Exploring Sustainable Strategies for Shelter Design at Refugee Camps: The Case of Domiz 1 Refugee Camp in Iraq

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by

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Abstract

The recent refugee crisis is considered the most pressing humanitarian crisis the world is witnessing today. With 4.9 million Syrian refugees around the world, the Syrian refugee crisis has a major impact, not only on the Syrian refugees, but also on the host communities. Iraq is one of the main host countries of Syrian refugees, besides the Internally Displaced People (IDPs) inside the country caused by the internal conflict, resulting in an over exhaustion of its resources, infrastructure, and services.
The need to conduct an investigation on sustainable strategies of shelter design in Domiz refugee camp in Iraq emerged as a result of direct communication with the UNHCR office in Iraq, aiming to improve the living conditions of the refugee population and reduce the pressure on host community and environment.

This study initially reviewed literature already existing on shelter design in refugee camps. Moreover, relevant case studies were presented. Data obtained through direct communication with the UNHCR office in Iraq was utilized to assess the current situation in Domiz refugee camp.

Based on that, a shelter upgrade strategy, referred to as The Incremental Home, is proposed. The Incremental Home is a phased upgrade strategy in which the involvement of the UNHCR and other NGOs is maximized in the beginning, gradually being overtaken by the involvement of the refugee population. Due to the multi-disciplinary nature of the research, a combination of qualitative and quantitative methodologies is utilized.

The first two phases of the Incremental Home strategy focus on the planning aspect of the shelters and the base structural frame. These phases are

assessed by referring to the literature review and successful case studies. In the third phase, a wall panel composed of layers of steel mesh, tarpaulin, and sand is proposed in two different configurations as a cost-effective sustainable replacement of the standard tent and the corrugated steel shelters. In the last phase, a sunspace and a roof canopy are proposed as passive heating and cooling strategies to enhance the thermal performance of the shelter. The last two phases are evaluated by conducting thermal simulations using IES-VE software and comparing the results of the proposed strategies to those of the present shelter typologies in Domiz camp.

Results of the study illustrate applying The Incremental Home strategy helps empower the refugee population by providing them with the knowledge and training needed to participate in the construction process and allowing for gradual implementation. As a result, the proposed strategy provides an opportunity for personalization and deepens the refugees' sense of belonging and dignity. Furthermore, a 42% decrease in cooling loads, and 31% decrease in heating loads was achieved by using the proposed wall panel, the sunspace during winter, and the roof canopy during winter, in comparison to the baseline case, the UNHCR tent.

نبذة مختصرة

تعتبر أزمة اللاجئين التي يشهدها العالم اليوم اكثر الازمات الانسانية الحاحاً. يبلغ عدد اللاجئين السوريين اليوم حوالي 4.9 مليون لاجئ منتشرين في جميع أنحاء العالم، مما له تأثير كبير ليس فقط على اللاجئين، وانما يمتد هذا التأثير ليشمل المجتمعات والحكومات المضيفة. يعد العراق واحداً من أهم البلدان المضيفة للاجئين السوريين، بالإضافة إلى حركة النزوح الداخلي الناجمة عن الصراعات والحروب الداخلية التي يشهدها البلد، مما أسفر عن وضع العراق تحت ضغوطات عارمة، منها استنفاذ الموارد واجهاد البنى التحتية.

بالاضافة الى ما سبق، فقد اعرب مكتب المفوضية العليا لشؤون اللاجئين في العراق، عقب الاتصال المباشر مع الباحث، عن الحاجة الى اجراء بحث حول الاستراتيجيات المستدامة لتصميم المساكن في مخيمات الاجئين، مع التركيز على مخيم دوميز في محافظة دهوك، بهدف تحسين الظروف المعيشية للاجئين ومساعدة المجتمعات والحكومات المضيفة.

استعرضت الدراسة في البداية الأبحاث في مجال تصميم المساكن في مخيمات اللاجئين. بالاضافة الى دراسة الحالات والمشاريع المشابهة في مختلف انحاء العالم. وقد تم استخدام البيانات التي تم الحصول عليها من خلال التواصل المباشر مع مكتب المفوضية في العراق لتقييم الوضع الحالي للمساكن في مخيم دوميز.

بناءاً على ما سبق، تم اقتراح استراتيجية متدرجة لتطوير المساكن في المخيم. في المراحل الأولى من عملية التطوير، تقترح الدراسة اعطاء الدور الاكبر للمفوضية والمنظمات غير الحكومية الأخرى، ويتقلص هذا الدور تدريجياً ليحل محله دور السكان اللاجئين. ونظراً لكون هذا البحث ذو طبيعة متعددة التخصصات، فقد تم استخدام مزيج من منهجيات البحث الكمية والنوعية بحسب ما تتطلبه الدراسة.

تركز المرحلتين الأولى والثانية من استراتيجية التطوير المقترحة على الجانب التخطيطي لتوزيع المساكن في المخيم وعلى الاطار الهيكلي للمبنى. وتم تقييم الاستراتيجيات لهاتين المرحلتين تم عن طريق الرجوع الى البحوث المشابهة والحالات الناجحة. في المرحلة الثالثة، تقترح الدراسة تغطية الجدران بطبقات من الشبكة المعدنية والقماش المشمع يتم تعبأتها بالرمل كبديل مستدام وقليل الكلفة عن الخيم التي يتم توفيرها للاجئين. أما المرحلة الرابعة والاخيرة، فتسلط الضوء على دمج الاستراتيجيات السلبية للتدفئة والتبريد لتعزيز الأداء الحراري للمسكن المقترح وهي الغرفة الشمسية واضافة مظلة للسقف.

تم تقييم المرحلتين الأخيرتين من خلال إجراء المحاكاة الحرارية باستخدام IES-VE برنامج ومقارنة نتائج تقييم الاستراتيجيات المقترحة بنتائج تقييم أنماط المساكن المستخدمة حالياً في مخيم دوميز.

توضح نتائج الدراسة أن تطبيق الاستراتيجية المقترحة لتطوير المساكن يساعد على تمكين اللاجئين من خلال تزويدهم بالمعرفة والتدريب اللازم للمشاركة في عملية البناء، واعطاء الفرصة للتنفيذ التدريجي للاستراتيجيات. كما توفر الاستراتيجية المقترحة فرصة لإضفاء الطابع الشخصي للمساكن وتعمق شعور اللاجئين بالانتماء والكرامة. وعلاوة على ذلك، تم تحقيق انخفاض 42% من الطاقة المطلوبة للتبريد، و31% من الطاقة المطلوبة للتدفئة باستخدام لوحة الجدران المقترحة واضافة الغرفة الشمسية في الشتاء ومظلة السقف في الصيف بالمقارنة بالخيم المغطاة بالقماش المشمع المنتشرة حالياً في المخيم.

Dedication

To all those who were forced to leave their homes seeking a safe haven.

Acknowledgements

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Abbreviations

UNRIC United Nations Regional Information Centre

IFRC International Federation of Red Cross and Red Crescent Societies

UN-HABITAT United Nations Habitat

UNHCR United Nations High Commissioner for Refugees

GERES Group for the Environment, Renewable Energy and Solidarity

BSHF Building and Social Housing Foundation

1 Chapter 1: Introduction

1.1 An overview of the current refugee crisis

Today, the world is witnessing an unprecedented refugee crisis. Until the time of writing, the estimated number of displaced people all around the world is 65.3 million, of which 21.3 million are refugees. More than half of all the refugees are from three countries: Syria, Afghanistan, and Somalia. 4.9 million of all refugees are Syrian. 39% of displaced people are hosted in the Middle East and North Africa (UNHCR 2016b).

