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An Investigation into Thermal Comfort of Shelters in Refugee Camps in Palestine Using Questionnaires and Computer Simulation

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Abstract: It is essential for building designer, as a major responsibility, to provide appropriate indoor conditions for human thermal comfort in order to attain healthy, productive, and effective lifestyle in buildings. Many researchers studied thermal environment and occupant's comfort in residential buildings of different climatic zones at various geographical locations. Specifically, in Palestine, such field studies have never been conducted on shelters in refugees camps. This paper intended to investigate thermal comfort in shelters in refugee camps in Palestine. Various factors that could influence thermal comfort in these shelters were inspected, including environmental factors, secondary factors, and shelters' envelope. Two main methods, questionnaire and computer simulation, were employed in this study. Questionnaires were utilized to evaluate the thermal environment of the shelters through interviews with 155 residents from Jabalia refugee camp, Palestine. Thermal simulation using Thermal Analysis Software (TAS v9.1.4.1) was employed to predict thermal comfort in the shelters. Twenty one shelters were simulated. The gathered data from the questionnaire and the predicted data from the computer simulation were analyzed and contrasted utilizing statistical analysis software (SPSS). The results from both methods indicated that the shelters are overall hot in summer and cold in winter. A statistically significant difference was found between the occupants' thermal sensation vote (TSV) gathered by the questionnaire and the predicted mean vote (PMV) estimated by the computer simulation. PMV is higher than TSV in summer, while TSV is higher than PMV in winter. However, the mean of PMV–TSV discrepancies was less than 0.25 scale units which is an acceptable bias.

Keywords: PMV, Thermal comfort, Refugee Camps, Computer Simulation

تقييم الارتياح الحراري في منازل مخيمات اللاجئين في فلسطين باستخدام الاستبيانات والمحاكاة بالحاسوب

ملخص: إنه من الضروري على مصممي المباني ، كمسؤولية أساسية، توفير الظروف الداخلية المناسبة للراحة الحرارية للإنسان من أجل تحقيق بيئة صحية ومنتجة وفعالة في المباني. إن العديد من الباحثين قاموا بإجراء دراسات على البيئة الحرارية وراحة الإنسان في المباني السكنية في مناطق مناخية مختلفة و مواقع جغرافية متعددة. و لكن وعلى وجه التحديد في فلسطين ، مثل هذه الدراسات لم تجرى على المنازل في مخيمات اللاجئين. هذه الورقة تهدف إلى دراسة الارتياح

الحراري في منازل اللاجئين في المخيمات في فلسطين. العوامل المختلفة التي يمكن أن تؤثر على الارتياح الحراري في هذه المنازل تم دراستها، و تشمل العوامل البيئية، والعوامل الثانوية ، ومواد الانشاء للعناصر الخارجية لهذه المنازل . وقد استخدمت طريقتين رئيسيتين في هذه الدراسة و هما: محاكاة الكمبيوتر والاستبيان.وقد استخدمت الاستبيانات لتقييم الارتياح الحراري في المنازل من خلال مقابلات مع 155 فرد من سكان مخيم جباليا للاجئين الفلسطينيين. كما أن المحاكاة الحرارية باستخدام برامج التحليل الحراري (TAS v9.1.4.1) استخدمت للتنبؤ بالارتياح الحراري في منازل اللاجئين. واحد وعشرين منزلاً تم محاكاتها حاسوبياً. وقد تم تحليل و مقارنة البيانات التي تم جمعها من الاستبيان والبيانات التي تم تنبؤها من المحاكاة بالحاسوب باستخدام برنامج التحليل الإحصائي (SPSS). أشارت النتائج من كلا الطريقتين أن المنازل بشكل عام حارة صيفاً وباردة شتاءً. وكشف عن اختلاف واضح إحصائيا بين التصويت الحراري للسكان (TSV) الذي تم جمعه بالاستبيان والتصويت المتوسط المتوقع (PMV) الذي تم تنبوئه باستخدام المحاكاة بالحاسوب. PMV أعلى من TSV في فصل الصيف، بينما TSV أعلى من PMV في فصل الشتاء. ومع ذلك ، كان متوسط الفرق بين PMV و TSV أقل من 0.25 وحدة قياس والذي يعتبر تحيز مقبول.

1 INTRODUCTION

Thermal comfort plays a major role among other indoor environmental parameters as it has the greatest effect on energy consumption and sustainability (Szokolay, 2008 and Hoof, 2008). Therefore, it is essential that thermal comfort in buildings must be taken into serious consideration. However, achieving optimum indoor thermal conditions for building's occupants should also be parallel with energy saving. In Palestine, studies about occupants' thermal comfort have never been conducted on shelters in refugee camps. Refugee camps are unique in terms of urban structure and political conditions, and the lifestyle and the economic status of the camps' occupants are different from those in other areas in Palestine. Due to the historical unstable political situation in Palestine, the refugee camps suffer from major drawbacks and the occupants are the most vulnerable. The refugee camps in Palestine have one of the highest population densities in the world, for instance, 108,000 registered refugees live in Jabalia camp whose area is only 1.4 km^2 (UNRWA, 2010), i.e. the population density exceeds 77,000 persons per km^2. This high population density is reflected in the overcrowded urban environment of the camps. Urban density is a major factor that influences the urban ventilation conditions as well as the urban temperature (Givoni, 1998). Urban density and lack of land and space are the key factors limiting the achieving of comfort indoor conditions and make it difficult to find suitable design (Hui, 2001). In hot humid climate, the urban structure should be scattered and loose in order to channel winds through the streets and inside buildings.

An Investigation into Thermal Comfort of Shelters

Refugee camps in Gaza strip are located in hot humid climate. Therefore, under the crowded and stressful urban environment, the shelters in refugee camps can experience uncomfortable indoor thermal environment. The use of natural ventilation and solar energy in refugee camps will be strongly affected by closely spaced as the alleys inside the camps are narrow, sometimes only a 0.6 metre wide, making the design optimisation of the shelters more complicated.

In order to improve refugees' living conditions in camps, the United Nations Relief and Works Agency (UNRWA) for Palestine Refugees in the Near East has been promoting shelter reconstruction programme for Special Hardship Cases (SHC) families all over the camps (UNRWA, 1999). The UNRWA has reconstructed SHC shelters according to criteria, which have been developed by a team of architects and engineers in view of the UNRWA experience in the field of shelter rehabilitation programme, in order to have functional, safe and comfortable shelters (UNRWA, 2009). Since the shelters in refugee camps is influenced by a wide range of complicated factors, including dense urban environment, economic limitations, and absence of regulations, the design of these shelters will be more difficult.

This study intended to investigate the thermal environment of SHC shelters in refugee camps in Gaza Strip-Palestine. Jabalia refugee camp is selected which is located in the north of Gaza Strip (see Fig 1).

