Retrofitting improved environmental performance in refugee housing in Jerash Refugee Camp Jordan

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Abstract: Jordan is the second largest refugee host country in the world per capita. Around fourteen Jordanian refugee camps have transitioned from emergency shelters to permanent settlements, with Jerash Refugee Camp being one of the oldest and most deprived camps. The current housing in the camp is believed to be responsible for thermal discomfort and illness to its inhabitants. This study examined a retrofit strategy to improve occupant's thermal comfort and indoor environment. Following a site visit, one house was selected and modelled digitally to represent a typical dwelling in the camp. This served as the baseline case against which to test the effectiveness of applying different several retrofit passive strategies, such as thermal insulation, natural ventilation, window size and passive heating, on the levels of indoor thermal comfort and indoor daylight quality. An epw weather file generated by Meteonorm for the camp's location was used with the dynamic modelling software DesignBuilder, and PMV thermal comfort levels were analysed. Very low daylight levels in the house add to the poor environment and so daylight levels were evaluated using the Revit plug-in for Sefaira software. The results of the simulations showed that the proposed strategies did have an impact on the indoor thermal comfort values, especially the addition of thermal insulation to the building's external envelope. The proposed passive strategies resulted in a shift in the hourly and daily-recorded PMV values to within the acceptable comfort range and an increase in the average daylight factor from 0.07% to 0.95%. The approximate cost estimation of the proposed retrofit strategy is around 21,243 JDs.

Keywords: PMV values, Thermal Comfort, Retrofit ,Design Builder, Sefaira , Long-term refugee settlements

Introduction

The U.N. High Commission for Refugees, states that there are 19.5 million refugees worldwide. Moreover, 38.2 million people are relocated within their own countries. Jordan is ranked amongst the top 10 refugee hosting countries in the world. It is also categorized as the second largest host country in the world of refugees per capita. Nearly 41.2 % of the country's population is refugees, thus making it the home for approximately 2.7 million refugees. Jordan encompasses approximately fourteen refugee camps; the settlements were originally set as temporary emergency solutions. Generally, refugee camps are designed as short-term shelter solutions in response to a crisis. Nevertheless, it appears to be that the average life span of a refugee camp is 17 years.(Lahn et al. 2016) In Jordan most of the refugee settlements were created 40 years ago and remain present to date. Jerash refugee camp is a camp that was initially set up as a temporary emergency settlement back in 1968 and is occupied by 11,500 displaced Palestinian refugees. Located about 5km away from the ruins of Jerash, the camp covers approximately 0.75 square kilometres of land. The current statistics on Jerash Refugee camp show that the camp is a home for over about 24,000 refugees occupying 2,000 housing structures.

With time, the occupants altered the temporary structure of the shelters to create for themselves more durable dwellings. The building envelope that makes up the current housing structures at the camp consists of the following elements; concrete walls covered with corrugated zinc roofs and asbestos sheets. The houses are poorly insulated with no sufficient daylight or proper ventilation. The structure of the housing is believed to be responsible for the cause of several diseases including cancer to its inhabitants. (FaFo Report,2013)

The focus in this study is derived from the necessity to improve the permanent post-disaster housing conditions in Jordan. With the number of refugee camps increasing and the settlements changing from temporary emergency shelters to long-term permanent settlements there appears to be a need to create more resilient and durable housing structures that offer comfortable indoor environments to its occupants.

Location of the Study

Geographically, Jordan is situated in Southwest Asia. The capital of Jordan is Amman. This research studies Jerash Refugee camp, which is located in Jerash Governorate, Jordan. Jerash is situated in the North of Jordan, about 48 km away from the capital city Amman.

Given that Jerash Camp is the field of this study, an understanding of the region's climate and geographical location must be established. This section outlines the location and climate conditions of Jerash Governorate, Jordan. Jerash's climate is classified as a "Csa" by the Köppen-Geiger system, which is essentially a representation of "Warm Mediterranean climate". The table below shows the monthly average temperature ranges for Jerash based on the epw weather files obtained from Climate Consultant. According to the climate analysis the hottest month of the year is July, and the coldest month is January.

