.3. Dummy Coding*

- Dummy coding for the gender variable female (1), male (0)
- Dummy coding for the season variable summer (1) winter (0)

All predictors were entered into the model simultaneously to account for variation and model performance. When the test was conducted, the variables entered were TA, TSV, clo value, and AV, while the removed variables included TPV, TG, RH, PMV, Met, TO, and WBT. The R² value was examined to determine the proportion of variance explained and the model's predictive performance.

*3.7.4. Interpreting the Output*

The stepwise regression was conducted using the criteria Probability-of-F-to-enter ≤ 0.050 and Probability-of-F-to-remove ≥ 0.100. As shown in Table 13, four models were generated, with the R² value reported for each.

The best-fitting model was the fourth model, where the explained variance reached 69.5% ($R^2 = 0.695$), indicating a strong fit to the observed data.

**Table 13. Shows the model summary for Stepwise regression for all variables, where some variables were removed, and the others were entered by forward steps, producing four models as follows**

| Model | R | R Square | Adjusted R-Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .790[a] | 0.624 | 0.623 | 21.73684 | |
| 2 | .808[b] | 0.653 | 0.650 | 20.93905 | |
| 3 | .826[c] | 0.682 | 0.678 | 20.06552 | |
| 4 | .834[d] | 0.695 | 0.690 | 19.70004 | 1.385 |
| a. Predictors: (Constant), TA | | | | | |
| b. Predictors: (Constant), TA, TSV | | | | | |
| c. Predictors: (Constant), TA, TSV, Clo value | | | | | |
| d. Predictors: (Constant), TA, TTSV,Clo value, AV | | | | | |
| e. Dependent Variable: PPD | | | | | |

Four models were produced by stepwise regression. The model summary based on Table 13 shows the following:

Model 1: R² = 0.624 (R = 0.790), indicating that 62% of the variation in the response variable (Predicted Percentage Dissatisfied, PPD) is explained by changes in the controlled variable, Air Temperature (TA). This demonstrates that air temperature is a major factor affecting PPD.

Model 2: R² = 0.653 (R = 0.808), showing that 65.3% of the variation in PPD is explained by the combination of Air Temperature and Thermal Sensation Vote (TSV).

Model 3: R² = 0.682, indicating that 68.2% of the variation in PPD is accounted for by Air Temperature, TSV, and total clothing value (Clo).

Model 4: $R^2 = 0.695$, showing that 69.5% of the variation in PPD is explained by the combination of Air Temperature, TSV, clothing insulation, and Air Velocity.

Comparing the models, Model 4 provided the best fit, with $R^2 = 0.695$ and adjusted $R^2 = 0.690$. A higher R² value reflects better explanatory power and model performance.

*3.7.5. Developing the Equation of Multiple Linear Regression*

According to Table 14, four model using MLR equation can be developed as below:

$$У = \beta 0 + \beta 1\, X$$

Model 1:

$$Y = -62.225 + 4.305\, XTA \quad (5)$$

Model 2:

$$Y = -48.930 + 3.587\, XTA + 6.673\, XTSV \quad (6)$$

Model 3:

$$Y = 0.540 + 2.458\, XTA + 7.938\, XTSV - 21.337 Xclo \quad (7)$$

Model 4:

$$Y = -5.99 + 2.8\, XTA + 6.7 XTSV - 20.6 Xclo - 22.9\, XAV + Ɛ \quad (8)$$

**Table 14. Shows the coefficients for stepwise regression**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t- value | Significant value |
|---|---|---|---|---|---|---|
| | | Coefficients | Standard Error | Beta | | |
| 1 | (Constant) | -62.225 | 5.793 | | -10.742 | 0.000 |
| | TA | 4.305 | 0.215 | 0.790 | 20.045 | 0.000 |
| 2 | (Constant) | -48.930 | 6.330 | | -7.730 | 0.000 |
| | TA | 3.587 | 0.262 | 0.658 | 13.673 | 0.000 |
| | TSV | 6.673 | 1.500 | 0.214 | 4.449 | 0.000 |
| 3 | (Constant) | 0.540 | 12.077 | | 0.045 | 0.964 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | TA | 2.458 | 0.346 | 0.451 | 7.096 | 0.000 |
| | TSV | 7.938 | 1.462 | 0.255 | 5.430 | 0.000 |
| | Clo value | -21.337 | 4.504 | -0.253 | -4.737 | 0.000 |
| 4 | (Constant) | -5.995 | 12.036 | | -0.498 | 0.619 |
| | TA | 2.800 | 0.357 | 0.514 | 7.846 | 0.000 |
| | TSV | 6.727 | 1.486 | 0.216 | 4.528 | 0.000 |
| | Clo value | -20.609 | 4.428 | -0.244 | -4.654 | 0.000 |
| | AV | -22.866 | 7.235 | -0.121 | -3.160 | 0.002 |
| **a. Dependent Variable: PPD** | | | | | | |

Based on Model 1, the standardized coefficient for Air Temperature ($\beta = 0.78$, $p < 0.05$) is significant, indicating that Air Temperature alone is a significant factor affecting the Predicted Percentage of Dissatisfied (PPD). In Model 2, the standardized coefficients for Air Temperature ($\beta = 0.658$, $p < 0.05$) and Thermal Sensation Vote (TSV, $\beta = 0.214$, $p < 0.05$) are both significant.