The UK Independent (2016) described the year 2016 as “a shameful chapter for European history” because of the escalating number of drowning deaths of refugees crossing the Mediterranean to seek asylum in European countries, stating that 2016 is close to being “the deadliest year on record”.

1.2 Refugees, Internally Displaced People, and Migrants

The term “refugees” refers to a person who is outside the country of their nationality and not under its protection due to fear of persecution for various reasons such as their race, religion, or social and political views. Unlike migrants, who choose to move to another country to improve their living situations, refugees are in a status where they are forced to seek asylum in other countries to protect their lives and preserve their freedom. Internally Displaced People (IDP), like refugees, are also forced to leave their homes but without crossing the national borders.

1.3 Syrian refugee crisis: reasons and impacts

In March 2011, civil protests started in Syria in the City of Deraa following the arrest of teenagers who were responsible for anti-regime slogans written on a school wall. Violence by the regime to stop the protests triggered a series of uprisings all around the country. A year later, the conflict turned into a full-scale civil war, and Syria was officially in a state of war (BBC 2016).

In June 2012, U.N. Under-Secretary-General for Peacekeeping Operations Herve Ladsous was asked if the conflict in Syria can be described as a civil war. He responded: “Yes, I think we can say that, clearly what is happening is that the government of Syria lost some large chunks of territory in several cities to the opposition and wants to retake control of these areas.” This was the first time the conflict in Syria is declared as a civil was by a senior U.N. official. (Reuters 2012)

Since the outbreak of the Syrian civil war, the number of Syrian refugees has been constantly on the rise. Syrian refugees are hosted by Turkey, Jordan, Lebanon, Iraq, Egypt, The EU, Norway, and Switzerland. Figure 1 shows the number of registered Syrian refugees by country of asylum from 2011 until 2016 (Migration Policy Center 2016).

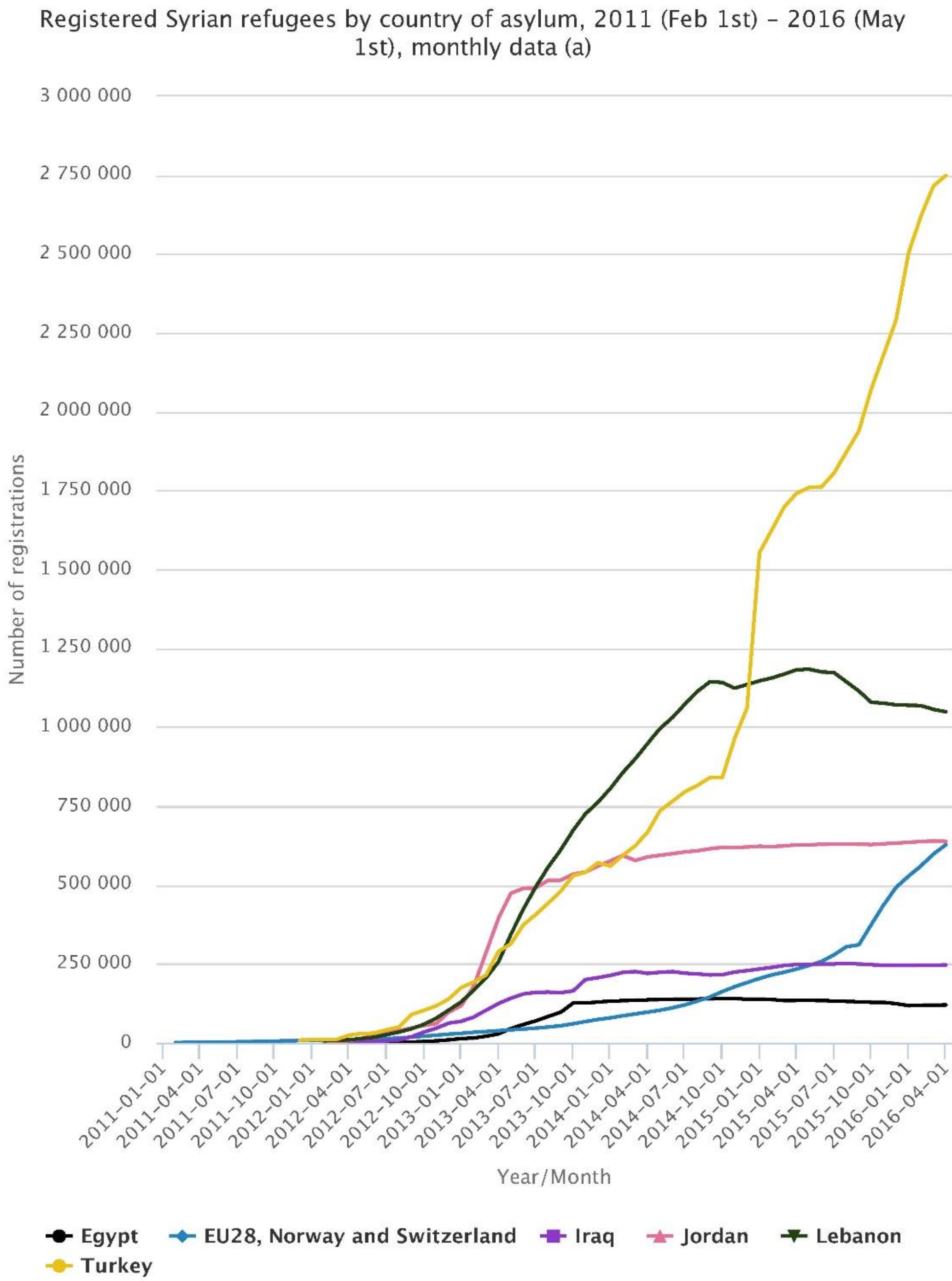

Figure 1*:* registered Syrian refugees by country of asylum from 2011 until 2016 (Migration Policy Center 2016)

A refugee crisis of such a scale has a great impact on host communities. In 2014, Ministry of Foreign Affairs of Denmark, the lead partner for the Regional

Development and Protection Program (RDPP), published a study that sheds the light on the pressure host countries are under to accommodate the refugees. The study focuses on Lebanon, Jordan and Iraq, since these countries are either already hosting millions of Palestinian and Iraqi refugees, and/or in a state of a conflict, making them the most vulnerable to the impact of the refugee crisis. Despite the significant solidarity that these countries exhibited towards the refugee population, none of them is signatory to the 1951 Geneva Convention or the 1967 Protocol. Weak infrastructure, inadequate healthcare and educational services, constitute a high risk of triggering tension between the refugee population and the host communities, bringing the two in the danger of a potential conflict.

1.4 Syrian Refugees in Iraq

Since the beginning of the Syrian Civil War, Iraq has received 220,000 Syrian refugees (Syrian Refugees 2016), of which 98% have stellated in Kurdistan Region of Iraq. Moreover, the internal conflict within Iraq and the complicated security situation in various parts of the country has led to the internal displacement of three million Iraqis, of which one million fled to the Kurdistan Region of Iraq. (UNHCR & UNDP 2016).

Figure 2 shows the distribution of the Syrian refugee population in Iraq.

There are eight refugee camps in Iraq: Domiz, Kawergosk, Gawilan, Basirma, Arbat, Al-Obaidi, Akre, and Qushtapa. According to the United Nations High Commissioner for Refugees (UNHCR) (2016b), Domiz camp is the largest refugee camp in Iraq hosting 31,032 refugees in Domiz 1 camp and 7,921 refugees in Domiz 2 camp.