Table 1 Temperature Values for Jerash Jordan Obtained from Climate Consultant

Monthly Means	**Jan**	**Feb.**	**Mar.**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Dry Bulb Temp. C°	8	9	13	16	21	24	26	25	23	20	14	10
Dew Point Temp. C°	3	4	5	6	8	12	15	16	14	11	6	4

Camp Overview

The average size of the families living in the camp is seven members per family. The average income of each household is 100 Jordanian Dinars (JDs), which converts to approximately £110. The average annual electricity bill is 120 JDs, which breaks down to 10 JDs a month. In effect, occupants spend about 10% of their monthly income on electricity bills. According to the Committee to improve Jerash camp, the main issues the camp faces are extreme poverty, a high percentage of unemployment, and overcrowding. Furthermore, UNRWA states that about 3 out of every 4 dwellings are not suitable for housing due to structural problems. (FaFo Report,2013)

The amenities available on the camp's site are;

- Four schools in two buildings with two shifts. (Due to the large number of students.)
- One food distribution centre.
- One health centre.
- One community rehabilitation centre.
- One centre for women's programs.
- One Development office for the camp

Identifying the gap

By observing the available examples of post-disaster settlements, a conclusion can be made that the energy performance of these structures is not efficient. When these settlements are built there is no consideration with regards to the sustainability and the durability of the housing structures. The available guidelines for post-disaster shelters are generic, with no specific regards to the settlements" location, climate, and cultural and social needs of the inhabitants. However, there is some recent research available regarding the implementation of sustainability and resilience in post-disaster settlements, for both temporary and permanent settlements. Nonetheless, there remains an evident absence for this consideration in permanent refugee settlements in Jordan.

Research Aim

The focus of the study will be on analysing the existing structures in Jerash Refugee Camp based on two indoor environmental factors; indoor thermal comfort and indoor daylight distribution. The study will investigate the impact of specific design parameters on the housing structures. This will be achieved by using the software DesignBuilder EnergPlus for thermal comfort analysed based to Fanger's PMV Index) followed by a daylight factor distribution using the software Sefaria. Improving the occupant's thermal comfort levels essentially refers to controlling the indoor environment of the houses to offer an enhanced indoor environment to the inhabitants. The main issues in the camp of extreme poverty, poor housing conditions and electricity bills costing 10% of the occupant's income, are factors that need to be taken into consideration (FaFo Report, 2013). Therefore, low-cost and technically simple interventions (i.e. insulation, double-glazed windows, shading overhangs, improved night ventilation) are proposed to encourage economic feasibility of improving the structures occupant's comfort in this particular refugee camp. Selecting the suitable methods will be determined by factors such as the climate zone, and the availability of materials. The final part of this research presents an initial cost analysis of the suggested retrofit strategies.

Thermal Comfort Analysis

One of the most significant parameters of Indoor Environmental Quality is thermal comfort. Thermal comfort is defined as "that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation"(ANSI/ASHRAE Standard 55-2010) Effectively thermal comfort refers to how satisfied an occupant is with the thermal conditions within a space. This comfort can be associated with the geographic location and climate, time of year as well as occupant's gender, race, and age.(Quang et al., 2014).Thermal comfort is considered a key factor in reducing a building's energy consumption as it is believed that if occupants are not comfortable with the indoor environment they will resort to alternative methods of heating or cooling. In the 1960's climatic chambers that controlled ambient air temperature, radiant temperature, air humidity and air stream velocity became more accessible. As a result, the assessment of these chambers led to the establishment of indoor human comfort indices to measure thermal comfort (Honjo ,2009). Ole Fanger was the first who developed a widespread model for thermal comfort. To date Fanger's mathematical model is the most acknowledged thermal comfort index and is used in a number of standards and programs.

The predicted mean vote (PMV) is a thermal comfort index developed by Fanger in 1972. It is essentially a function of the following variables: air temperature; mean radiant temperature, air velocity, humidity, clothing resistance and metabolic rate. (Orosa,2009,sustainabilityworkshop. 2017)

The predicted Mean Vote (PMV) uses a seven point sensation scale ($-0.3 < PMV < +0.3$). The scale runs from -3 sensed as cold, to +3, sensed as hot. (designbuilder.co.uk 2017, Autodesk

Sustainability Workshop 2017) This Index will be used to measure the thermal comfort for this research.