Figure 1: The geographical location of Palestine, reproduced from WCIP, 2010

Gaza Strip is hot and humid during summer and mild during winter. The average daily mean temperature ranges from 25^{o}C in summer (May-August) to 15^{o}C in winter (December-February). Average daily maximum temperatures range from 32^{o}C to 19^{o}C and minimum temperatures from 21^{o}C to 11^{o}C, in the summer and winter respectively (PEA, 2010). Relative humidity is high throughout the year. The daily relative humidity fluctuates between about 63% in the daytime and 83% at night in the summer, whereas between 52% in the daytime and 81% at night in winter. Gaza Strip has a relatively high solar radiation. It has approximately 2861 annual sunshine-hour throughout the year, which covers about 310 days. The daily average solar radiation on a horizontal surface is about 222 W/m^2 (ibid).

Both groups of SHC shelters were considered and examined; the shelters which are not reconstructed by the UNRWA yet (referred to as old shelters) and the shelters which already were reconstructed by the UNRWA (referred to as new shelters). Studying the two groups of shelters, old and new, was to help assessing the value of improvement in thermal comfort that has already taken place by the UNRWA and to bring greater comprehension of thermal comfort parameters that still needs more enhancements.

2 THE STUDIED SHELTERS

All old shelters (110 shelters) which wait reconstruction in Jabalia refugee camp were surveyed in this study. In addition, the most recent reconstructed shelters (94 new shelters) in Jabalia camp were selected for the investigation in order to get shelters with the fewest changes and extensions which generally applied by the occupants. The average response rate was 74% with a total of 155 shelters were successfully surveyed including 85 new shelters and 70 old shelters. Table 1 provides descriptive analysis of the studied shelters and figure 2 shows photographs of the two types of shelters.

Variable	Shelter Type	Mean	Mode	Min.	Max.	Std.Dev.
No. of Families	old	1.59	1	1	5	0.88
	new	1.45	1	1	4	0.72
No. of occupants	old	8.71	8	1	30	4.86
	new	7.47	8	1	19	3.55
Area	old	112.42	60	21	430	90.75
	new	81.16	80	20	250	35.24
No. of rooms	old	2.90	2	1	8	1.44
	new	3.38	3	1	7	1.09
Area/Person	old	15.38	15	2.15	65	11.57
	new	17.91	20	4.67	80	13.72
No. of floors	old	1.04	1	1	2	0.20
	new	1.71	2	1	3	0.61

Table 1: Descriptive features of the studied shelters

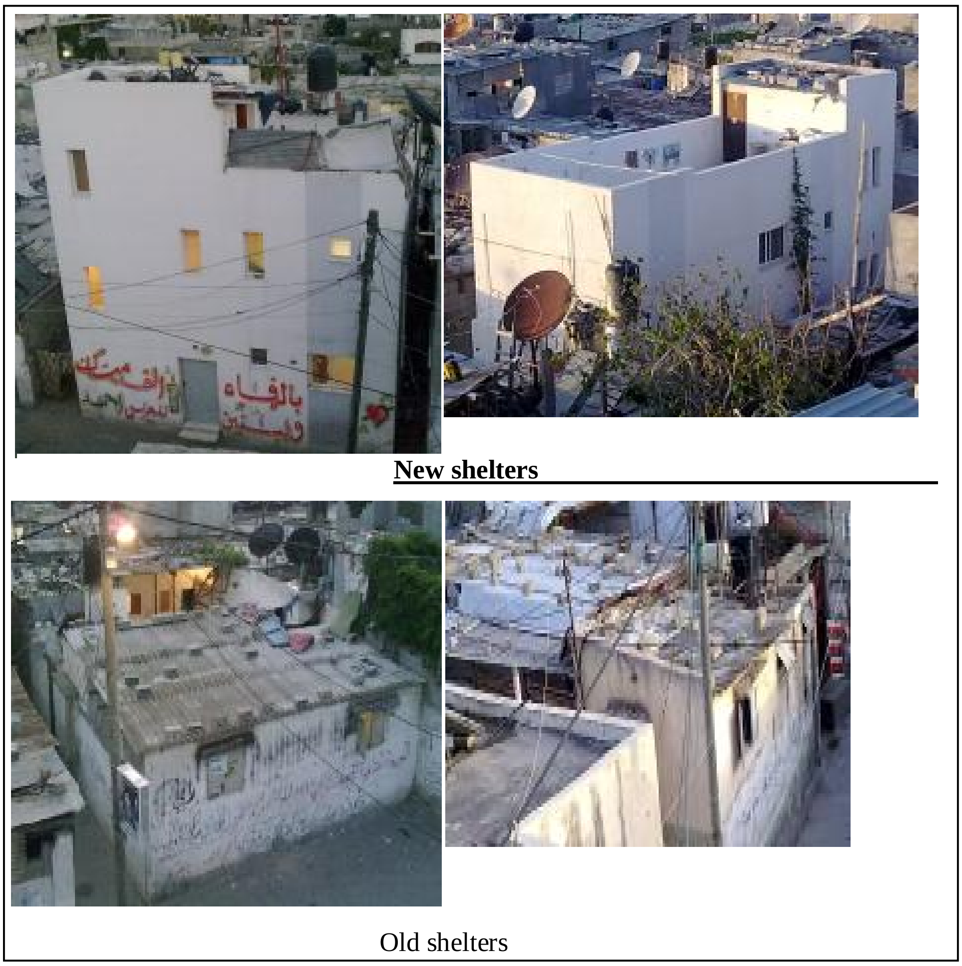
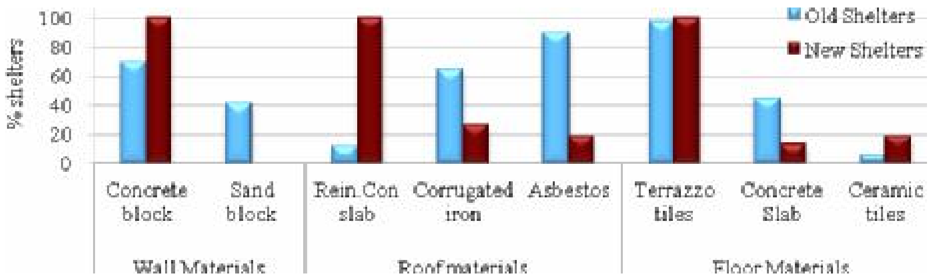


Figure 2: Photographs for the two types of shelters (old and new), Survey 2010

The vast majority of old shelters (95.7%) are one-floor height houses attached on one, two, or three sides. Some of old shelters (about 43%) still comprise open courtyards. The new shelters are almost detached houses or attached on one side. Over one-half of the new shelters are two-floor height, and almost 37% is one-floor, while a mere 8.2% is three-floor height. It is worth mentioning that the UNRWA has been constructing one or two floors for SHC families, however, occupants almost extend vertically in accordance with their needs and family growth.

The most common types of construction materials of SHC shelters are cement blocks for walls while the roofs are mostly asbestos, corrugated iron, or combination of them. Few old shelters include concrete slab which is used to cover some spaces particularly bathrooms. All new shelters include flat reinforced hollow concrete slab and the walls are cement blocks. Corrugated iron is used in new shelters to cover staircases. For flooring, terrazzo tiles are used in all new shelters and vast majority of old shelters, while ceramic tiles are used in few shelters in particular spaces such as kitchens and bathrooms. Plain concrete are also used as flooring material in few new shelters and in lower than one-half of old shelters. Figure 3 provides the percentage of shelters according to the types of construction materials for walls, roofs, and floors.