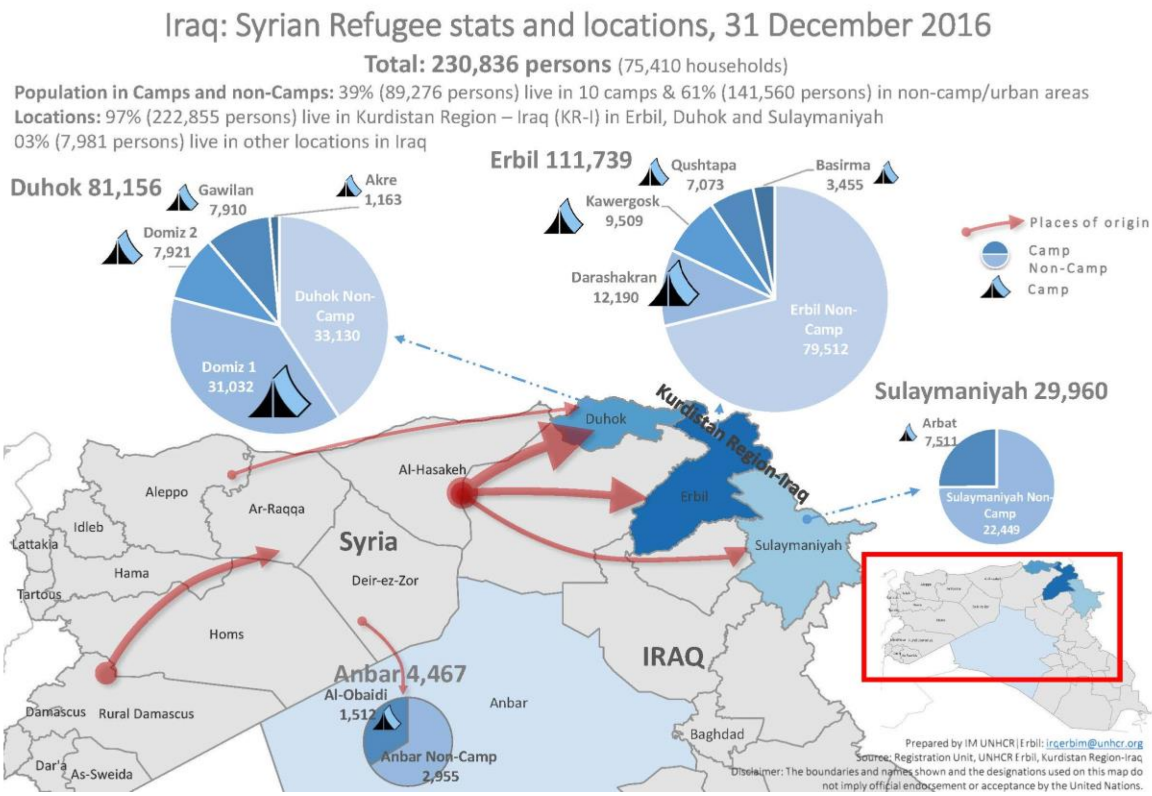

Figure 2: Syrian refugee statistics and locations in Iraq (UNHCR 2016b)

1.5 Domiz Refugee Camp: An Overview

Domiz refugee camp was established in 2012. It is south east of Duhok city northern Iraq, along the highway connecting Duhok to Musil Governorate. Duhok is one of the three governorates, besides Erbil and Sulaimanuya that makeup the Kurdistan region. The camp, which was initially planned to accommodate 30,000 refugees is now home to nearly 40,000 Syrian refugees, mostly from Kurdish areas in Syria, who left their homes in Syria seeking a safer place across the borders in Iraq. The camp consists of two parts, Domiz 1 and Domiz 2, covering an area of 1,142,500 m² and 300,000 m² respectively (UNHCR 2016b).

It is worth mentioning that the climate in Duhouk is semi-arid continental. In summer, the weather is hot and dry, with temperatures reaching up to 40 degrees C. Winters, on the other hand, are mild with temperatures dropping to 7 degrees C. The temperature drops even further in the mountainous areas (World Weather Online 2012). Duhok, and Kurdistan region in general, is characterized by the high percentage of fertile land, high precipitation and mild weather making it an appropriate location for agriculture (Kurdistan Board of Investment 2016).

The camp report published by the UNHCR in 2014 states that the shelter situation in Domiz refugee camp is below the standard. The area per person in 2014 was $26m^2$, while the minimum standard is 30m, and 20% of the population are living in inadequate dwelling (UNHCR 2014a). The reports of 2015 and 2016 mentions that there has been an improvement with the shelter situation, and these enhancements were done by the refugees themselves (UNHCR 2015a)(UNHCR 2016a).

1.6 Problem Statement

Refugee crisis is the most pressing human crisis the world is witnessing today, therefore, research in the refugees' issues is needed more than ever. In a country like Iraq, where conflict is causing its population to be internally displaced, and is still welcoming refugees from neighboring countries, academic research can help the UNHCR local offices, the host governments, and the refugees, enhance living standards at refugee camps. Moreover, refugee camps in Iraq is a widely understudies subject, which makes the case of Iraq suitable to carry out this investigation. Domiz refugee camp is the biggest refugee camp in Iraq, and shelter enhancement is considered a priority by the UNHCR local office in Iraq as stated in their correspondence with the author on an early stage of starting this research. The need to investigate shelter design in Domiz refugee camp is confirmed by the Regional Refugee & Resilience Plan 2016-2017 (UNHCR & UNDP 2016):

“In Gawilan, Domiz 1,Domiz 2 and Darashakran camps, there is a need to construct additional shelter plots to accommodate new arrivals, including refugees relocating from urban areas. Considering that tents are a short term shelter solution, the upgrade of tents to more durable shelters forms a critical part of the longer term vision to make the camps “tent free”.

1.7 Aims and objectives

The research aims to investigate alternative shelter design approaches in post-conflict settlements and establish a shelter typology proposal for Domiz refugee camp in Iraq.

Objectives

- Review of general sustainable development strategies and design guidelines of shelters in refugee camps
- Explore successful case studies. References may include refugee camps, emergency shelters, poor areas, vernacular architecture and off-grid settlements.
- Review and assess the current situation in Domiz refugee camp in terms of shelter
- Study the context, climate, available materials and building technologies of Domiz camp
- Propose alternative shelter design and/or shelter design enhancement strategies and recommendations
- Utilize digital simulation to assess the performance of the proposed solutions where applicable

- Attempt to collaborate with the UNHCR Iraq office for data collection and guidance.

2 Chapter 2: Literature Review

2.1 Overview

This chapter is prepared to understand the role of the UNHCR in responding to refugee crisis. A description of the challenges and requirements of post-conflict shelter is presented, followed by a review for the past and current efforts towards better shelter solutions. The literature review will also provide a general understanding of the current shelter situation in Domiz refugee camp and its context and climate.

2.2 UNHCR Establishment

The concept of granting protection to people expelled from their homes can be traced back to the first century BC, and is present throughout history. However, the world witnessed the largest refugee crisis during World War II. WWII resulted in more than 40 million refugees in Europe alone. The scale of the disaster pushed the need to establish international organizations and laws to deal with the refugee crisis. As a result, in 1950 the UNHCR was established.

2.3 The 1951 Refugee Convention

One of the milestones in refugee protection legislation is the 1951 Refugee Convention that still function as the basis of international refugee protection laws until today. The 1951 Refugee Convention was the first document to define the term “refugee” regardless of the group a refugee belongs to. This convention was the first legislation to define the rights of refugees and the obligations of host and other states towards them. Countries that have signed the 1951 Refugee Convention are obliged to offer refugees protection, and not to return then to their home countries if the situation is life threatening. The

1951 Convention is the only international agreement that covers the issue of refugees comprehensively. Moreover, it ensures that burden sharing is distributed among the different states and promotes corporation on an international level to deal with the issue of refugees and ensure that the refugee population have access to the basic human rights. (UNHCR Department of International Protection 2001)

2.4 The UNHCR Response to Refugee Crisis

The UNHCR response to displacement crisis happens in two phases. The first phase, the emergency response phase, immediately follows the start of the crisis. The second phase, on the contrary, comes at a later stage when long term solutions ae needed.