The following equation shows Fanger's thermal comfort model that is used to calculate PMV;

$$\boxed{\begin{aligned}PMV = [0.303e^{-0.036M} + 0.028]\{(M - W) - 3.96E^{-8}f_{cl}[(t_{cl} + 273)^4 - (t_r + 273)^4]\\ - f_{cl}h_c(t_{cl} - t_a) - 3.05[5.73 - 0.007(M - W) - p_a] - 0.42[(M - W)\\ - 58.15] - 0.0173M(5.87 - p_a) - 0.0014M(34 - t_a)\}\end{aligned}}$$

(Autodesk Sustainability Workshop, 2017)

With

$$\boxed{\begin{aligned}&f_{cl} = \frac{1.0 + 0.2I_{cl}}{1.05 + 0.1I_{cl}}\\ &t_{cl} = 35.7 - 0.0275(M - W) - R_{cl}\{(M - W) - 3.05[5.73 - 0.007(M - W) - p_a]\\ &\qquad - 0.42[(M - W) - 58.15] - 0.0173M(5.87 - p_a) - 0.0014M(34 - t_a)\}\\ &R_{cl} = 0.155I_{cl}\\ &h_c = 12.1(V)^{1/2}\end{aligned}}$$

(AutodeskSustainabilityWorkshop, 2017)

Where

e	Euler's number (2.718)	f_{cl}	clothing factor	h_c	convective heat transfer coefficient
I_{cl}	clothing insulation [clo]	M	metabolic rate [W/m2] 115 for all scenarios	p_a	vapour pressure of air [kPa]
R_{cl}	clothing thermal insulation	t_a	air temperature [°C]	t_{cl}	surface temperature of clothing [°C]
t_r	mean radiant temperature [°C]	V	air velocity [m/s]	W	external work (assumed = 0)

(Autodesk Sustainability Workshop, 2017)

Methodology

To achieve the set research aim of "improving the occupant 's comfort and the indoor environment in long_-term refugee houses in Jordan." the following research methods were followed: Firstly, data were collected from secondary research such as case studies on existing refugee housing solutions, methods of achieving thermal comfort and low-cost retrofit projects. Investigating the existing knowledge was highly beneficial in forming the base of my research. A basic criterion for this research's design proposal was achieved by combining concepts from other refugee housing as well as retrofit strategies.

Secondly, a site visit was taken to gather data on the existing housing structures, in the form of photographs, notes and sketches.

Thirdly, the digital mock-up model of the existing house was created to be tested using Design Builder EnergPlus. The model is based on the most typical dwelling structure found at the camp. Design Builder's simulation engine is Energy Plus has enabled the author to attain precise records on annual, monthly, and hourly demands for each model, as well as indoor temperature values in housing units and the thermal comfort ranges. Followed by the natural daylight distribution within the structure study performed using the software Sefaria.

The Energy Plus simulation software is a tool used within Design Builder. Energy Plus is a thermal simulation software instrument that permits the investigation of energy performance throughout a building and helps determine the thermal load and energy consumption. The software tool simulates models for heating, cooling, lighting, ventilation, and occupant's comfort. DesignBuilder EnergPlus simulations can generate a number of data on environmental conditions within the building and resultant occupant comfort levels. There are a number of comfort-related outputs that can be generated using Design Builder Energy

Plus. One of the available outputs associated with comfort measurements is Fanger's Predicted Mean Vote calculated based on ISO 7730(Fanger PMV).This output was used for this study to establish the occupant's comfort levels in the existing housing solutions as well as after applying the proposed retrofit methods.(designbuilder-v2.co.uk,2017) Sefaira's daylight analysis function provides day lighting and energy analysis that shows the daylight Factor visualization, and analyse the impact of the glazing ratios, window orientation, and shading strategies on the buildings performance.

The next step acquired was an analysis of the climatic data and the location of the camp. Based on that analysis the initial design strategies for improving the existing structure were proposed.

Next, following the analysis obtained from the climate study as well as the sustainable design approach of the three-tier system presented by Norbert Lechner, some passive basic building design methods were proposed to help improve the thermal comfort and energy performance those include; insulation, improving the walls thermal mass, changing the windows shapes and size to allow for more natural daylight, and shading. The analysis procedure followed is similar procedure to the one used by Heras et al. (2005) was followed. Heras et al monitored a number of buildings calculating indoor temperatures in the winter season as well as summer, investigated the level of thermal comfort reached in each period.

The strategies were added singularly and the model was simulated after every alteration to observe the impact of each strategy individually on the performance of the building. The simulations were run on the model to evaluate it in terms of its thermal comfort based on Fanger's PMV Index. The final step included a brief cost analysis of the proposed design solutions.