In terms of windows materials, there is an observed difference between old and new shelters, with a variety of types as shown in figure 4. Single glazed windows with external wooden shutters (DW) are existed in majority of new shelters, followed by glazed windows. In old shelters, wooden windows are the highest percentage across the other windows types; followed by plastic louvered windows, and steel windows.



3 METHODS OF THE INVESTIGATION

3.1 The Questionnaire Survey

The questionnaires were applied to collect data about thermal environment in 155 shelters including occupants' thermal sensation vote, environmental factors of thermal comfort (air humidity, air circulation, and indoor solar radiation), secondary factors (gender, age, and occupancy period), and shelters' envelopes. As human thermal comfort has great effect on energy savings, data related to energy consumption for heating and cooling were collected too. As the study is concerned with thermal comfort in both summer and winter, field survey was conducted in autumn (from November to the mid of December 2009) in order to avoid extreme seasons' effects.

Occupants of SHC shelters were asked to rate their thermal comfort (for both summer and winter) in the main spaces of their shelters; including rooms, halls, kitchens and courtyards, utilizing ASHRAE's seven-point thermal sensation scale ranging from cold (−3) to hot (+3). They were also asked to rate indoor air humidity (from "too humid" to "too dry"), air circulation (from "too much circulation" to "still"), and indoor solar radiation (from “too much” to “no solar radiation”) in their shelters as overall in both summer and winter.

3.2 The Computer Simulation

As computers can run the most sophisticated calculations, computer simulation became a powerful tool to analyse buildings’ thermal performance and predict human thermal comfort. The accuracy of the results of the simulations changes as a function of the quality of the input data and basic assumptions supplied (Hyde, 2000, Clarke, 2001, and CIBSE, 2006). TAS was used to predict thermal comfort in SHC shelters through calculating the predicted mean vote (PMV) considering all possible sources of input data that required for the simulation. Out of 155 surveyed shelters, 21 shelters were selected to be simulated (10 old shelters and 11 new shelters). The difficulties in obtaining model inputs for SHC are a major obstacle particularly with regard to shelters’ geometry, construction material, and internal gains. These data were collected through field survey and the weather data were obtained for Bayt Dajan weather station 32^{o}N 34.82^{o}E which is located in the north of Jabalia camp in the coastal area in Palestine.

Predicted mean vote (PMV) was calculated for the main spaces in the shelters using TAS. The parameters of metabolic rate, air velocities, and clothing are required to be entered by the user of the programme for calculating the PMV, where other parameters such as temperature and humidity are calculated by the TAS itself. A single value is required to be set for metabolic rate and a range of two values are required to be set for air velocities and clothing. It is worth noting that in estimating PMV by TAS, two PMV values are calculated (one using the lower air speed and upper clothing value, the other using the upper air speed and the lower clothing value) and the better of the two in terms of thermal comfort is provided as outputs. This means that the lower clothing value and the upper air speed are used to calculate PMV in summer while the upper clothing value and the lower air speed are used to calculate PMV in winter. A metabolic rate of 1.2 met, which is the value for sedentary activity (EN ISO 7730, 2005), was set to calculate PMV in the studied shelters. The lower clothing value was set 0.5 clo (which is for light summer ensemble), and the upper clothing value was set 1 clo (which is for typical indoor winter ensemble) (Goulding et al., 1992). Internal air speed was set 0.1 to 0.3 m/s, where 0.1 m/s is classified as “not noticeable airflow” and 0.3 m/s is classified as “barely noticeable airflow” (Natural frequency, 1994).

4 ANALYSIS AND DISSCUSSION

4.1 Thermal Sensation Vote (TSV) in Summer and Winter

Occupants' thermal sensation vote (TSV) was collected for every space, and then TSV was calculated for the whole shelter (TSV_t) by computing the average thermal sensation votes for all spaces. As some old shelters comprise open courtyards, TSV for old shelters it is calculated for the indoor spaces (TSV_{indoor}) and for the whole shelter including courtyards (TSV_t). The results for old and new shelters are presented in table 2. Mean TSV_t for old shelters is over (+2), while mean TSV for courtyards is (+1.41) which is lower than that for indoor spaces ($TSV_{indoors}$= +2.59). In new shelters, mean TSV_t in summer is slightly lower (+2). In winter, mean TSV_t for both old and new shelters is lower than (-2), with the highest reported for new shelters (TSV_t= -2.07), followed by indoor spaces of old shelters ($TSV_{indoors}$= -2.46), and the lowest reported for courtyards (TSV_{court}= -2.87).

Season	Shelter type	TSV	Mean	Mode	Min	Max	Std. dev.
Summer	Old	TSV_{court}	1.41	.00[a]	0	3	1.15
		$TSV_{indoors}$	2.59	3	.25	3	0.66
		TSV_t	2.48	3	.25	3	0.66
	New	TSV_t	1.95	3	-.25	3	1.05
Winter	Old	TSV_{court}	-2.87	-3	-3	-1	0.43
		$TSV_{indoors}$	-2.46	-3	-3	0	0.77
		TSV_t	-2.50	-3	-3	-.17	0.72
	New	TSV_t	-2.07	-3	-3	0	1.03

a. Multiple modes exist. The smallest value is shown

Table 2: Thermal Sensation Vote TSV in old and new shelters

For a comparison between the two groups of shelters, preliminary analyses were performed first to examine the normality of TSV in summer and winter for the both groups of old and new shelters. The normality test revealed that TSVs are not normally distributed (see figure 5); therefore, non-parametric test Mann-Whitney U is applied to compare TSV in old shelter with TSV in new shelters.

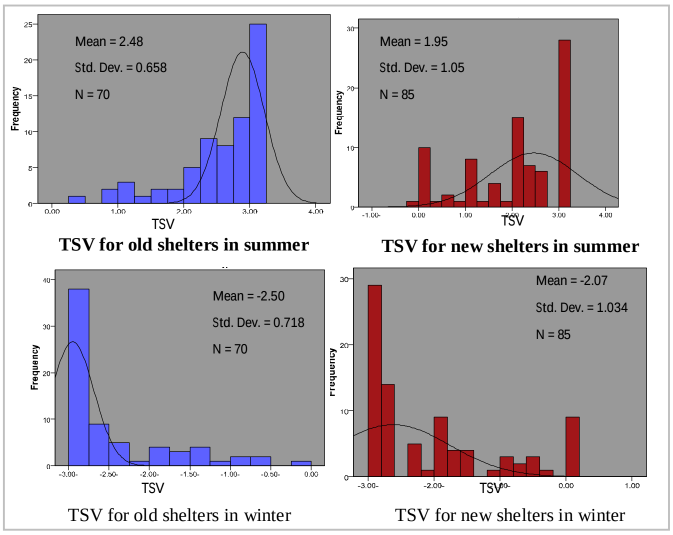


Figure 5: TSV distribution for old and new shelters, in summer and winter

In summer, a Mann-Whitney U test revealed a statistically significant difference in TSV for old SHC shelters (n=70) and TSV for new SHC shelters (n=85), ρ=.004, with a small effect size (r=.23). The median of TSV for old shelters (Md=2.75) is higher than the median of TSV for new SHC shelters (Md=2.2) as indicated in figure 6. In winter, a Mann-Whitney U test revealed also a significant difference in TSV for old SHC shelters and TSV for new SHC shelters, ρ=.010, with a small effect size (r=.21). The median of TSV for old shelters (Md=-2.87) is lower than the median of TSV for new SHC shelters (Md=-2.6).