2.4.1 Emergency Response Phase

Most of the UNHCR operations start as an emergency situation, when the lives of refugees is threatened unless immediate action is taken. Therefore, ensuring preparedness and flexible quick responses to emergency crisis is a crucial aspect of the UNHCR work. During the emergency response phase, the priority for the UNHCR work is to provide protection for the refugees and assist the host country

2.4.2 Durable solutions Phase

After fulfilling the basic needs for refugees at the start of an emergency situation, the attention of the UNHCR shifts to finding a durable solution for the refugees and help them restore their lives and rights. According to the UNHCR, there are three main long-term solutions for refugees:

The first solution is voluntary repatriation, which remains the hope of most refugees around the world. Ensure that the country of origin is committed to reintegrate the refugees. In order to facilitate the return of refugees to their home countries, the UNHCR works on compiling information about the country of origin during the refugees' exile to plan their return. "go-and-see" visits are also organized.

When returning home is not an option due to the persistence of the situation that forced the refugees to leave their countries, refugees are left with two options, either to integrate with the host society and start a new life, or to relocate to third country. Local integration is a complex process that have to be carried on gradually to ensure that social, economic and cultural aspects of both the individuals and the host society are taken into consideration. Less than 1% of refugees resettle in a third country as only few countries around the world are part of the UNHCR resettlement program. (UNHCR 2016d)

2.4.3 Protracted Refugee Situations

Refugee crises are often looked at as a temporary situation that will get resolved as soon as the conflict is resolved. Therefore, it is often responded to with short-term solutions leading to what the UNHCR referred to as "protracted refugee situations", where refugees' exile would last for years. In such situations, the lives of the refugees are not in danger anymore but their basic needs remain unfulfilled. A long-lasting phase that moved beyond the emergency phase but with no hope of any durable solution. While more than 60% of refugees today are trapped in exile where they are not able to return home or to integrate with the local community, and they remain dependent on external aid. More attention is often given to emergency situations while no light is shed on the protracted situation that represent one of the most persistent challenges in the face of humanity. Difficulties in defining the scope and the nature of the chronic refugee situations problem has led to a bigger challenge to set the legislation required to ensure rights and protection for refugees. A general definition of refugees in protracted situation are those in exile for 5 years or more in a developing country. (Office of the United Nations High Commissioner, 2006)

2.5 Transitional Shelter

Various definitions and classifications of post-disaster shelters are found in the literature. According to Corselis et al. (2005), a house can be defined as a permanent dwelling unit that is provided with the needed infrastructure that enables the inhabitants to resume their normal household activities such as housekeeping, working...etc. A shelter, on the other hand, is defined as a living space that provided its inhabitants with security, privacy, health & dignity. Unlike houses, shelters are considered basic solutions that are used in the period that immediately follows a disaster and are not provided with the related infrastructure needed to resume normal daily activities. For this reason, shelters are considered temporary solutions until a more durable solution is figured out. In the period of time that follows the provision of a temporary shelter and is prior to establishing a long-term durable solution is a third category that is referred to as ‘Transitional Shelter’.

Félix, Branco, and Feio (2013b) suggest a more distinct classification and propose four stages for post-disaster dwellings. The first stage is the emergency shelter, which refers to the place where disaster survivors stays for a short period of time immediately following the disaster. The second stage is the temporary shelter, a basic dwelling unit where disaster survivors can stay for a few week such as a tent. A more durable form of dwelling is the temporary house in which people can stay in up to 3 years and can resume their daily activities. The final stage is the present house which involves either the return of disaster survivors to their original houses or to a new house where they settle permanently.

A slightly different classification is presented by the IFRC (2013), 4 stages are presented:

- Emergency shelter, which are the shelters provided in the period immediately following the disaster.
- Temporary shelter, transitional shelter both referred to as T-shelter.
- Progressive shelters are designed to be later upgraded into more permanent ones.
- Core shelters that reach the permanent housing standards, however, they cannot be considered a permanent house.

According to Corselis et al. (2005), a Transitional Settlement is a ‘settlement and shelter resulting from conflict and natural disasters, ranging from emergency response to durable solutions. The study suggests two types for transitional settlements. The first type is dispersed settlement, which includes host families, rural self-settlement, and urban self-settlement. The second type is grouped settlements, which include mass shelter, self-settled camps, and planned camps. This research focuses on the last type which is planned camps.

Planned camps are considered the option of last resort by organizations such as the UNHCR due to various reasons. First, planned camps are usually isolated from host communities and they promote the dependency culture among refugees making aids withdrawal more challenging. The process of establishing a planned camp can be divided into the following phases: contingency phase, emergency phase, care and maintenance, and phased exit strategies. It's worth mentioning that the case study at hand, Domiz refugee camp, is in the care and maintenance phase, which is the phase where upgrading activities may commence. According to the UNHCR (2016), the camp is closed for new refugees except for family reunion situations.

2.5.1 Provision of transitional shelter

The process through which the transitional shelters are provided to the beneficiaries is referred to in this paper as the provision of transitional shelter. Hany Abulnour (2014) identifies seven main stakeholders that are often involved in this process: disaster relief organization, governments, civil organizations, private sector, professionals and researchers, and media.

Two provision approaches are identified in the literature, the top-down approach and the bottom-up approach.

The top-down approach is the conventional approach of shelter provision in which one or more of the stakeholders, such as disaster relief organizations, are responsible of providing the disaster survivors with the needed shelters. The top-down approach is the most common because it provides standard solutions that can be applied in a short period of time to provide a large number of shelter units. Since this approach usually involves importing the shelter from a different place, it's more technology oriented. However, this approach is often criticized for cultural and contextual inadequacy (Abulnour 2014).

The bottom-up approach, on the other hand, is community based where the beneficiaries are involved in the decision making and construction process. It can be implemented with the help of one or more of the stakeholders. This approach is characterized by being more responsive to the cultural and economic circumstances. The bottom-up approach help empower refugee populations to be an independent self-sustained community and avoid the need for environmental rehabilitation projects in a later stage. It also helps create employment opportunities among the population (Amstislavski, n.d.).

In his recent talk, Alejandro Aravena, the winner of Pritzker Architecture Prize in 2016, emphasizes on the importance of the bottom-up approach when it comes to humanitarian architecture. He highlights, through a number of his successful projects, how incremental community-based interventions can lead to great results (Ted 2014).