Analysis of Existing Structure

Building Geometry

Provided that the current houses in the camp are a result of the occupant's alterations to what was initially set as temporary housing solutions, the houses in the camp are dissimilar. However, the majority are constructed from the same materials; they have the same floor area and exterior render. The base line model for this research will be based on the most typical housing structure found in the camp. Almost every dwelling is made up from the following building elements; concrete walls covered with corrugated zinc roofs and asbestos sheets. The one-story structures each have a total floor area of 80-90m^2. As presented in the image below, the house is divided into an open space area which is generally used for storage, seating and in some cases an empty space that acts a buffer zone between the entrance the rooms. There are typically 2 bedrooms in each house that accommodate 3 to 4 people each.

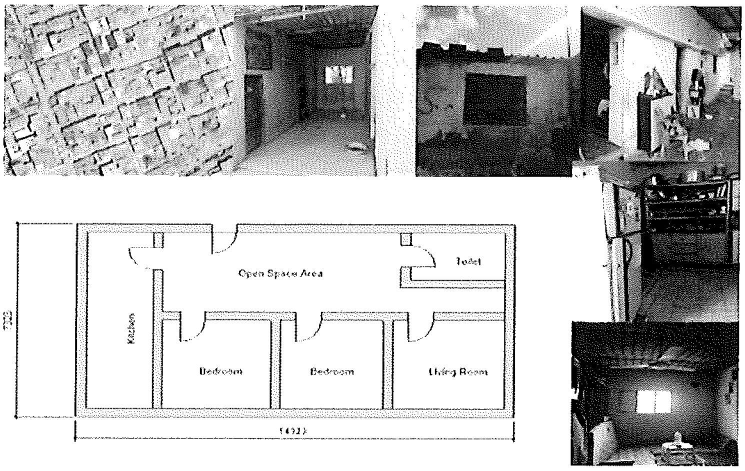

Figure 1 Summary of the Current Dwellings in Jerash refugee camp

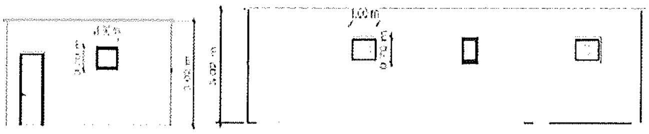

Figure 2 Elevations of the digital mock-up model created by the author to represent the typical dwelling at the camp

Setting the Energy Model Parameters

Prior to running the energy simulations certain parameters need to be defined for the area of study. Weather data in the form of epw files were generated by Meteonorm based the camp's location " Jerash "were imported into DesignBuilder so that the simulations would be based on the climate conditions of the camp's location. To design a sustainable building that consumes less energy the site's climate should be taken into account as for it guides the designer in choosing the adequate passive strategies that are most effective for the specified site. The weather settings remained constant throughout the entire study.

Provided that the houses do not have an HVAC system, the heating and cooling set point temperatures, were set to 0°C. According to the Design Builder's manual, the value of 0 indicates that the equipment is switched off, thus they will not be included in the simulations. (Designbuilder-v2.co.uk.2017). To represent the cracks and holes found in most of the houses in Jerash Refugee Camp, the airtightness settings were set to "crack template " on the scale "very poor". The remaining settings were kept as default settings.

Retrofit Strategy

Airtightness (Alteration 01)

Air tightness depends on the number and size of air leakage paths as well as the difference in air pressure between the inside and outside. By observing the external fabric of most of the housing structures in the camp it can be clearly predicted that the cracks in the external walls are a major source of air leakage. Air tightness will enhance the indoor comfort as well as the overall air quality. To improve the airtightness it is proposed that all cracks and openings in the external fabric should be fixed. This was represented in Design Builder by changing the cracked template from "poor" to "excellent" to resemble fixing the holes and cracks in the existing wall structure.

Insulation

For insulation a layer of Polystyrene boards with a thickness of 5 cm was added to reduce the thermal transmittance. The current wall structure in Jerash camp consists of un-insulated concrete block walls with an estimated U-value of 2.181 W/m. In a study Al Zyood et. al. shows that a thermal insulation 5.7 cm and of trombe wall, is able to decrease a building's heating requirements by approximately 82%.Therefore it is predicted that such a strategy will be effective in terms of creating a more comfortable indoor environment during the winter.