According to Model 3, the standardized coefficients for Air Temperature ($\beta = 0.451$, $p < 0.05$), TSV ($\beta = 0.255$, $p < 0.05$), and total clothing value (Clo, $\beta = -0.253$, $p < 0.05$) are significant.

In Model 4, the standardized coefficients for Air Temperature ($\beta = 0.514$, $p < 0.05$), TSV ($\beta = 0.216$, $p < 0.05$), Clo ($\beta = -0.244$, $p < 0.05$), and Air Velocity (AV, $\beta = -0.121$, $p < 0.05$) are all significant. These results indicate that Air Temperature, TSV, total clothing value, and air velocity are significant predictors of PPD. Overall, Model 4 provides the best fit to the data compared to Models 1, 2, and 3.

According to Table 14, the stepwise regression results using SPSS 25 show that four steps were used to select the significant predictors.

In Step 1, XTA had the smallest p-value ($p = 0.000 < 0.05$) and was the first variable entered into the model.

In Step 2, XTSV had $p = 0.000 < 0.05$, and thus entered as the second variable.

In Step 3, XClothing (Xclo) entered the model with $p = 0.000 < 0.05$.

In Step 4, XAir Velocity (XAV) entered the model with $p = 0.002 < 0.05$.

In the final model, XTA was retained with a coefficient of 2.8, t-value = 7.846, and p = 0.000. Variables with weak or non-significant correlations with the dependent variable were removed at each step. In conclusion, the stepwise regression identified four significant predictors: Air Temperature, Thermal Sensation Vote, total clothing value, and Air Velocity. The fourth model showed the highest $R^2 = 0.695$(69.5%), making it the best-fitting model among the four tested.

*3.7.6. Coefficients for Stepwise Regression*

The strongest predictor of the Predicted Percentage of Dissatisfied (PPD) is Air Temperature (TA). According to the SPSS coefficient results, the shared contribution of TA to the criterion variable is 20.2% (0.45^2), while its unique contribution is 7.8% (0.28^2).

Thermal sensation vote : shared: (.28)2 = 7.8% , unique: (0.16)2, 2.5 %

Total clothing value : shared: (.29)2 = 8.4% , unique: (0.17)2, 2.8 %

Air velocity : shared: (.20)2 = 4 % , unique: (0.11)2, 1.2%

**Table 15. Coefficients for stepwise regression**

| **Coefficient Correlations** | | | | |
|---|---|---|---|---|
| | | **Zero-order** | **Partial** | **Part** |
| **Fourth Model** | (Constant) | | | |
| | (TA) Air temperature | 0.79 | 0.453 | 0.28 |
| | (TSV) Thermal sensation vote | 0.619 | 0.281 | 0.162 |
| | (Clo value) Total clothing value | -.665- | -.288- | -.166- |
| | (AV) Air velocity | 0.059 | -.200- | -.113- |

*Testing Regression Equation*

$$y = -5.99 + 2.8\,XTA + 6.7XTSV - 20.6Xclo - 22.9\,XAV + \text{Ɛ} \quad (9)$$

y is the dependent or response variable, and it is the predicted percentage of dissatisfaction.

X they are the independent or predictor variable.

Testing the linear regression equation (Equation 9), the Predicted Percentage of Dissatisfied (PPD) for an occupant with Air Temperature = 35°C, TSV = 3, Clo value = 0.93, and Air Velocity = 0.01 m/s is 94.2%.