The same concept was endorsed by Kilian Kleinschmidt, who formerly ran the Zaatari Syrian refugee camp in Jordan. In a recent documentary film titles "Salam Neighbor", Kleinschmidt sheds the light on the budget limitations that the UNHCR faces when it comes to camp development. He argues that the refugees' desire to rebuild their lives and regain the sense of normalcy is a powerful drive. Given the needed guidance, the refugee population is able to achieve a lot more than what the UNHCR can offer them. (Living on One Dollar and 1001 MEDIA, 2016)

2.5.2 Sustainability

Refugee crises are often looked at as a temporary situations that will get resolved as soon as the conflict is resolved. Therefore, it is often responded to with short-term solutions. In a recent interview with Kilian Kleinschmidt, a world leading figure in humanitarian aid issues, he described refugee camps as “the cities of tomorrow” and argued that it is necessary to recognize that refugee camps are, in most of the cases, permanent solutions. For this reason, sustainable planning for refugee camps and shelters must be considered. (Dezeen 2015a)

Kreuzer (2010) argues that sustainable design and planning for refugee camps is crucial to respond to the fact that these camps can be functional for years. The study states that sustainable development is a new concept in international policy and is not necessarily considered in the UNHCR strategies. Additionally, the study highlights one of the misconceptions of the nature of the UNHCR work, that it functions in emergency situations offering short-term solutions, while in fact, in most of the cases it is difficult to relocate the refugees to a permanent settlement making the refugee camps grow to become cities on the long term referring to this situation as “protracted refugee situation”. The transition from the emergency stage to the permanent stage is very critical and requires careful management and planning with sustainability in mind. The study emphasizes on the UNHCR recognition of the importance of integrating sustainability in refugee camps planning, management and design. Also, the study shows that innovations, even on a micro level, can enhance the sustainability of the solutions offered by the UNHCR, and that small enhancements can have a major impact on the living conditions of refugees.

Dinesh Shrestha, senior water and sanitation officer in the UNHCR, mentions in an interview the importance of planning with sustainable development in mind because in many situation camps will function beyond emergency situations. (Kreuzer 2010)

The issue of sustainability of refugee camps was raised by Amstislavski (n.d.). In his study, he argues that the poor planning of refugee camps and the absence of long-term sustainability when planning refugee camps have a negative impact on the environmental surrounding and on the refugee population consequently.

The study highlights three main issues related to sustainability: not taking into consideration ecological issues, the lack of utilizing sustainable and renewal energy and construction materials, and the absence of the refugee population participation in decision making. The absence of sustainable and ecological approach in planning makes rehabilitation on a later stage difficult and complex. Also, ecological degradation of the area occupied by the refugees often can trigger conflicts between the refugee population and the local population. Moreover, this makes it more difficult for the host governments to accept the refugees due to the fear of further environmental and ecological damage caused by the refugee population. The paper suggests an approach referred to as “Eco-Bridge” which aims at combining imported technology with local resources and local ecology to provide long-term solutions for refugees.

Another study that looks into the issue of the sustainability of transitional shelters argues that the need to incorporate sustainability into transitional shelters is pushing towards a shift in from a humanitarian assistance approach to a more resilience approach in which the local community, both refugees and host communities, are more involved. (Afify, Farahat, and Alhabbal, 2016)

2.5.3 Materials

Selection of the most suitable material for constructing transitional shelters is crucial. It is important to take into consideration speed and simplicity of construction when selecting the material. In this section, an overview of common construction materials used for constructing transitional shelters is presented.

2.5.3.1 Bamboo Construction

Bamboo is a very fast growing plant that is available in many countries across the world today. It can be used for both load-bearing and non-load bearing elements. In most of the cases, bamboo is produced locally and transported for short distances only. It can be used as structural elements similar to timber poles, or for roofing after being covered with plastic sheeting.
Since bamboo is hollow, nailing and screwing should be avoided when fixing as they might cause splitting. Instead, fixing the bamboo should be done by bolting, drilling, or bounding (Corselis et al., 2005). Bamboo matting walls were used in Core Shelter in Bangladesh that was constructed in 2007 (figure 3).

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Figure 3: Core Shelter in Bangladesh (IFRC 2013)

2.5.3.2 Bricks

Bricks are made by firing clay in a kiln and they come in different sizes depending on the country in which they are produced. Bricks are hard to use for emergency shelter construction because they are often hard to source and to transport. Bricks are mostly used in constructing low walls around emergency shelters which helps protect the space from animals and intruders. Also, it can be utilized as a wind break. Bricks are often used in constructing more permanent structures or introduced during the second phase of shelter construction, referred to in this study as transitional shelter phase (Corselis et al., 2005). One example of using bricks in the construction of transitional shelters is the One Room Shelter in Pakistan that was constructed in 2010 (figure 4).

Figure 4: One Room Shelter in Pakistan (IFRC 2013)

2.5.3.3 Mud blocks

The main difference between mud blocks and bricks is that the latter is fired in kilns. Mud blocks, on the other hand, are made by mixing clay and water and let the mix dry in molds. Other materials can be introduced to the mix to add to its stability. For example, cement can be added in a 1:10 percentage (cement/clay). Stone aggregate can also be added to add strength to the mixture. Mud blocks are often produced on site by digging a pit. An average of

300 block per day can be produced by a team of 3-4 people. However, one of the drawbacks of using mud blocks is the high rate of water consumption required for production. It is important to train groups of the beneficiaries in mud blocks production if it is used in construction. One of the suggested methods to keep people motivated is to create a prototype as a demonstration (Corselis et al. 2005). Figure 5 shows an example of mud blocks being using for transitional shelters construction.

Figure 5: Mud blocks construction (IFRC, UN-HABITAT & UNHCR 2014)

2.5.3.4 Timber construction

Timber is used in the construction of transitional shelters for building the structural frame using timber poles, either bush poles or sawn timber is used for this purpose. Bush poles are preferable as they produce les waste in comparison to sawn timber, and they form stronger structural elements since their structural cross-section remains undamaged. Moreover, timber boards are used for walls and roof covering (figure 6).

Figure 6: T-Shelter in Haiti (IFRC 2013)

2.5.3.5 Concrete

Concrete blocks are a common building material when shelter enhancement is needed. Building with concrete blocks is of a more permanent nature. Concrete can be produced off-site and transported in urban areas. In isolated areas, on the other hand, concrete has to be produced on site or imported as precast elements (Corselis et al., 2005). Core Shelter illustrated in figure 7 is an example of using concrete in the construction of transitional shelters (IFRC 2013).

Figure 7: Core Shelter in Sri Lanka (IFRC 2013)

2.5.3.6 Thermal Comfort

One of the main challenges of transitional shelter is that these shelters are often produced elsewhere, imported, and provided to the beneficiaries. For this reason, they often provide generic solutions that are not context and climate specific.

Taking the climate into consideration when designing shelters is crucial for the health and wellbeing of the inhabitants. Extreme weather conditions are one of the biggest risks that face refugees in camps all over the world. In an interview with Mostafa Munjid, a doctor with the International Medical Corps who supervises health care in four different refugee camps, he stated that in summer, the number of deaths in refugee camps rises due to the impact of extreme heat on food storage and water contamination. (Integrated Regional Information Networks 2016)

A recent news report by Al Jazeera’s Mohammed Jamjoom from Baharka camp in Erbil, describes the situation in the camp during winter as “another

catastrophe” that the Internally displaced persons in this camp have to cope with. The report shows the poor shelter conditions that provide almost no protection form strong winds, heavy rain, and hail. (Al Jazeera 2016)
Amin Awad, the Syria Refugee Response Coordinator for the UNHCR, expressed his concerns with regards to the expected extreme weather conditions in a press briefing in Geneva. He said that winterization kits, which include thermal insulation for tents, plastic sheets, and water proofing, have been distributed to as many of the refugee population as possible. However, the UNHCR is struggling to cope with the demand as the number of refugees keep escalating. (United nations Regional Information Center 2016)
It is, therefore, of a great importance to design transitional shelter taking into consideration the climatic conditions.

According to Corselis et al. (2005), the number of deaths in communities tends to rise in extreme cold conditions. Also, the rate of respiratory diseases also increases. Add to that, people in refugee camps are confined within small spaces making the situation even more difficult. When designing for a cold climate, it’s important to take into consideration wind direction and provide adequate wind sheltering on the scale of the settlement and the shelter units. The most effective heating strategy for shelters in cold climates is heaters and stoves. However, these strategies must be accompanied by an efficient ventilation system to protect the inhabitants from the risk of smoke.
Another important strategy is the provision of a well-insulated enclosure.
When using plastic sheets, double plastic sheets are recommended as they work similar to the double glazing providing better insulation. In wet climates, on the other hand, the most important strategy is providing sufficient rainwater drainage by maintaining a 20-30 sloped roofing, and placing the shelter on elevated plinth. Raised flooring is recommended. Also, good ventilation is important to reduce the effect of humidity.