The parameters were changed in the DesignBuilder model were; the addition of a 5 cm thick polystyrene layer of insulation and exterior render to the walls. This improved the U-values to 0.50 W/m. Insulating the buildings envelope will help keep a constant indoor temperature all year round. By insulating the envelope, the structure will be protected against cold in winter and excess heat gain in summer. (AutodeskSustainabilityWorkshop, 2017)

Apertures for Natural Ventilation & light distribution (Alteration 02)

Due to the housing layout in Jerash Refugee Camp the massing and orientation of the housing structures is limited. Therefore, the proposed passive cooling strategy for this retrofit will investigate the impact of cross ventilation by placing opening on adjacent walls. As well as the daylight distribution within the dwellings.

For the baseline Model, the windows and openings placed where based on the analysis of the typical houses found in Jerash Refugee camp, about 3 windows per house. The sizes of the windows varied but the most typical ones were (0.5x0.5m) and (0.7mx0.5m). The proposal for Alteration 02 suggests an increase in the number and size of windows per house. The window to wall ratio chosen for this study is 20% total wall area of the south elevation. The size of the elevation represented in the mock-up baseline model is 42 m^2; therefore, the total glazing area for that wall should be around 8 $m^{2..}$ As for the West facing façade the total area is 21 m^2 therefore the total glazing area for that wall should be around 4 $m^{2.}$ The chosen windows that will be placed are long horizontal strip windows in order to ventilate the space more evenly. Following the rule of thumb that states," an area of operable windows or louvers should be 20% or more of the floor area, with the area of inlet openings roughly matching the area of outlets for an adequate amount of air to flow across the building." (Autodesk Sustainability Workshop, 2017).

Glazing Type

The total floor area of the house is relatively 90m2, as a result the area of operable windows should be 18 ≥. Figure 3and4 shows the elevation views of the changes in the windows" size and numbers. It should be noted that the model's setting are set on 'Calculated' Natural ventilation" Model option. Furthermore, the type of glazing was changed from single glazed to " double grey 6mm/6mm Air".

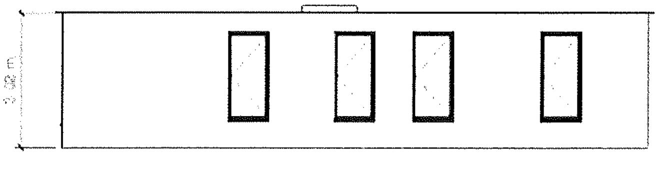

Figure 3 Elevation view of the digital model after the second alteration

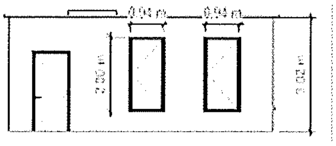

Figure 4 Elevation view of the digital model after the second alteration

External Shading (Alteration 03)

With the increase of the number of windows, the thermal analysis results for Alteration 02 have shown some values of discomfort during the summer analysis for the month of July, this can be a result of overheating due to increasing the area of glazing in the dwelling. Since increasing the size and number of windows has shown drastic improvements in the indoor daylight factor analysis they will remain the same. However, a proposed solution was to add external shading devices in the form of louvers above the windows External shading devices were integrated to the structure to prevent over-heating and maintain comfortable indoor temperatures.

Simulation Results and Discussion

The main objective of the proposed retrofit strategies is to improve the Occupants thermal comfort, therefore the simulations run measured and analysed the PMV thermal comfort levels. Design Builder's simulation engine is Energy Plus; has enabled the author to attain precise records of annual, monthly, and hourly demands for each model, as well as indoor temperature values in housing units and the thermal comfort ranges based on Fanger's PMV method. The output is referred to as **Pierce PMV SET** - the Predicted Mean Vote (PMV) calculated using the 'Standard' effective temperature and the Pierce two-node thermal comfort model. (DesignBuilderOnlineManual,2018)

In consonance with the epw weather analysis data obtained for Jerash, the lowest average temperatures fall in the month of January and the highest average temperatures are in July. Therefore the thermal comfort analysis periods for this study are the full months of January and July. These periods remained constant throughout the four simulations that were performed. The graph below shows the temperature records for the months of January and July. The following periods remained constant throughout the four simulations that were performed. The graph below shows the temperature records for the months of January and July.