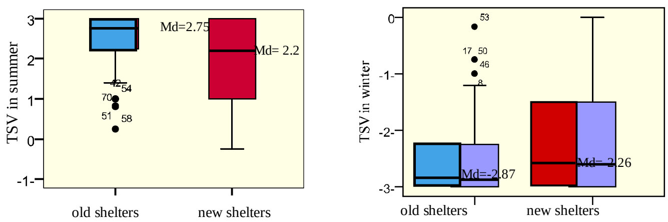


Figure 6: **Box-plots of TSV distribution in summer and**

For a comparison between summer and winter, occupants were asked to indicate in which season they think that their shelters are better in terms of thermal comfort, by providing them three option for selection (in winter– in summer– the same). Another approach for the comparison is also applied by inspecting TSV_t which calculated earlier as the average for all spaces, for summer and that for winter. In this approach, the absolute value of TSV in winter $|TSV_{winter}|$ is used, then winter is considered better when ($TSV_{summer} > |TSV_{winter}|$), summer is considered better when ($|TSV_{winter}| > TSV_{summer}$), and they are considered the same when ($TSV_{summer} = |TSV_{winter}|$). Figure 7 provides comparison between summer and winter by applying the two methods explained above; (in general) approach and (mean TSV) approach. As indicated in figure 7, the distribution of old shelters across the three options is similar to the distribution of new shelters. About 40% of occupants demonstrated that their shelters are better in summer which is compatible with the (mean TSV) method. However, only 7 to 13% of occupants demonstrated that their shelters are better in winter which is not compatible with (mean TSV) approach, where one-third of shelters are considered better in winter. The second approach (mean TSV) is more accurate because occupants rated every space in their shelters using the 7–point thermal sensation scale. The reason that voting for winter is decreased by the occupants could be related to psychological and behavioural factors such as occupants' suffer from rain leaks to their shelters during winter. Besides, most activities in winter have to be done indoors, unlike summer where many activities are done outdoors, where the thermal environment is more comfortable than indoor condition.

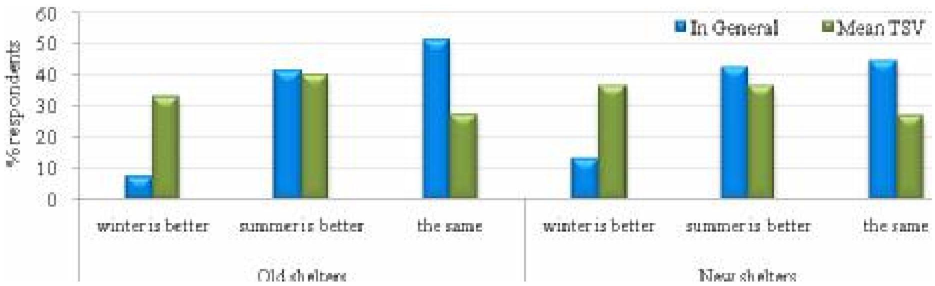


Figure 7: Which is better in terms of thermal comfort: summer or winter?

To compare TSV_{summer} with $|TSV_{winter}|$. a Wilcoxon Signed Ranks Test is utilized as the variables of TSV are not normally distributed and the data are paired. The test revealed no statistically significant difference between TSV_{summer} and $|TSV_{winter}|$ in both old SHC shelters (ρ=.574) and new SHC shelters (ρ=.44) with very small effect size (r=.05 in old shelter and r=.06 in new shelters). In old shelters, the median of TSV_{summer}, Md=2.75 is close to median of $|TSV_{winter}|$, Md=2.87. In new shelters, the median of TSV_{summer}, Md=2.2, is also similar to median of $|TSV_{winter}|$, Md=2.26.

To sum up, indoor thermal environment during summer and winter is not comfortable in both old and new shelters; with trend to be worse in old shelters. Further, in inspecting which season is worse in terms of thermal comfort, summer or winter, it was revealed no significant difference between them.

4.2 Energy Consumption for Cooling

Means used by shelters' occupants for cooling during summer were surveyed revealing that vast majority of occupants (96-97%) were utilizing natural ventilation for cooling. Besides, around 80% and 82% of respondents were using electric fans for cooling in old and new shelters respectively. Air conditioning is not used in the shelters. The times and hours of using natural ventilation and electric fans during summer days were explored in old and new shelters along with investigating of potential correlation between number of hours and TSV. Figures (8 and 9) show the times of using natural ventilation and fans through 24 hours.

Figure 8: Times of using natural ventilation

Figure 9: Times of using electric fans

a. Natural Ventilation (NV): In the morning, the percentage of occupants using natural ventilation for cooling rises gradually reaching peak of 95.3 and 97.1% in new and old shelters respectively at 10-12 am. After that, the percentage of using natural ventilation remains almost stable till 8:00 pm where it starts to drop steadily. At 2:00 am the percentage of occupants using natural ventilation levels off at 50.6% in new shelters and at 25.7% in old shelters. There is almost no difference in the percentage of using NV between old and new shelter during the day, while in the evening and during the night using NV in new shelters tends to be higher with a maximum difference of 25%. As shown in figure 8, the trend of external temperature is similar to the trend of percentage of using NV, where external temperature and using NV reach peak in the morning and both drop during the night. Subsequently, it could be concluded that using natural ventilation in SHC shelters is more affected by other factors than it is affected with thermal factor. Most of the occupants close windows during the night (where the windows should be opened to allow for night ventilation as external temperature falls down) seeking for more security, or more visual privacy, or to avoid hazards.

b. Electric Fans: Overall, percentage of using electric fans for cooling is higher than that of NV with minimum of 60.07% and 68.6% in old and new shelters respectively. In the morning, the percentage of occupants using electric fans rises gradually reaching peaks of 98.6% at 14-16 in new shelters and 98.2% at 16-18 in old shelters. Afterwards, in new shelters, using electric fans decreases steadily till 2:00 am where it levels off at 68.6%. In old shelters, using fans drops sharply from 87.5% at 22:00 to 60.7% at midnight.

Unlike using NV, times of using electric fans are somewhat more affected by thermal factor; as by rising in external air temperature, there is generally an increase in using electric fans and by dropping in external air temperature, using fans almost decreases.