In hot and dry climates, maximum shading is highly recommended to protect people from heat exhaustion. On the settlement level, it is recommended to place the shelters close to each other for shading. However, by doing so, the risks of fire increases and safety measures must be applied. On the level of individual shelter, building with heavy materials is advised to provide thermal mass making the shelter cool in daytime and warm at night. Double roofs are also recommended to prevent from overheating. Providing small window openings is suitable for hot-dry climates as it prevent overheating in day time and reduce heat loss at night.

2.5.3.7 Safety

Another important factor to be considered when constructing transitional shelter is safety. Natural hazards include fire, storm, and strong winds.
Fire is one of the common risks that face shelters in refugee camps, and one of the drivers that pushes people to upgrade the building materials of their shelter. Fire preventions measures can be taken on two scales: on the scale of the settlement urban planning, and on the scale of buildings.
It is generally recommended to incorporate firebreaks in the design of the camps by wind breaks that prevent fires from spreading. The distance between buildings should be at least twice the height of the buildings. Besides fires, smoke is considered a major risk as it affects the immunity system and causes diseases in respiratory system, Therefore, it is important to provide adequate cooking facilities, enhance the ventilation of the space, and reduce as much as possible reliance on burning woods and fossil fuels for heating purposes by utilizing solar heating strategies.

Storm may refer to wind, rain, snow, and dust storms. To ensure protections from storms on the settlement level, grouping of buildings may help create microclimate and protect buildings from strong winds and dust. Also, vegetation plays a role. Controlling wind is tricky since cross ventilation would be required for a healthier environment and for cooling in summer, in the same time it is not desirable in winter when temperatures drop down and in the case of dust storms.

On the building level, stronger structure and stronger joints is crucial. Moreover, hip roofs are preferable as they are more wind resistant than gable roofs.

Uplift load resistance to protect from strong winds can be achieved by anchoring the shelter properly to its foundation and ensure strong secured joints. Additionally, planting trees around the shelter to provide wind shields. However, the distance between the trees and the shelter must be in a range where it would provide protection from winds but in the same time limit any risks of these trees falling on the shelter. (Corselis et al. 2005)

In addition to natural hazards, safety from theft and violence is a crucial aspect to be taken into consideration. Security issues are often dealt with through camp management measures such as enhancing the security at the gates of refugee camps, introducing internal checkpoints inside the camp, and distributing police officers in civilian clothing (The Guardian 2017a). When it comes to shelter, inadequate shelters and overcrowded situation increase the risk of violence and theft in the camps. Enhancing the shelters and providing solutions were secured locks can be integrated is essential (Smith 2017).

2.6 Case Studies

In this section, a number of case studies are reviewed. The reviewed case studies include shelters in refugee camps, low cost solutions, and off-grid shelters. Pros and cons of each case study are discussed. Finally, a summary of the lessons learnt is presented.

2.6.1 Sandbag Shelter

Sandbag shelter project was carried out by Iranian Architect Nader Khalili in which he explored the potential of utilizing earth construction to provide solutions to the housing need problem for the millions of refugees all over the world.The proposed system is based on traditional vernacular architecture in Iran and is a combination between the traditional tensile structure of the Bedouins and a load bearing structure that is strong and durable, resistant to earthquakes and floods.

The system is composed of sandbags and earth filling. The sandbags can be made of two types. The first type is natural materials which is best suited when if the structure is planned to be a temporary structure as it degraded with time. Synthetic material on the other hand, are more suitable for a more durable structure. A layer of plaster can be added on top of the sandbags to protect from erosion. Earth filing can be any type of earth depending on what's available on site. Figures 8,9,10 show different views a sandbag shelter prototype. Figure 11 show a number of finished sandbag shelters in Baninajar Refugee Camp in Iran.

Figure 8: Sandbag Shelter Prototype (Agha Khan Award for Architecture 2004)

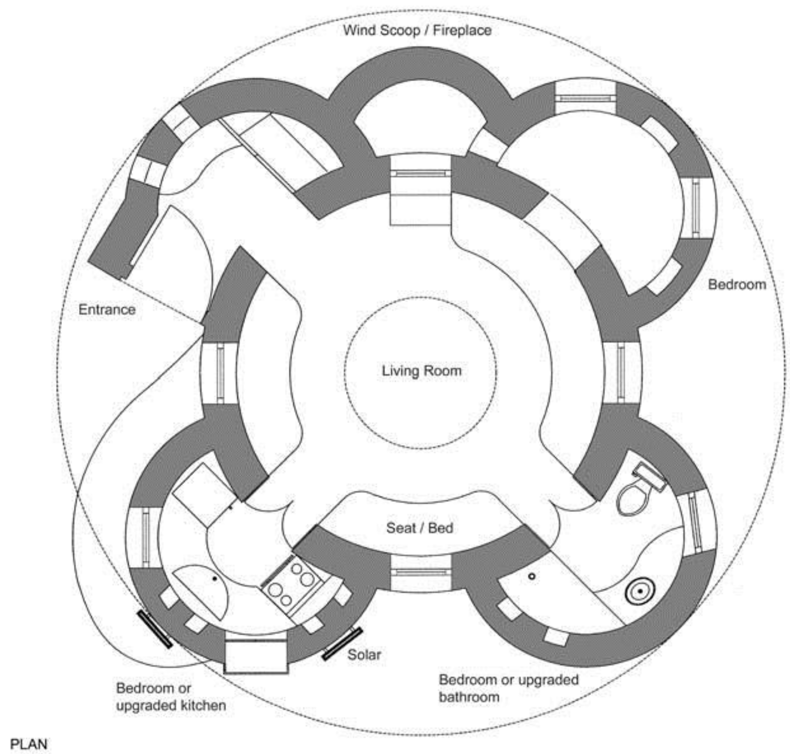

Figure 9: Sandbag Shelter Prototype Plan View (Agha Khan Award for Architecture 2004)

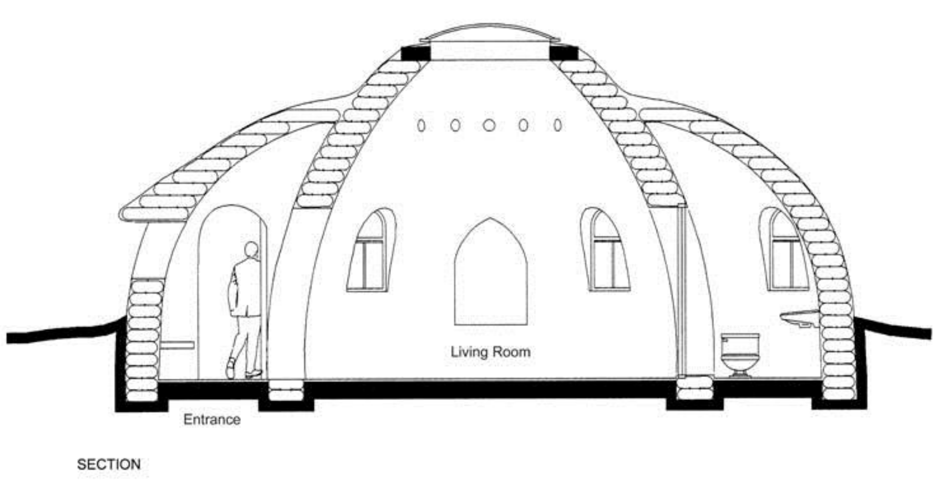

Figure 10: Sandbag Shelter Prototype Section View (Agha Khan Award for Architecture 2004)