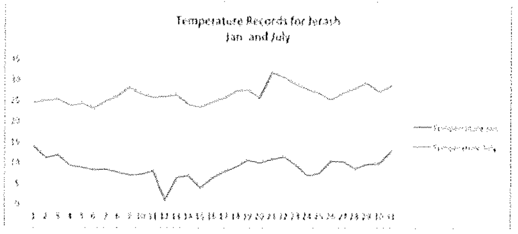

Figure 5 Graph showing the temperature records for January and July attained from Design Builder Energy plus

Simulation 01(Baseline Model)

The graphs below presents the PMV values for the baseline model obtained from DesignBuilder during the month of January as well as the month of July. As mentioned earlier, the PMV is based on a seven-point sensation that runs from -3, sensed as cold, to +3, sensed as hot. The suggested adequate PMV range of thermal comfort for an indoor environment according to ASHRAE 55 is between the range of -0.5 and +0.5. (AutodeskSustainabilityWorkshop, 2017)

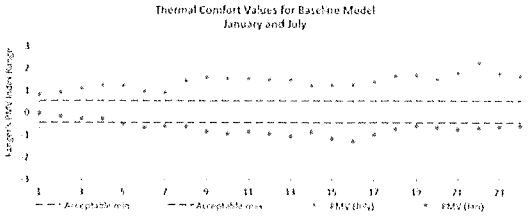

Figure 6 PMV Thermal Comfort Values for the baseline model, January and July

It can be observed that most values fall outside the acceptable PMV comfort range of -0.5 - +0.5. According to Fanger's PMV sensation scale the values below -0.5 are classified as slightly cool conditions and the values above +0.5 is classified as slightly hot. The initial simulations for the baseline model detected deficient indoor comfort conditions for the coldest and hottest months of the year.

There is a direct correlation between the outside temperatures, indoor temperatures and the PMV values. Where in January (coldest month of the year) recorded values indicate that as the outside temperature decreases the comfort value decreases to a colder sensation (-values).

The values for July (the hottest month of the year) show that as the temperatures increase the PMV values increase falling outside the acceptable comfort range, however this time moving towards a hotter sensation (+ values). As a result of this observation the retrofit strategies aimed to keep the PMV values relatively constant despite the changes in exterior weather temperatures.

July Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Baseline	0.79	0.87	1.04	1.21	1.19	0.91	0.87	1.4	1.55	1.52	1.49	1.45	1.44	1.19	1.21	1.23	1.36	1.62	1.65	1.46	1.76	2.22	1.72	1.6	1.41	1.34	1.29	1.51	1.78	1.73	1.69
Alt.01	0.09	0.12	0.15	0.14	0.13	0.06	0.08	0.21	0.33	0.35	0.35	0.35	0.34	0.24	0.24	0.25	0.29	0.36	0.4	0.34	0.44	0.58	0.53	0.5	0.43	0.36	0.34	0.43	0.51	0.54	0.53
Alt.02	0.34	0.37	0.35	0.28	0.24	0.17	0.18	0.33	0.48	0.5	0.48	0.47	0.45	0.33	0.36	0.42	0.45	0.49	0.52	0.46	0.55	0.71	0.75	0.69	0.57	0.48	0.44	0.52	0.65	0.72	0.68
Alt.03	0.23	0.26	0.25	0.18	0.14	0.06	0.11	0.24	0.38	0.43	0.41	0.39	0.37	0.25	0.25	0.29	0.36	0.42	0.47	0.41	0.52	0.65	0.67	0.63	0.51	0.4	0.37	0.47	0.58	0.62	0.59

Figure 7 Table of July PMV values for all models obtained from Design Builder Energy Plus

Jan. Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Base line	-0.08	-0.21	-0.21	-0.3	-0.54	-0.71	-0.63	-0.66	-0.87	-0.99	-0.91	-0.98	-1.1	-0.91	-1.21	-1.32	-1.03	-0.76	-0.63	-0.71	-0.79	-0.73	-0.68	-0.64	-0.58	-0.49	-0.68	-0.77	-0.61	-0.61	-0.49
Alt.01	0.05	0.01	-0.1	-0.17	-0.25	-0.34	-0.32	-0.32	-0.42	-0.56	-0.54	-0.6	-0.64	-0.56	-0.59	-0.65	-0.62	-0.54	-0.46	-0.43	-0.39	-0.36	-0.38	-0.43	-0.43	-0.39	-0.45	-0.4	-0.35	-0.37	-0.32
Alt.02	0.36	0.28	0.07	-0.07	-0.21	-0.28	-0.22	-0.2	-0.34	-0.46	-0.44	-0.56	-0.59	-0.51	-0.51	-0.6	-0.56	-0.47	-0.39	-0.41	-0.31	-0.27	-0.32	-0.39	-0.39	-0.33	-0.39	-0.26	-0.19	-0.26	-0.25
Alt. 03	-0.01	-0.07	-0.14	-0.21	-0.1	-0.38	-0.38	-0.41	-0.48	-0.56	-0.54	-0.64	-0.69	-0.62	-0.67	-0.7	-0.65	-0.57	-0.48	-0.46	-0.42	-0.39	-0.41	-0.47	-0.47	-0.43	-0.45	-0.42	-0.38	-0.4	-0.34