У= - 5.995 + 2.8 (35.5) + 6.72 (3) -20.6(.93) – 22.9 (.01) + Ɛ

У= 94.2

*3.7.7. Linear Regression for PPD and TA*

Linear regression for each controlled variable with the response variable (predicted percentage dissatisfied). The relation between independent variables and dependent variables must be linear. The degrees presented. Describing the negative movement of the independent variable. According to Figure 12, linear regression shows both a positive relationship of the simple linear regression model and the quadratic linear regression model, indicating the significant impact of Air temperature on the predicted percentage of satisfaction. The blue square shows the estimated range of ASHRAE TA

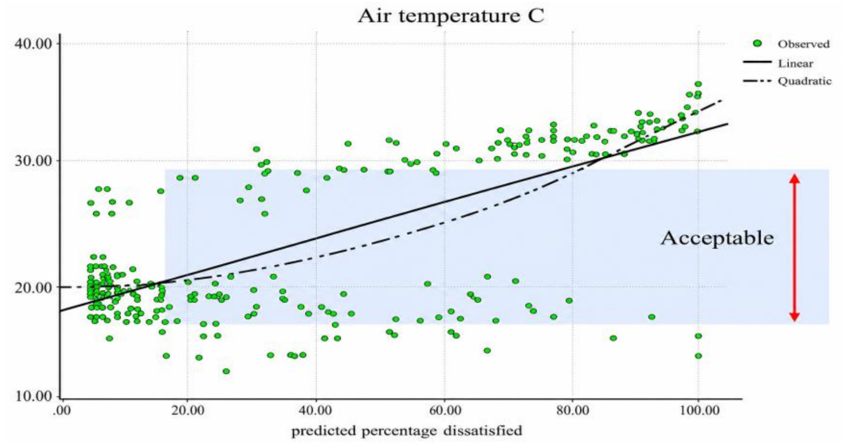


**Fig. 12 Linear regression for PPD and TA**

For thermal comfort purposes, the temperature should range between 20°C and 28°C. Many observed values exceeded the ASHRAE standards in both summer and winter. This highlights a strong need for controlling the indoor air temperature to improve occupant satisfaction.

Linear Model:

$$Y = 0.145\,X + 17.96 \qquad (10)$$

Quadratic Model:

$$Y = 19.7 + 0.01\,X + 0.001\,X2 \qquad (11)$$

*3.7.8. Simple Linear Regression for PPD and TSV*

The results of the Pearson correlation indicated a significant positive association between PPD and TSV, as shown in Figure 13. For every 0.66 decrease in TSV, the Predicted Percentage of Dissatisfied (PPD) increases by 1%.

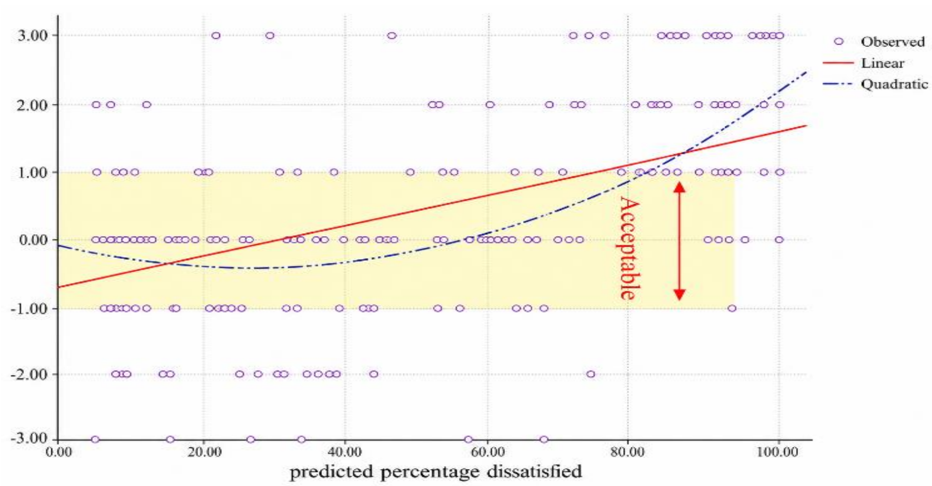


**Fig. 13 Simple Linear Regression for PPD and TSV**

The linear regression illustrates both the positive relationships of the simple linear regression model and the quadratic regression model, indicating the significant impact of Thermal Sensation Vote (TSV) on the Predicted Percentage of Dissatisfied (PPD). The yellow square represents the estimated range of ASHRAE TSV. For thermal comfort purposes, the temperature must range from (1, 0,-1). Many odd values exceeded the ASHRAE standard 55. There is a huge demand for controlling the Thermal sensation vote to increase satisfaction for the occupants.

Linear Model:

$$Y = 0.023\,X - 0.66 \qquad (12)$$

Quadratic Model:

$$Y = -0.059 - 0.023\,X + 0.0005\,X2 \qquad (13)$$

### *3.8. Simple Linear Regression for PPD and AV*

Simple Linear regression for PPD and AV shows the simple linear regression for PPD and AV. Figure 14 shows that the linear regression shows both the positive relationship in the simple linear regression model and the quadratic regression model, indicating the significant impact of Thermal Sensation Vote (TSV) on the Predicted Percentage of Dissatisfied (PPD). The yellow square represents the estimated ASHRAE TSV range.