In addition to investigate times of using cooling means, number of hours using them is also examined. It is revealed that about 47% and 55% of old and new shelters (which utilize fans for cooling) respectively use electric fans 24 hours. Besides, almost one-quarter of old shelters and one-half of new shelters utilize natural ventilation 24 hours. Table 3 provides statistical description for the number of hours using cooling means.

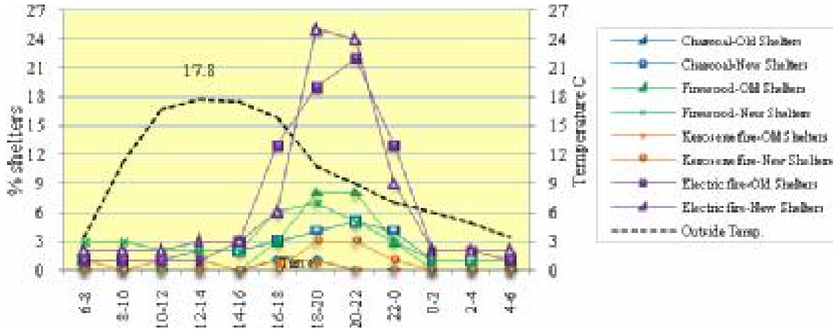
Cooling means	Shelter Type	Mean	Mode	Median	Min.	Max.	Std.Dev.
Electric fans	old	18.68	24	24	2	24	6.97
	new	19.91	24	24	4	24	6.57
Natural ventilation	old	16.03	14	16	0	24	6.06
	new	18.56	24	24	0	24	6.55

Table 3: Descriptive statistics for number of hours using cooling means

For a comparison between old and new shelters, preliminary analyses were firstly performed to examine the normality of number of hours of using fans and NV for the both groups of old and new shelters. The normality test revealed that number of hours variables are not normally distributed; therefore, non-parametric test Mann-Whitney U is applied. The test revealed no statistically significant difference in number of hours using electric fans as cooling means in old SHC shelters with that in new SHC shelters (ρ=.339), with a very small effect size (r=.09). However, a Mann-Whitney U test revealed a significant difference in number of hours using Natural Ventilation NV as cooling means in old SHC shelters (n=70) and that in new SHC shelters (n=8), ρ=.005, with a small effect size (r=.22). The median of total hours using NV in old shelters (Md=16) is lower than the median of total hours using NV in new SHC shelters (Md=24). Furthermore, potential correlations between TSV in summer and the number of hours of using fans and NV were explored using Spearman's rho Correlation Coefficient. It was revealed that there are non-significant weak positive correlations between TSV and number of hours of using Fans, r= .07, n=126, ρ=.433 and between TSV and number of hours of using NV, r= .04, n=155, ρ=.596.

4.3 Energy Consumption for Heating

Survey revealed that various means for heating during winter are used in SHC shelters including; electric fires, firewood, charcoal and kerosene fires. No air conditioning or gas fires are used. It is worth to mention that over one-half of SHC shelters' occupants (56.1%) do not use any heating means in winter which could be related to their financial conditions. Electric fires are the most used (about one-third of shelters) followed by firewood, charcoal, and the least used is kerosene fires. The times and hours of using heating means during winter days were explored in old and new shelters along with investigating of the potential correlation between number of hours and TSV. As revealed by the survey, most of occupants use heating means in the evening where the percentage rises at 16:00 reaching the peak between 18:00 and 22:00 then fall at the mid of the night. External temperature usually reaches its peak at 12:00-14:00 then starts to fall down to its minimum during the night (see Fig 10). It could be deduced that the times of using heating means are significantly affected by human behaviour and activities along with thermal factor. When all family members gather in the evening, they cluster around the heating device, and they turn it off before getting into bed for safety issue.



In addition to investigate times of using heating devices, number of hours using them is also examined and statistical description is provided in table 4. It is obvious that the median hours range between 4-8 hours, while the minimum is two hours a day and the maximum is 24 hours a day.

Heating Means	Shelter Type	N	Mean	Mode	Median	Min.	Max.	Std.Dev.
Kerosene fire	old	1	4	4	4	4	4	
	new	4	5	2[a]	5	2	8	2.58
Charcoal	old	1	4	4	4	4	4	
	new	6	8.7	6	6	4	24	7.55
Firewood	old	8	5.5	6	6	4	6	0.93
	new	7	10.3	4[a]	8	4	24	6.97
Electric fire	old	24	6.6	6	6	2	24	4.11
	new	26	6.3	4	4	2	24	5.14

a.Multiple modes exist. The smallest value is shown

Table 4: Descriptive statistics for number of hours using heating means

Preliminary analyses were also performed to examine the normality of number of hours of using each heating device for both old and new shelters. The normality test revealed that the hours variables are not normally distributed; therefore, Mann-Whitney U test is applied to compare old shelter with new shelters and Spearman's rho Correlation Coefficient is utilized to find the relationship between TSV in winter and hours of using heating means. Since the numbers of users for Kerosene fire, Charcoal, and Firewood are small, the comparison between old and new shelters was performed on only the hours of using electric fires (n=50).The test revealed no statistically significant difference in hours using electric fires in old SHC shelters (n=24) and number of hours in new SHC shelters (n=26), ρ=.121, with a medium effect size (r=.22).

In terms of correlation between TSV in winter and hours of using heating means, it was revealed a statistically significant and strong negative correlation between TSV and number of hours using Kerosene Fire, r= -.947, ρ=.014, with high level of TSV associated with lower number of hours using Kerosene Fire. However, statistically non-significant correlations were found between TSV in winter and the rest heating means.

4.4 FACTORS OF THERMAL COMFORT

Various factors that could influence thermal comfort in SHC shelters were inspected including; environmental and secondary factors along with examining the effect of floor level and envelope materials. Potential correlations between TSV and these factors were explored as well. The results and findings are discussed below.

4.4.1 Environmental Factors

Air humidity, air circulation, and indoor solar radiation in SHC shelters were investigated. It is observed that majority of occupants (85.7%) in old shelters demonstrated that the air is too humid inside their shelters during winter, while around two-fifth and 38.8% of new shelters were recorded to be "too humid" and "humid" respectively (see fig 11).

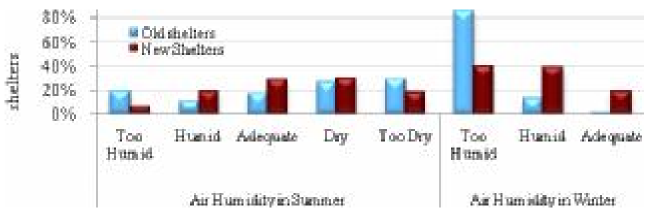


Figure 11: air humidity in old & new shelters

In terms of air circulation in summer, around two-third of old shelters' occupants and less than one-half of new shelters' occupants reported that the air is "still" inside their shelters, while the rest of occupants demonstrated that the indoor air circulation is moderate. In winter, "too much" air circulation was recorded for majority of old shelters and one-fifth of new shelters, while "moderate circulation" was recorded for one-fifth of old shelters and two-fifth of new shelters (see fig 12).