Figure 8 Table of Jan. PMV values for all models obtained from Design Builder Energy Plus

Looking at the PMV values demonstrated in the table above in figure 5, it can be observed that during the month of July all values baseline values fall outside the comfort range. As for the month of January more than 85% of the values fall outside the comfort range. This is indicated by the blue colour, which highlights all the values falling outside the comfort range. Therefore it can be agreed upon that the current dwellings situation is causing discomfort to its occupants during the coldest and hottest months of the year.

Results for Simulation 02 (Alteration 01)

The indoor comfort levels are directly affected by the outdoor temperatures, therefore to maintain acceptable indoor comfort values the objective would be to ensure that the indoor temperature remains in the acceptable comfort range regardless of the outdoor weather conditions. Alteration 01 focused on improving the airtightness of the exterior envelope by ensuring the exterior walls have no cracks. As well replacing the corrugated zinc roof with a concrete insulated roof structure. Also by adding a layer of 5cm thick polystyrene insulation board to the exterior walls. (Al-Hinti and Al-Sallami, 2017) The addition of the insulation board and the fixing of the cracks in the walls resulted in a major shift of almost all the PMV values towards the acceptable comfort range. This is shown in Figure 5 where most of the values are highlighted in yellow. Despite the major shift in the comfort levels towards the acceptable range, the addition of openings and glazing was highly recommended due to the poor daylight transmittance observed during the site visit.

Daylight Factor Analysis

The levels of natural daylight transmittance in a space are critical to create an adequate indoor environment that is comfortable to its occupants. There are several benefits attributed to suitable daylight levels in an indoor space. Firstly, a well-lit space has on impact on the occupant's phycology, where sufficient daylight can stimulate both the human visual and circadian systems. Secondly, facilitating daylight transmittance into an indoor space offsets artificial lighting, which consequentially saves energy. Moreover, it has a positive impact on the inhabitant's performance, attentiveness, and makes the environment more comfortable for people to undertake day-to-day tasks.

Visual observations were made during the site visit to Jerash Refugee Camp that the houses lacked sufficient daylight due to the low number of windows, the distribution of the windows and the small sizes of the windows in the houses. The images in Figure 6 below show an example of the quality of daylight inside the houses during the afternoon period.

Figure 9 Images showing the interior lighting condition in two dwellings, captured by the author during the site visit 2017

The results of the daylight analysis simulations performed using Sefaira have shown that daylight factor analysis supported the visual observations made on site as the daylight factor for the baseline model is 0.07%, which is far below the acceptable range of 2%. After the alterations of the openings and apertures were applied a shift in the average daylight factor was observed from 0.07% to 0.95% As shown below;

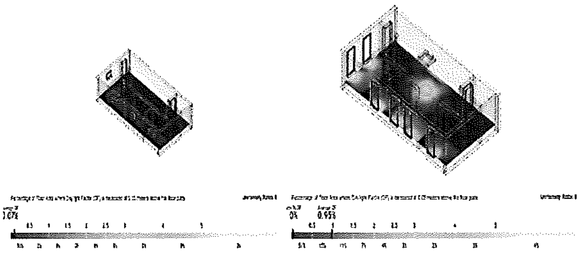

Figure 9 Daylight Factor Analysis results obtained from Sefaira for baseline Model and Alteration 02, 12pm typical March day

Results for Simulation 03 (Alteration 02)