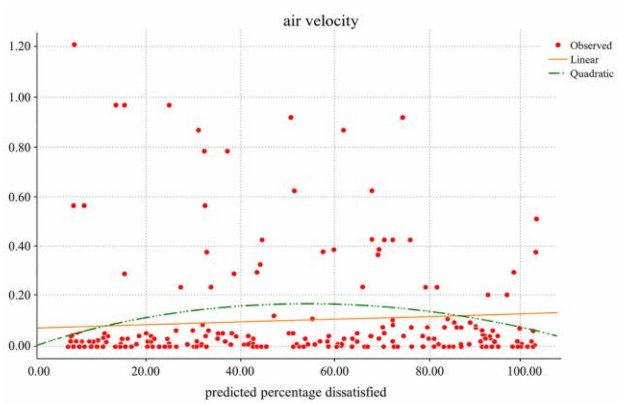


**Fig. 14 The Simple Linear Regression for PPD and AV**
*Source: Authors*

For thermal comfort purposes, Air Velocity (AV) should be maintained within a suitable range. Many observed values exceeded the ASHRAE standards in both summer and winter. This highlights a strong need for controlling indoor AV to improve occupant satisfaction. According to Equation 15, for every 0.07 increase in AV, the Predicted Percentage of Dissatisfied (PPD) increases by 1%.

Linear Model:

$$Y = 0.0004\,X + 0.079 \qquad (14)$$

Quadratic Model:

$$Y = 0.02 + 0.005X - 4.4X2 \qquad (15)$$

### *3.9. Neural Network Analysis*

An MLP neural network was utilized as a predictive model to interpret how strong the correlations are between the variables so it could obtain a higher percentage of prediction for dissatisfaction. The multilayer perception module of IBM SPSS Statistics 26 was utilized to develop the neural network and to verify the model's accuracy. The MLP neural networks trained by back-propagation learning algorithm utilize gradient descent to adjust the weights toward minimizing the error function.

The objective of this study is to find out if a MLP neural network can aid in determining the significance of each variable. Data on saltwater recreational anglers was collected and utilized for this analysis. The case processing summary showed the data collection was divided into two groups: a training set with 234 cases (70.1%); and a testing set with 100 cases (29.9%). Two additional cases were eliminated, as seen in Table 16.

**Table 16. Neural Network Case Processing Summary**

| Case Processing Summary | | | |
|---|---|---|---|
| | | N | Percent |
| Sample | Training | 234 | 70.1% |
| | Testing | 100 | 29.9% |
| Valid | | 334 | 100.0% |
| Excluded | | 2 | |
| Total | | 336 | |

The network was configured with nine input variables, using a standardized rescaling method. The hidden layer contained seven neurons, and the output layer consisted of a single neuron. As illustrated in Table 16. It is generated using SPSS 25, and the diagram shows the relative strength of the variables in the model. The model summary provides information on the results for both the training and testing samples Table 17.

The Sum of Squares Error is reported because the analysis is based on an algorithmic function and is calculated for both samples, as it represents the error function minimized during the network training stage. The SSE value (5.848) indicates the model’s capability to predict the PPD.

The SSE for the testing sample was smaller than that for the training sample, indicating that the network model was not overfit to the training data. In this study, the Relative Error for the training sample was 5%, resulting in a 95% correct prediction rate, which demonstrates good predictive performance in a qualitative study for assessing PPD in relation to the nine input variables.

**Table 17. Neural Network Model Summary**

| Neural Network Model Summary | | |
|---|---|---|
| Training | Sum of Squares Error | 5.848 |
| | Relative Error | 0.050 |
| | Stopping Rule Used | 1 consecutive step(s) with no decrease in error[a] |
| | Training Time | 0:00:00.03 |
| Testing | Sum of Squares Error | 2.114 |
| | Relative Error | 0.041 |
| Dependent Variable: predicted percentage dissatisfied | | |

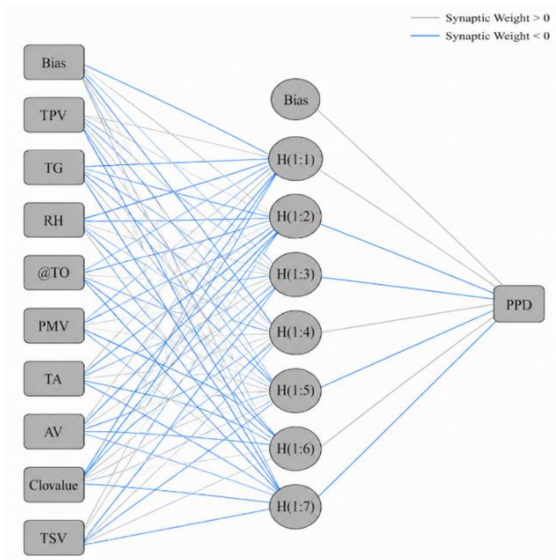


**Fig. 15 MLP Neural Network: Influence of independent variables on PPD**

*Source: Authors*

According to Figure 15, this neural network illustrates the strength of each independent variable's influence on the Predicted Percentage of Dissatisfied (PPD) across three layers. The width and thickness of the links reflect the relative importance of different variables in determining the thermal satisfaction of shelter residents. It can be observed that some variables have a greater impact than others, suggesting they are key factors to consider when optimizing interior design and shelter environment management.