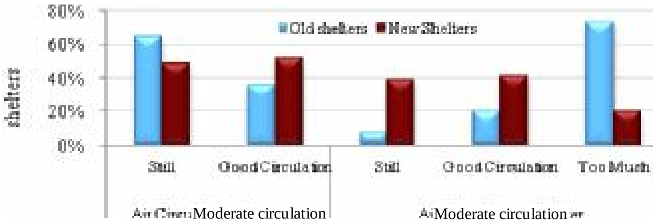


Figure 12: air circulation in old & new shelters

Indoor solar radiation was examined in SHC shelters through surveying its access frequency to shelters a line with rating for its intensity during summer and winter. The survey revealed that, solar radiation never access almost one-half of shelters during winter and it seldom access about 43.5% of new shelters and one-third of old shelters. Subsequently, almost 44% of new shelters' occupants and 38% of new shelters' occupants demonstrated that the intensity of solar radiation in their shelter is poor. In summer, as indicated in figure 13, solar radiation always access almost one-quarter of old shelters and only 7.1% of new shelters while it often access about two-fifth of new shelters and 23% of old shelters. Accordingly, almost 17% of new shelters' occupants and a mere 3.5% of new shelters' occupants demonstrated that the intensity of solar radiation inside their shelter is too much during summer (see fig 13 and 14). The survey also revealed that almost three-quarter of occupants in old shelters did not have control on solar radiation inside their shelters.

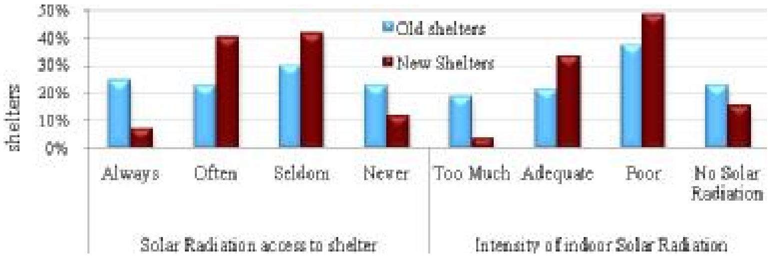


Figure 13: Indoor solar radiation in summer

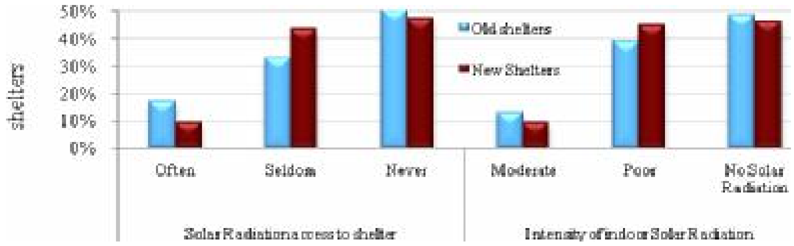


Figure 14: Indoor solar radiation in

Comparisons between old and new shelters in terms of environmental factors were carried out utilizing Pearson Chi-square test. It was revealed statistically significant association between old and new shelters in air humidity in summer (ρ=.02, 4df) and in winter ($p<.001$, 2df) where air humidity level in old shelters is higher. In addition, the test revealed statistically significant association between old and new shelters in air circulation in summer (ρ=.045, 1df) and in winter ($p<.001$, 2df) where air circulation in new shelters is lower. On the other hand, no statistically significant association between old and new shelters was found in solar radiation access in winter (ρ=.226, 2df) and indoor solar radiation intensity in winter (ρ=.664, 2df). However, in summer, statistically significant association between old and new shelters was revealed in solar radiation access (ρ=.002, 3df) and indoor solar radiation intensity (ρ=.006, 3df) where access and intensity of solar radiation are higher in old shelters.

4.4.2 Correlation Between TSV and Environmental Factors

As TSV variables are not normally distributed, the relationships between TSV and the environmental factors; including air humidity, air circulation, availability, intensity and control of solar radiation, were explored for summer and winter using Spearman's rho Correlation Coefficient. In addition, the relations between these several factors were examined. The results are presented in the correlation matrixes in tables (5 and 6).

In summer: the correlation analysis revealed a statistically significant moderate negative correlation between TSV_{summer} and air circulation (r= -.401, $p<.001$), with high level of air circulation associated with lower level of TSV. The correlations between TSV_{summer} and the other factors are found statistically non-significant. In addition, the test showed the sort of relations between environmental factors each other. The highest and the strongest correlation was found between intensity of solar radiation and availability of solar radiation (r = 0.888, $p<.001$), which is an expected result as more available sunshine associated with more intensity of solar radiation.

The rest of correlations between environmental factors ranged between weak and moderate correlations. Among the statistically significant correlations, a weak positive relation was revealed between air circulation and availability and intensity of solar radiation (r=.288, and r=.263 respectively).

		Spearman's rho	TSV in Winter	Air Humidity	Air Circulation	Control Air Circul.	Solar Rad. Avi.	Solar Rad. Int.
	TSV in winter	Correla. Coeff.	1					
		Sig. (2-tailed)	.					
		N	155					
	Air Humidity	Correla Coeff.	**-.374****	1				
		Sig. (2-tailed)	**.000**	.				
		N	**155**	155				
	Air Circulation	Correla. Coeff.	-.152	**.340****	1			
		Sig. (2-tailed)	.058	**.000**	.			
		N	155	**155**	155			
	Control Air Circulation	Correla. Coeff.	.107	-.155	-.117	1		
		Sig. (2-tailed)	.377	.200	.334	.		
		N	70	70	70	70		
Solar Radiation	Availability	Correla. Coeff.	.098	-.126	**.274****	-.008	1	
		Sig. (2-tailed)	.226	.119	**.001**	.946	.	
		N	155	155	**155**	70	155	
	Intensity	Correla. Coeff.	.145	**-.189***	**.243****	.022	**.917****	1
		Sig. (2-tailed)	.071	**.019**	**.002**	.854	**.000**	.
		N	155	**155**	**155**	70	**155**	155

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table 6: Intercorrelations-TSV in winter and Environmental Factors

In winter: The analysis showed that TSV_{winter} correlated moderately with air humidity (r= -.374, p<.001), with high level of air humidity associated with lower level of TSV. The other revealed correlations are non-significant weak positive and negative. Besides, the correlations between environmental factors each other ranged between weak and strong correlations. Like summer, the strongest significant correlation was found between intensity of solar radiation and availability of solar radiation (r = .917, *p<.001*). In addition, air circulation correlated moderately with air humidity (r = 0.340, *p<.001*), while the rest significant correlations between environmental factors were weak.

4.4.3 Secondary Factors of Thermal Comfort

As TSV variables are not normally distributed, the relationships between TSV and the secondary factors; including gender, age, and occupancy period were explored for summer and winter using Spearman's rho Correlation Coefficient. All correlations revealed by the analysis were weak, positive and negative, with only one significant correlation between TSV_{winter} and occupancy period (r = -.164, *p=.041*), while other correlations were non-significant (see table 7).