The proposal for Alteration 02 suggests an increase in the number and size of windows per house. The chosen windows to be placed are long horizontal strip windows in order to ventilate the space as well as to allow for more natural light to enter the space. Furthermore, to create more daylight distribution the addition of a skylight is proposed. The placement of the skylight follows the "Skylight-to-Roof Ratio (SRR) that is the net glazing area divided by the gross roof area. A rule of thumb1 is that the SRR should be between 3% and 6."(Autodesk Sustainability Workshop, 2017) Area of the skylight $= (3 \text{ x}1.5)^2 \text{ x } 5\%$

$$= 0.9m^2$$

Referring back to the results displayed in figure 7, it is shown that during the July period the increase in the glazing area, the size and the number of windows some PMV values have slightly shifted outside the acceptable comfort range. This can be a result of the increase in the heat energy penetrating the structure through the glazing. Nonetheless this has only been observed in the simulation results during July (summer period). Furthermore, this is observed during 10 out of 31 July days and during 6 out of 31 January days. Provided that the strategy appears to effect the summer month more by shifting the values to a slightly hotter sensation, the aim of the next proposed strategy was to ideally reduce the indoor temperatures during the summer period while maintaining the same comfort level during the winter season.

Results for Simulation 04 (Alteration 03)

The addition of the external shading devices has caused an insignificant shift in the PMV values, as it can be observed in Figure 7, final row. In comparison with the results for Alteration 02 the values do not seem to shift to the comfort range. Therefore, there appears to be no need to include that in the retrofit strategy, as the impact is not that evident.

Cost Analysis Table

Table 2 Cost Estimation Analysis

Building Element	Unit Price	Quantity Required	Total Price
Closing the gaps and openings	5 JDs / m^2	About 2-3 m^2 per dwelling	15 JDs
Wall Plastering and Render	4.5 JDs/ m3	36.8 +44.8+22.4 +18.4 m^2 = 122.4 m^2	330 JDs
5 cm Polystyrene Insulation Layer	70-80 *m2*	122.4 m^2	9,792 JDs
Creating New window Openings in Concrete walls	60 JDs / m^2	6 openings 2X 0.94 m^2	676 JDs
Standard Double Glazed Window	50- 60 JDs / window with Aluminium frame	6 windows	360 JDs
Ceiling and roof Installation	100-110 JDs per m^2	80-90 m^2	9,990 JDs
Skylight Opening Single glazed	70-80 JDs m^2	1 *m2* opening	80 JDs

Total: 21,243 JDs

(Waddah Al-souki Consulting and Engineers, Jordan Polystyrene Company.Al Saif Industrial Co, Jordan Insulation Materials Company, JIMC)

The following cost estimate is an approximation based on the current prices in Jordan provided from a few local suppliers. It should be noted that this is only a rough estimation that is included to provide a rough cost estimation of the strategies as an initial starting point. The quantities are based on the proposed retrofit fit strategies explored throughout this research.

An estimated cost of the Typical Houses in the camp is calculated as a comparison, the values were obtained from the Jordan Green Building Council "Green Affordable Homes Project and are according to 2 local builders and Al Yanabea' CBO in Ajloun. The cost analysis shows that the proposed design strategies will potentially cost 51.2% more than the traditional construction method adopted at the camp. (Visser,2018)

Table 2 Cost Analysis of the Typical Construction Methods Adopted by the occupants at the Camp

Elements	*Unit Price*	Total Price of Required Quantities
Block layers	Single layer 80JDs/ M2	9,792 JDs
Plaster Finishes	4.5 JDs/ m3	330 JDs
3cm Thermal Insulation (Roof, Wall, Floor)	/	/
Single Glazed (Dbl. Glazed -17JDs)	40 JDs per window	240 JDs
Rough Total Cost of Construction	**10,362JDs**	

Conclusion

This study examined a retrofit strategy to improve occupant's thermal comfort and indoor environment. After analysing the available literature on retrofit projects, a number of researches agree that the energy performance of existing buildings can be enhanced significantly through improving the thermal insulation of the building envelope (efficient windows, low u-values of walls). This statement was particularly valid in the case of this study. The most evident impact on the occupant's thermal comfort was observed after Alteration 01, which consisted of increasing the insulation levels in the wall and roof structures to meet the requirements set by Jordanian Green Building Standards. The research concludes that the proposed passive strategies excluding the addition of external shading has resulted in a shift in the hourly and daily-recorded PMV values to within the acceptable comfort range and an increase in the average daylight factor from 0.07% to 0.95%. The approximate cost estimation of the proposed retrofit strategy is around 21,243 JDs, with the roof and the addition of insulation being the highest cost. To determine the economical feasibility of the study the next step would be to analyse the energy loads of the dwellings and compare the energy consumption of the proposed strategies to the typical construction method. Following an economical payback period calculation, which will determine the exact payback time and thus show the economical practicality of the proposed retrofit strategy.

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