A positive correlation is observed, as shown in Figure 16. The Independent Variable Importance chart illustrates the influence of each variable in the MLP neural network model in terms of relative and normalised importance Table 18.

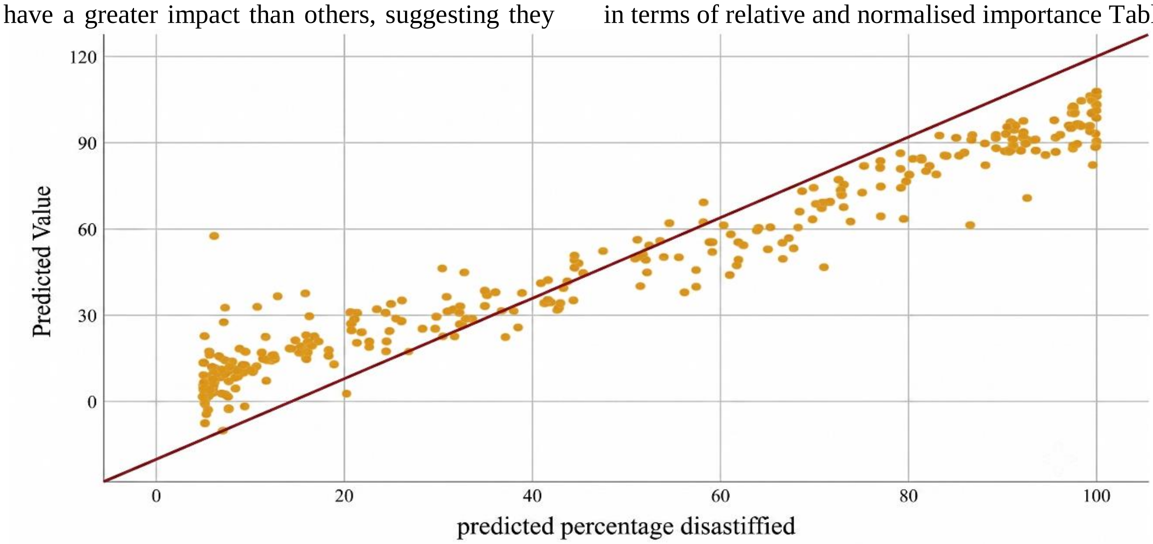


**Fig. 16 The predicted model for the data by a Neural Network**

*Source: Authors*

The three most dominant factors are: Cooperative Temperature with the highest importance (100%), followed by Air Temperature (83.1%) and Total Clothing Value (80.7%). The next significant factors are Globe Temperature (79.7%), Air Velocity (25.6%), and Predicted Mean Vote (20.5%). Variables with lesser impact include Humidity (14.9%), Thermal Sensation Vote (11.4%), and Thermal Preference Vote (10.5%).

Table 18 illustrates the relative and comparative significance of each independent variable in the MLP neural network model. It shows that cooperative temperature is the most influential factor on the Predicted Percentage of Dissatisfied (PPD), reaching 100% significance.

This is followed by air temperature at 83.1% and total clothing value at 80.7%, indicating that these three factors have the greatest impact on thermal population satisfaction. Other factors, such as globe temperature, air velocity, and predicted mean vote for thermal comfort, have a moderate impact, while relative humidity, thermal sensory voting, and thermal preference show a relatively lower impact on PPD.