	Spearman's rho	TSV in summer	Gender	Age	Occupancy period
TSV in summer	Correlation Coefficient	1.00	-.038	-.031	.055
	Sig. (2-tailed)	.	.641	.702	.493
	N	155	155	155	155
TSV in winter	Correlation Coefficient	-.379**	.062	-.077	**-.164***
	Sig. (2-tailed)	.000	.441	.340	**.041**
	N	155	155	155	**155**

Table 7: Intercorrelations-TSV and secondary factors

4.4.4 The Effect of Materials on Thermal Comfort

The effect of envelop materials (comprising walls, roofs, and windows) on thermal comfort was examined by applying statistical analysis tests such as Kruskal-Wallis test and Mann-Whitney test. In SHC shelters, several materials could be found in a single shelter. To examine the effect of single material of one building component on TSV, shelters with one type of material is considered in the analysis and shelters with several materials are excluded. For instance shelters with concrete roofs were compared with shelters with asbestoses sheets roofs, while shelters including concrete and asbestoses sheets roofs together were excluded. Thus the number of cases considered in these tests decreased. The effect of the various floor materials on TSV could not be conducted because the number of shelters comprising a single type of floor materials is small, excluding only one type of floor material (terrazzo tiles).

a. Wall Materials: To examine the influence of wall materials, TSV for shelters comprising only concrete block walls was compared with TSV for shelters comprising only sand block walls, while shelters comprising concrete and sand block together were not considered. As the variables of TSV are not normally distributed and the data are unpaired, Mann-Whitney test was utilised which revealed a significant difference in TSV for shelters with sand block (n=21) and TSV for shelters with concrete block (n=126) in summer and winter, with a small effect size (ρ=.041, r =.16 for summer and ρ=.015, r =.2 for winter). In summer, the median of TSV for shelters with concrete block (Md=2.31) is lower than the median of TSV for shelters with sand block (Md=2.31), while, in winter, the median of TSV for shelters with concrete block (Md=-2.67) is higher than the median of TSV for shelters with sand block (Md=-3). This means that shelters consisting of sand block walls are hotter in summer and colder in winter than shelters consisting of concrete block walls (see fig 15).

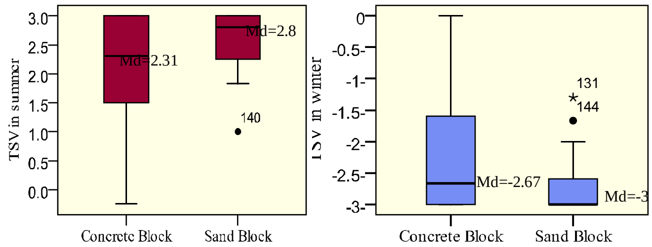


Figure 15: distribution of TSV according to wall materials

b. Roof Materials: Kruskal-Wallis Test was utilized to investigate the effect of roof materials on thermal comfort by comparing TSV of three groups of shelters comprising; shelters roofed with only concrete slab, shelters roofed with only asbestoses sheets, and shelters roofed with only corrugated iron. This test was applied as the variables of TSV are not normally distributed and the data are for more than two groups. The test showed a statistically non-significant difference in TSV across the three groups (ρ=.231 for summer, ρ=.140 for winter). Mann-Whitney Test was then performed between pairs of groups to investigate if there is any significant difference in TSV between every two types of roof materials. The test also indicated no statistically significant difference (see Fig 16). What is interesting to note (although it is statistically not significant) that the highest recorded TSV in summer was overall for corrugated iron shelters followed by asbestoses sheets shelters and the lowest TSV recorded for concrete slab shelters. In winter, TSV in concrete slab shelters is generally higher than that of asbestoses sheets and the lowest TSV was reported for corrugated iron shelters.

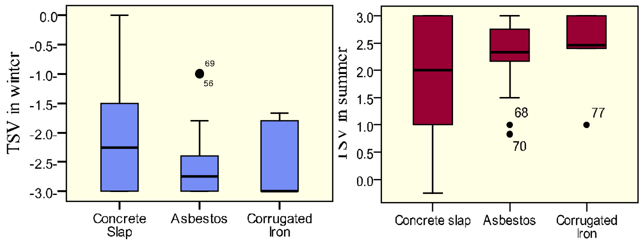


Figure 16: distribution of TSV according to roof materials

c. Windows Types: Kruskal-Wallis Test was also performed to investigate if there is significant difference in TSV for shelters with different windows types. The test is applied on three types of windows; wooden, plastic louvered, and glazing with external shutters windows, as the numbers of the rest types are small. The test showed a non- significant difference in TSV for shelters with the three types of windows for summer (ρ=.165) and winter (ρ=.094). Mann-Whitney Test was then performed to investigate if there is any significant difference in TSV between every two types of windows. The test indicated only a significant difference in TSV for winter between shelters comprising wooden windows (n=29) and shelters comprising glazing with external shutters windows (n=45), ρ=.031, with a small effect size (r=.25). The median of TSV for shelters with wooden windows (Md=-3) is lower than the median of TSV for shelters comprising glazing with external shutters windows (Md=-2.75) (see fig 17). This means that shelters comprising wooden windows are colder in winter than shelters comprising glazing with external shutters windows.

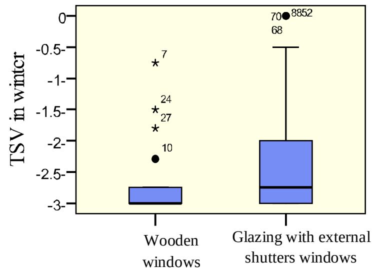
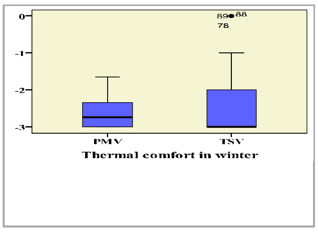


Figure 17: distribution of TSV in winter according to windows types

4.5 THERMAL COMFORT– TAS RESULT vs. SURVEY RESULT

Thermal comfort in the main spaces of the SHC shelters is predicted by TAS through estimating the hourly Predicted Mean Vote (PMV), and is also estimated in the field survey by the occupants' thermal sensation vote (TSV). Comparisons between the results from the both methods of predicting thermal comfort were carried out where; the maximum PMV is contrasted with the occupants' TSV for summer, and the minimum PMV is contrasted with the occupants' TSV for winter. The courtyards are excluded from the comparison between the PMV and the TSV because the PMV is designed for the internal spaces.

Potential correlations between PMV and TSV were explored at first using Spearman's rho Correlation Coefficient. The results revealed that PMV correlated moderately with TSV in both summer and winter (r=.416 & .348, ρ<.0001 & ρ=.001 respectively, and n=93). A Wilcoxon Signed Ranks Test was utilized also to investigate if there is a significant difference between TSV and PMV. The test revealed a statistically significant difference between TSV and PMV where; PMV is higher than TSV in summer (ρ=.001), while TSV is higher than PMV in winter (ρ=.030) (see figure 18).