In addition to the sandbags and filling, another component, the barbed wire, was introduced to the system to overcome the problem of the lack of tensile capabilities of the resulting structure. The barbed wire is used between the sandbags to ensure tensile and shear capabilities making the structure stronger and more durable. (Agha Khan Award for Architecture 2004)

Figure 11: Baninajar Refugee Camp in Iran (Agha Khan Award for Architecture 2004)

One of the main strengths of the system is that the material production time is relatively short. Unlike brick construction for example, of which the process of baking the bricks takes time. Also, it requires minimal skilled labor and can easily be constructed by the refugees themselves with short training sessions. Consequently, this system enables the people to participate in the construction of their homes and promotes the bottom-up approach and community engagement which results in easier transitions into independence when the external aids are phased out. The material required for construction are the sandbags and the filling. The sandbags, based on a research conducted by the project team, can be sourced locally easily. The filling is composed of earth from the camp site and required no production or transportation. The resulting structure is temporary, which responds to the laws of the host countries which forbids the construction of permanent structures in refugee camps. Moreover, it responds to the hope of the people to eventually return home. In the same time, it has the potential to become permanent if needed by adding a layer of plaster on top of the sandbags. Borrowing inspiration form vernacular architecture, the resulting system is sustainable is terms of materials and energy requirements by utilizing passive cooling and heating techniques used in traditional architecture. Also, the bottom-up approach feeds on the social sustainability aspect. Moreover, the ability of sourcing the materials locally and utilizing the skills of the local people enhances the economic sustainability aspect. However, sandbag constriction in general is criticized as it requires a lot of manpower and physical strength. For this reason, it is not adequate for emergency situation when speed of construction is the priority. Also, one may argue that the circular domes houses built due to structural limitation, are not expandable, and they offer limited flexibility to the users in term of layout configuration.

2.6.2 Better Shelter

Better Shelter is a collaboration between IKEA Foundation and the UNHCR that emerged from the need to provide refugees with a better shelter solution that provides more durability, safety, security and privacy.

Better Shelter system (figures 12 and 13) is composed of almost 140 components that are delivered in two flat boxes of which each weigh around 80KG containing a manual on how to assemble the shelter.

The shelter is composed of galvanized steel foundation that is anchored to the ground making it rain, snow and winds resistant. On top of the steel frame, polyolefin panels are placed forming the walls and the roof. The panels are treated with UV protection and therefore are more resistant to damage caused by the strong sunlight. The shelter are provided with windows, a lockable door, and a PV panel on the roof. The lifespan of Better Shelter is 3 years. (Better Shelter 2016)

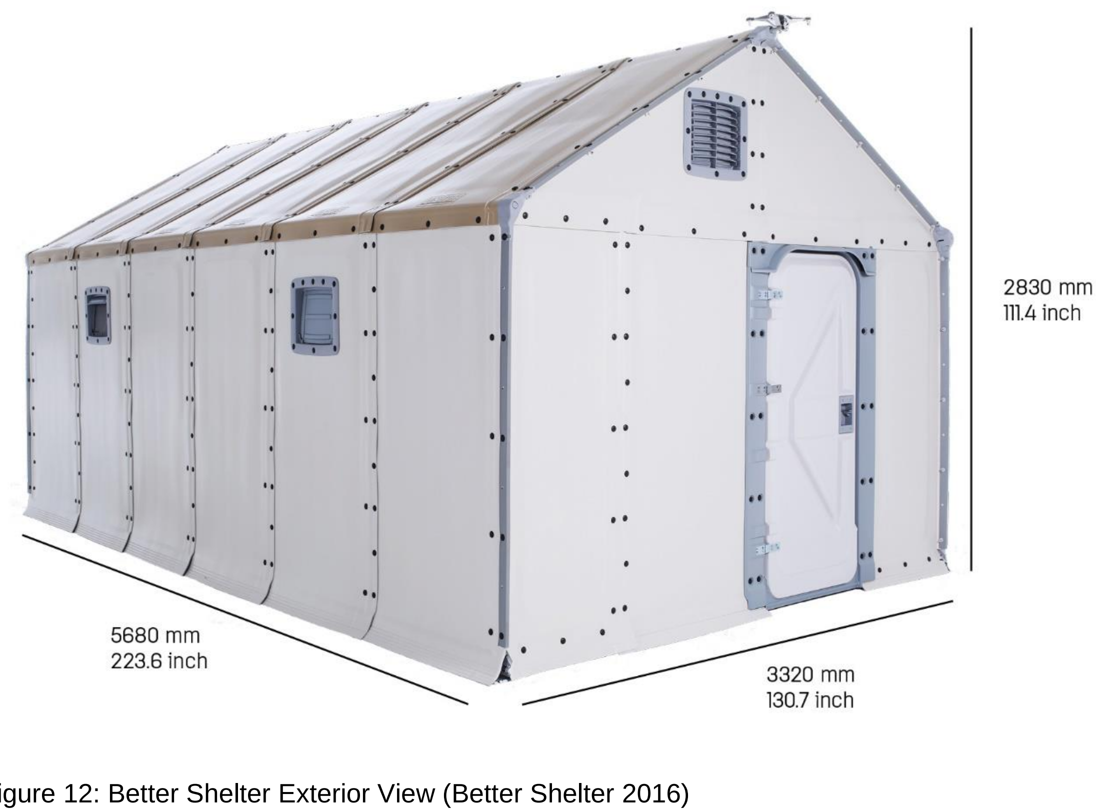

Figure 12: Better Shelter Exterior View (Better Shelter 2016)

Figure 13: Interior of a Better Shelter Prototype in Kawergosk Refugee Camp, Erbil, Iraq (Better Shelter 2016)

The system addresses the electricity issue in refugee camps by providing each shelter with a roof-installed PV panel. The electricity produced from the PV panel charges an LED lamp for up to 4 hours and provide an outlet to charge mobile phones via a USB port. It is easy to assemble and requires little manpower as it can be assembled by 4 people and would take 4-8 hours. Each pack is provided with an assembly manual that is easy to understand. The shelter is also easy to dismantle and move when needed. Add to that, one of the key concepts of Better Shelter is its flexibility and adaptability by creating a modular structure and interchange components making it easier to replace damaged components. It is also highly adaptable to personal needs. The layout, locating of the doors and windows are flexible. Moreover, the structure offers the option of adding or removing certain sections. Better Shelter is considered a more durable solution in comparison to tents. Therefore, it doesn't have to be replaced as often as in the case of tents, making it a more cost-efficient solution on the long term. Although very simple, Better Shelter highly resembles a house by having a high ceiling, walls with windows, and a lockable door, providing people the feeling of safety and a higher sense of dignity.

However, prefabricated shelters are criticized for being irrelevant to cultural and climatic context, since they are manufactured to be suitable for various locations. Moreover, imported solutions that are imposed on the refugee populations have a risk of promoting an attitude of dependence among the refugees since they provide no sense of belonging or decision making.
Also, safety tests conducted on Better Shelter units by the Swiss city of Zurich suggests that these shelters are easily combustible (The Guardian 2017b).

2.6.3 Earthship Biotecture

The Earthship concept is a sustainable housing method using heavyweight earth construction to create a self-sustained structure (figures 14 & 15). The concept was introduced by US architect Michael Reynolds in the 1970s, with around 3000 Earthship houses built around the globe today (Earthship Biotecture 2016).