**Table 18. Independent variable importance by Neural Network**

| | Importance | Normalized Importance |
|---|---|---|
| Thermal preference vote | 0.025 | 10.5% |
| Globe temperature C | 0.181 | 76.7% |
| Relative humidity % | 0.035 | 14.9% |
| Cooperative temperature | 0.236 | 100.0% |
| predicted mean vote | 0.048 | 20.5% |
| Air temperature C | 0.196 | 83.1% |
| air velocity | 0.060 | 25.6% |
| total clothing value Clo | 0.191 | 80.7% |
| Thermal sensation vote | 0.027 | 11.4% |

**Table 19. Pearson correlation and subjective perceptions, with their significance**

| | | Subjective Perceptions Votes | | Indoor environmental variables | | | | | Personal Parameter | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TSV | PPD | Met | TO | AV | TG | TA | AGE | SEX | WEIGHT | Clo value |
| Subjective Perceptions Votes | Thermal Sensation Vote | 1.00 | 0.62 | -0.02 | 0.63 | -0.03 | 0.62 | 0.61 | -0.01 | 0.08 | -0.03 | -0.34 |
| | Predicted Percentage Dissatisfied | | 1.00 | -0.07 | 0.78 | 0.06 | 0.77 | 0.79 | -0.09 | -0.14 | -0.11 | -0.67 |
| Indoor environmental variables | Metabolic Rate Met | | | 1.00 | -0.10 | -0.03 | -0.08 | -0.11 | 0.03 | 0.03 | 0.02 | 0.05 |
| | Cooperative TEMPERATURE | | | | 1.00 | 0.25 | 1.00 | 0.99 | -0.07 | -0.03 | -0.15 | -0.71 |
| | Air Velocity | | | | | 1.00 | 0.26 | 0.27 | 0.05 | 0.09 | -0.02 | -0.19 |
| | Globe TEMPERATURE | | | | | | 1.00 | 0.98 | -0.07 | -0.03 | -0.14 | -0.71 |
| | Air TEMPERATURE | | | | | | | 1.00 | -0.07 | -0.04 | -0.17 | -0.72 |
| Personal Parameter | Age | | | | | | | | 1.00 | 0.01 | 0.39 | 0.15 |
| | Sex | | | | | | | | | 1.00 | -0.13 | 0.55 |
| | Weight | | | | | | | | | | 1.00 | 0.08 |
| | TOTAL CLOTHING VALUE Clo | | | | | | | | | | | 1.00 |

| Correlation coefficient range | | |
|---|---|---|
| Positive strong correlation | | 0.51 to 1.0 |
| Positive moderate correlation | | 0.5 to 0.31 |
| Positive weak correlation | | 0.1 to 0.3 |
| No correlation | | 0 |
| Negative weak correlation | | –0.1 To –0.3 0. |
| Negative moderate correlation | | –-0.31 to –0.5 |
| Negative strong correlation | | –-0.51 to –1.0 |

### *3.10. Correlations between the Response Variable and the Controlled Variables*

A Pearson Correlation analysis was performed between subjective votes and physical measurements, as seen in Table 19. Pearson's correlation matrix in Table 19 illustrates the relationship between subjective thermal comfort votes and both indoor environmental and population-specific variables.

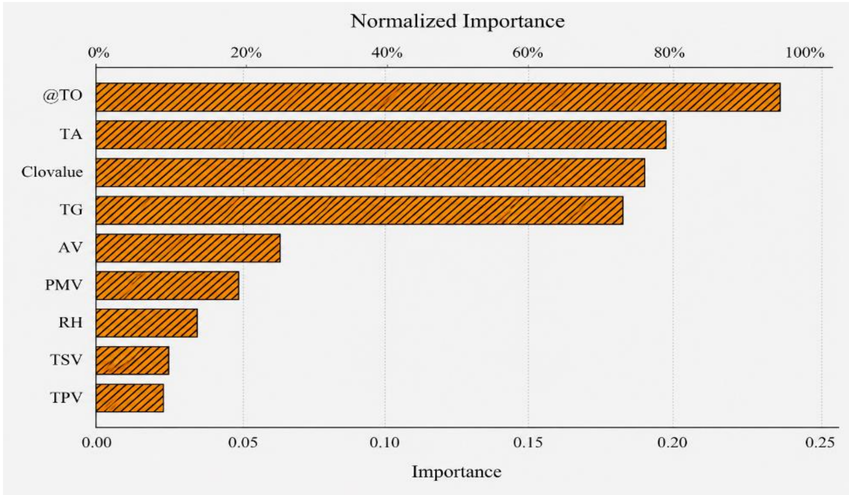


**Fig. 17 Ranking of the variables that have the highest significant impact on the predicted percentage of satisfaction**

## 4. Results

The results show the following: Strong and Significant Relationships: There is a strong and positive correlation between Predicted Percentage of Dissatisfied (PPD) and TSV (r = 0.62), indicating that thermal comfort votes are directly related to predicted thermal dissatisfaction. Cooperative Temperature, Air Temperature, and Globe Temperature show strong correlations with PPD and TSV (r ≈ 0.61–0.79), suggesting that temperature is the primary environmental factor influencing population thermal satisfaction.

Moderate Relationships: There is a moderate positive correlation between Air Velocity and both PPD and TSV (r ≈ 0.26), indicating that air movement influences thermal comfort but is not the strongest factor.