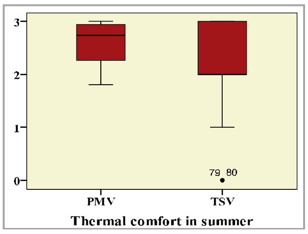


Figure 18: Distribution of TSV and PMV in SHC shelters in both summer and winter

These results agree with various field studies in hot climate which have shown that the PMV is higher than the actual mean vote by the occupants (Ealiwa et al. 2000, Olesen and Parsons 2002, Heidari and Sharples 2002, Humphreys and Nicol 2002a, CIBSE 2006, and ASHRAE 2009). The difference between the survey data (TSV) and the computer modelling data (PMV) could be due to the occupants' behavioural, physiological and psychological adaptations which make the occupants more tolerant to hot and cold environments, particularly that the studied shelters are naturally-ventilated. This also appears to confirm the suggestions by Olesen and Parsons (2002) and Nicol (2004) about the limitations of the PMV in predicting thermal comfort in naturally-ventilated buildings.

Humphreys and Nicol (2002b) in their research paper stated that by subtracting TSV from the corresponding PMV for each survey instance, an unbiased but low precision estimate of the discrepancy between PMV and TSV can be obtained, and they suggested using ±0.25 scale unit as the indication of whether the PMV has significant bias in predicting TSV. Therefore, the mean of PMV–TSV discrepancy would need to be within ±0.25 scale unit to indicate an acceptable bias

It is worth to highlight that the tools and processes used to calculate the PMV and the TSV in this study are different from those used by previous researches and that could allow for a wider margin of acceptable bias for two reasons. First, in the previous researches the PMV is calculated using the parameters (including temperature, humidity, air velocity, pressure, metabolic rate, and clothing value) which are measured in the field at the same time of recording the TSV while the PMV in this study is calculated using computer simulation. In simulating the PMV by TAS, some parameters such as humidity and temperature are estimated by the programme and other parameters such as air velocity, metabolic rate, and clothing value are assumed by the researcher as mentioned earlier. Measuring these values in the field would be more precise than estimating or assuming them. Second, in the previous researches the TSV is recorded by the respondents for the time of conducting the survey, while in this study TSV for both summer and winter is recorded through a survey conducted in autumn. Because of time constraints, the survey was conducted once through the study where autumn was selected to avoid the effects of the extreme hot or cold seasons on the respondents' thermal sensation votes as mentioned earlier.

In this research, discrepancies between PMV and TSV were calculated and their distributions are presented in the histograms in figure

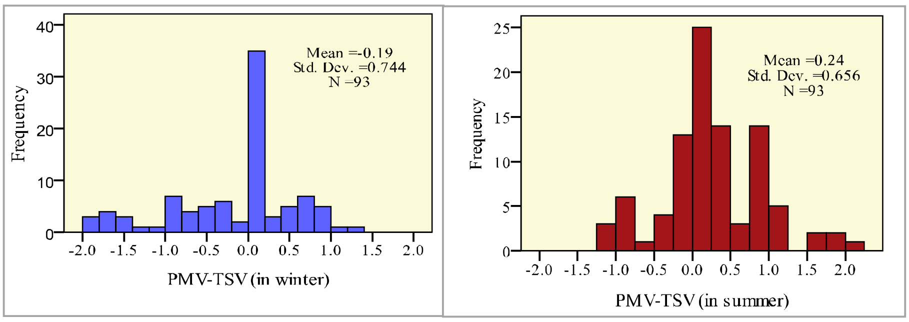


Figure 19: Histograms of PMV–TSV discrepancies in both summer and winter

19. The PMV–TSV discrepancy pattern is a non-normal distribution with a majority of discrepancy of about 0.0 scale units and a maximum discrepancy of about 2.4 scale units. Table 8 summarizes the mean values and standard deviations for PMV–TSV differences in old shelter, new shelter and the combined data in both types of shelters. For both summer and winter, the standard deviations of PMV–TSV discrepancies are less than one scale unit and the mean of PMV–TSV discrepancies is less than 0.25 scale units which is considered an acceptable bias according to Humphreys and Nicol suggestions (2002b). This indicates that PMV estimated by TAS simulation is free from serious bias and could be utilized to predict thermal comfort in the SHC shelters.

PMV-TSV	**old shelters**		**new shelters**		**all shelters**	
	summer	**winter**	**summer**	**winter**	**summer**	**winter**
mean	0.240	-0.241	0.240	-0.146	0.240	-0.191
Std. Deviation	0.453	0.621	0.801	0.843	0.656	0.744
Median	0.000	0.000	0.300	-0.070	0.010	0.000
N	44	44	49	49	93	93

Table 8:: PMV–TSV discrepancies

5 CONCLUSION

The results indicate that indoor thermal environment during summer and winter is not comfortable in both old and new shelters, with trends to be worse in old shelters. For cooling, vast majority of occupants have been utilizing natural ventilation and around 81% of them have been using electric fans as well. Almost one-half of shelters' occupants use electric fans 24 hours a day. For heating during winter, various means are used in SHC shelters including; electric fires, firewood, charcoal and kerosene fires, with an average ranged from 4 to 10 hours a day. However, over one-half of SHC shelters' occupants do not use any heating means which can be related to their financial conditions.

Various factors that could influence thermal comfort in SHC shelters were inspected. The survey revealed that the air is too humid in the majority of shelters in winter. Besides, the indoor solar radiation is generally poor in shelters particularly in winter. The analysis revealed statistically significant moderate negative correlations between TSV_{summer} and air circulation, and between TSV_{winter} and air humidity. Through examining the effect of materials on thermal comfort, results showed that TSV in shelters with concrete block walls is lower than TSV in shelters with sand block walls, in both summer and winter. For roofing materials, although not significant statistically, the highest recorded TSV in summer is for corrugated iron shelters followed by asbestoses sheets shelters and the lowest TSV recorded for concrete slab shelters. In winter, TSV in concrete slab shelters is generally higher than that of asbestoses sheets shelters and the lowest TSV was reported for corrugated iron shelters. In winter, TSV for shelters with wooden windows is lower than TSV for shelters comprising glazing with external shutters windows. Finally, comparison between TSV (questionnaires results) and PMV (TAS results) was conducted. The analysis indicated that PMV correlated moderately with TSV in both summer and winter. A Wilcoxon Signed Ranks Test revealed a statistically significant difference between TSV and PMV; where PMV is higher than TSV in summer, while TSV is higher than PMV in winter. However, the mean of PMV–TSV discrepancies was less than 0.25 scale units.

LIST OF ABBREVIATIONS

NV	Natural Ventilation
PMV	Predicted Mean Vote
SHC	Special Hardship Case
TAS	Thermal Analysis Software
TSV	Thermal Sensation Vote
UNRWA	United Nations Relief and Works Agency

LIST OF NOMENCLATURE

df	Degree of freedom
Md	Median
n	Number of cases
r	Correlation coefficient
Std. dev.	Standard deviation
ρ	Probability value, or significance of a test

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