Weak or negative correlations: Personal variables such as Clo value (population clothing), weight, age, and sex showed weak or negative correlations with PPD and TSV, meaning that personal factors have less of an impact compared to environmental variables.

## 5. Discussion and findings

The results indicated that the thermal performance of the temporary shelters in the two camps failed to provide acceptable thermal comfort conditions according to ASHRAE 55 (Adaptive Comfort Model) standards in both seasons, albeit to varying degrees. In winter, 10% of the calculated operational temperature values fell within the thermal comfort range. This means that the vast majority of refugees experience cold or thermal discomfort inside the shelters. This result also indicated that the shelters have poor thermal insulation, lack sufficient thermal stability, and may indicate reliance on inadequate or irregular heating methods. In summer, all values were found to be outside the thermal comfort range. This indicates that the shelters suffer from excessively high internal temperatures. This result also indicated that the materials used in the shelters have low thermal capacity and allow easy penetration of external heat. Furthermore, natural ventilation is ineffective, and there are no suitable cooling strategies. This finding differs from the findings of Albadra et al. (2018), which concluded that suitable thermal ranges were available for refugees in the Azraq and Zaatari camps [5]. Thus, the current findings stressed the need for interventions that can reduce the risk of cold in winter and increase ventilation in summer. This is precisely what Domínguez-Amarillo et al. (2021) indicated, emphasizing the necessity of using insulation materials and moisture-permeable polyester linings to reduce the need for heating and maintain comfortable indoor temperatures [2]. Moran et al. (2021) also support this, highlighting the importance of roof insulation and nighttime ventilation as interventions that can lower temperatures and thus improve thermal comfort within shelters. Furthermore, Ma'arof et al. (2019) and Lai Lee (2019) supported the use of air catchers for their effectiveness in providing thermal comfort during the summer [21, 22].

The results showed that the thermal insulation values (clo) of the clothing exceeded the ASHRAE reference values in both seasons, ranging from 0.4–1.0 clo in summer and from 0.5–2.1 clo in winter. A similar average of 0.7 clo in summer and 1.0 clo in winter was recorded in the Zaatari and Azraq camps. The average metabolic rate of the sample was approximately 1.2 Mt, reflecting low to moderate activity levels.

Furthermore, the results of the linear and quadratic regression analysis show that the relationship between expected thermal comfort and the thermal insulation value of clothing is not a simple linear one, but rather a non-linear one, reflecting complex adaptive behaviour among residents of shelters. Although a negative correlation was observed in both models, the quadratic model showed a higher fit to the field data, indicating that changes in clothing patterns do not occur at a constant rate as thermal comfort improves. This underscores that the assumptions of standard thermal comfort models, particularly those adopted in ASHRAE 55, do not adequately capture the behavioral and cultural dynamics governing clothing choices in the context of refugee camps. Furthermore, the observed clo values exceeding the assumed ranges highlight the role of cultural and environmental factors in shaping thermal comfort and reinforce the importance of adopting non-linear analytical models to understand the interaction between the user and the built environment in emergency housing.

The thermal perception results indicated that the current design of temporary housing does not provide a balanced thermal response for all users, despite the high percentage of neutral perceptions. This underscores the need to improve the thermal envelope of the dwellings through insulation and shading to reduce thermal stress, especially during periods of high temperatures. The results also highlight the importance of adopting flexible design solutions that consider the variation in thermal perception among users, such as improving natural ventilation and individual control of the indoor environment. These data reflect the need to develop contextual design models for emergency housing that go beyond standard assumptions of thermal comfort.

Based on the results of the Pearson correlation matrix between physical measurements and subjective perceptions, with their significance, the results showed that the indoor environment, particularly temperature variations, is the primary determinant of thermal satisfaction or dissatisfaction (PPD) among residents. Personal variables have a lesser impact, while air velocity has a moderate effect. These findings underscore the importance of monitoring and controlling the indoor environment to achieve thermal comfort in shelters [4].

As the current study used multiple linear regression and a Multilayer Perceptron (MLP) for predicting statistically as well as incorporating field measurements with occupants' perceptions of thermal comfort in an operational setting, but did not use computational building performance simulation models to support its findings from actual field measurement data. Future studies should combine results from field observation with those from building energy simulation models and computational heat transfer models in order to compare various alternatives to provide optimal thermal comfort under varying climatic conditions by comparing different alternative shelter design options and/or climate responsive passive cooling options.

Relative to previous research, this new analysis provides additional evidence that thermal discomfort within desert refugee shelter conditions are determined almost exclusively by those factors related to indoor temperatures as opposed to solely by individual characteristics. As previously demonstrated, there was an emphasis on overheating and inadequate performance of thermal envelopes in emergency shelters; however, the evidence provided here demonstrates that the combination of air temperature, operative temperature, globe temperature, clothing insulation and air velocity explains a significant portion of the variance in predicted dissatisfaction. The results further demonstrate that standard comfort assumptions do not fully account for cultural influenced clothing practices and behavioral adaptations that occur within refugee shelters. Overall, this study builds upon the prior research by incorporating seasonal field measurement, subjective perceptions, regression modeling and neural network based ranking of independent variables into one integrated analytic methodology.

### *5.1. Policy, Implementation, and Social Implications*

The findings of this research will influence how shelters in humanitarian emergencies are planned and implemented at the level of camps. In the first place, when designing shelter interventions, upgrading priorities must include modifications to the thermal envelope of the shelter (including insulating roofs, applying reflective surface treatments to exterior walls, installing shade structures or other shading devices on walls and roofs; reducing uncontrolled heat transfer via lightweight enclosures). In the second place, all of the passive-cooling techniques which provide thermal relief without requiring operational energy consumption must be included as part of the shelter-design process; i.e., cross ventilation; shaded windows/doors/openings; ventilated roofs; nighttime ventilation. In the third place, whether or not shelter-intervention efforts succeed depends upon both the technical capabilities of the intervention effort and on its success from the viewpoint of residents; e.g., thermal comfort is influenced by what residents wear; their need for private areas within their living spaces; who uses each area for sleeping/other purposes based on gender; and/or residents' belief in their ability to control their indoor environment.

Practically speaking, relatively inexpensive, modular design-based solutions may represent a better route to take toward achieving successful outcomes rather than replacing every existing shelter. Therefore, priority should be placed upon developing scaleable upgrade options which can be locally purchased, installed, maintained and modified by local residents/camp administrators. While conducting a complete economic benefit analysis of the various options was outside the scope of this research project, there is strong evidence to suggest that interventions designed to address temperature-control issues and improve airflow (because these two factors were most strongly associated with predicted levels of dissatisfaction) will result in the largest increases in satisfaction.

### *5.2. Ethical and Social Implications*

While this study used secondary anonymous data (and thus had no direct involvement with refugees and/or humanitarian agencies during the data collection), it has very real implications for the future of participatory shelter development. Involving camp residents, humanitarian agencies, architects, engineers and policy makers in both the evaluation, design and implementation of thermal comfort interventions will be crucial for ensuring future shelter designs and improvements are technically viable, culturally relevant, socially acceptable and meet the long term needs of refugee populations.

## 6. Conclusion

Research findings confirm that the Azraq and Zaatari refugee camps suffer from a clear deficiency in meeting thermal comfort requirements according to the ASHRAE 55 Adaptive Comfort Model. In both summer and winter, the vast majority of operating temperatures exceeded the comfort range, particularly during the summer. This underscores the poor thermal envelope efficiency of the shelters and their limited capacity to adapt adequately to seasonal changes.

The study's findings indicate that adaptive clothing-related behaviour plays a pivotal role in shaping thermal comfort within refugee shelters, in a manner inconsistent with the linear assumptions of standard models. These results underscore the need to develop more culturally and environmentally sensitive thermal comfort models when designing and evaluating emergency shelters in hot, dry climates. The results of the MLP neural network analysis provide evidence that input variables significantly contribute to predicting thermal dissatisfaction among shelter residents. The model demonstrates its ability to differentiate between various factors and their impact on resident comfort, highlighting the importance of considering these variables when designing housing or improving its interior environment. These findings can be used to guide design solutions that reduce thermal discomfort and enhance resident well-being.

Moreover, correlation analysis indicates that indoor environmental factors, particularly varying temperatures, are the primary determinants of thermal satisfaction or dissatisfaction among shelter residents, while the influence of personal factors such as age, gender, and clothing is less pronounced. These findings underscore the importance of designing indoor environments that control temperature and airflow to ensure residents' comfort and enhance their well-being.

Thus, there is a clear need for relevant authorities to reconsider the architectural designs of refugee camps, ensuring the application of international thermal comfort standards and their adaptation to local climatic characteristics and design and economic constraints. It is recommended to improve the thermal envelope of dwellings, in addition to incorporating the passive solutions such as shading and improved ventilation levels into design strategies.

## Ethical Approval

This study utilized anonymized secondary data from a publically available data source for research purposes. Consequently, there was no direct contact with refugee participants; therefore, the authors did not require additional ethics approvals. Anonymity of the refugee population and aggregation of the data were employed during the analysis to avoid personal identifying information and to protect vulnerable populations.

## Conflicts of Interest

The author declares that there are no competing financial or non-financial interests that could have influenced the work reported in this paper.


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