Earhship houses are off-grid structures built from recycled local materials that are built taking into consideration passive cooling and heating methods and utilizing the earth mass as a temperature stabilizer. Hence, Earthship structures provide thermal comfort in different climates throughout the year.

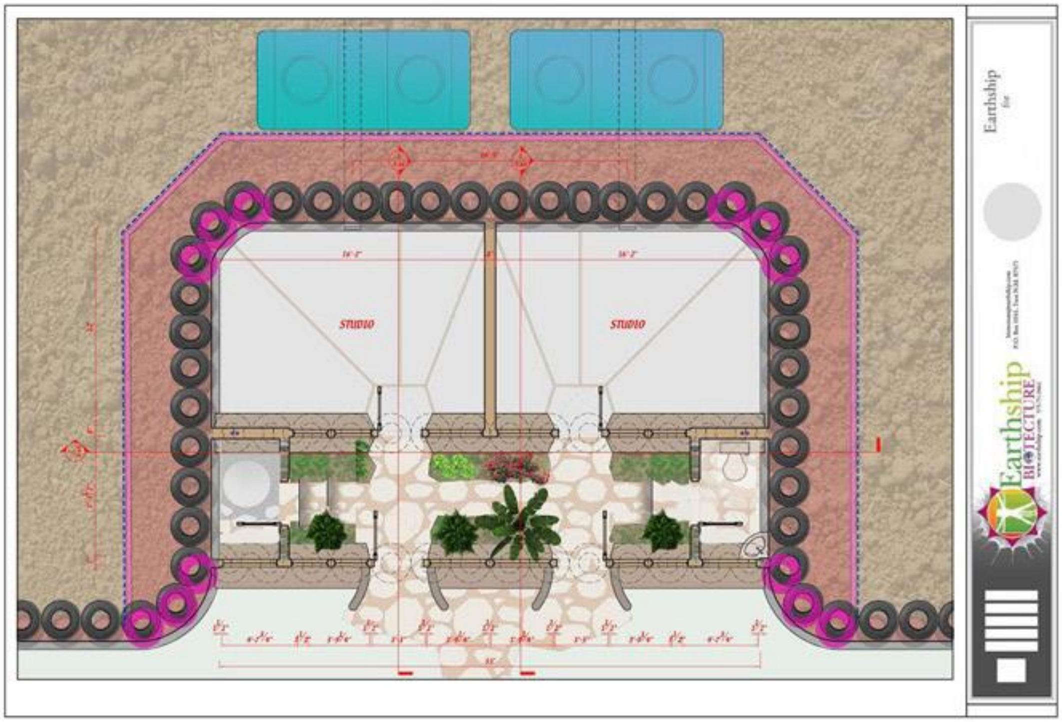

Figure 14: Earthship floor plan *(Earthship Biotecture 2016)*

Figure 15: Example of an Earthship structure (ecobrookly 2013)

Earthship is designed following 6 principles as follows:

Principle 1: solar heating and cooling, solar gain, thermal mass, and natural convection

The living spaces are surrounded from three sides with thermal mass in the form of automobile tyres rammed with earth. In winter, the full glazed south facing façade lets the sun in during the morning. The heat is absorbed by the thermal mass surrounding the living spaces, and is released when the temperature drops down at night. In summer on the other hand, the sun is higher in the sky and the sun only penetrates the part of the living space where planters are placed. The naturally cool temperature of the deep earth cools the building.
Moreover, the difference in temperature and air pressure resulting from the distribution of glazing and thermal mass, as well as the operable windows, help generate natural ventilation through natural convection.

Figure 16: Example of an Earthship structure (ecobrookly 2013)

A study published in 2009 investigate the thermal performance of one Earthship structure in the UK. The structure is located in Brighton and was completed in 2006. The study focused on the performance of the rammed earth tyre wall. Results of the study demonstrated the effectiveness of this design solution in moderating the severe external conditions and shows that it is successful in maintaining a higher indoor temperature. However, more heating is still required to achieve the optimum thermal comfort levels. The study also discussed the problem of overheating of the south facing façade in summer and suggest improvement of natural ventilation to prevent the greenhouse effect in summer.

Principle 2: Energy generation

Earhship houses are equipped with PV panels and/or wind power system. The generated energy is stored in batteries and distributed to power outlets around the house.

Principle 3: Recycled or reclaimed building materials

Earthship structures utilize local byproducts of modern society as building materials including the following: automobiles tyres, plastic and glass bottles, aluminum and steel cans, natural mud and straw plaster, and reclaimed wood.

Principle 4: Water harvesting

Earhship houses are equipped with a variety of water harvesting systems such as roof water catchment systems and cisterns. Water is used 4 times and treated on site.

Principle 5: Sewerage treatment - Botanical cells

Sewerage treatment systems in an Earthship is composed of indoors and outdoors botanical cells that help filter grey water from sinks and showers that is used for flushing. Moreover, Black water is used in outdoors landscaping.

Principle 6: Food production

Grey water botanical cell provides an opportunity to grow some fruit and vegetables making Earhship houses self-sufficient food producing structures.

2.6.4 Dissemination of Bioclimatic Solutions for Urban Housing in Afghanistan

The Group for the Environment, Renewable Energy and Solidarity (GERES) is a non-governmental organization that focuses on clean and sustainable energy and preservation of natural resources by developing technologies and providing services that help reduce fuel poverty issues in the world. GERES have been working on a number of projects to enhance the energy efficiency levels of homes and public buildings in different cities in Afghanistan. In 2014, GERES started working on a new project in Bamiyan city in Afghanistan, aims at improving the energy efficiency of houses and provide affordable solutions to heat spaces during harsh winters. The project also attempts to spread awareness at the community level (Group for the Environment, Renewable Energy and Solidarity 2015).

The project aims at utilizing local materials and techniques to upgrade existing houses into Passive Solar Houses (PSH). One example of the implemented strategies is the addition of Passive Solar Verandas (figures 17 & 18). A Veranda, or a sun space, is a wooden farmed structure covered with affordable polythene sheets built on the south façade of the housing units. Due to the greenhouse effect, the temperature inside is on average above 20°C. Therefore, the veranda creates an additional living space that is warm and comfortable for the people who suffer from extreme cold climate and expensive fuel.

This installment of verandas in households created a warm pleasant gathering space for the family in winter (figure 19), helped increase the indoor air temperature by +10 to 15°C, reduced the need for heating fuel between 5 and 30% annually, and reduced CO_2 emissions to 50%. Additionally, since this program was developed in collaboration with the local craftsmanship by offering training sessions, it helped create additional sources of income for them. Moreover, this ensured that the local people are able to operate this project independently on the long run. (Building and Social Housing Foundation 2016)

Figure 17: dissemination of bioclimatic solutions for urban housing in Afghanistan (Group for the Environment, Renewable Energy and Solidarity 2015)

Figure 18: Verandas installed by GERES in Bamiyan city (Building and Social Housing Foundation 2016)

Figure 19: Interior of a veranda installed in a house in Afghanistan (Building and Social Housing Foundation 2016)

2.6.5 T- Shelters in Azraq Camp

T-shelters are composed of interlocking steel frames that are cladded with IBR sheeting as shown in figure 20, 21 and 22. This kind of shelters were implemented in Azraq Camp in Jordan with 13,500 T-shelter units housing 67,000 Syrian refugees. The size of each shelter is $24m^2$. The total cost per unit is US$ 2,330 (IFRC, UN-Habitat & UNHCR 2014)

Figure 20: Diagram of the T-Shelter showing its layers and the possibility of adding a side entrance for privacy

Figure 21: T-Shelters under construction (UNHCR 2015b)

Figure 22: Interior of a T-Shelter (UNHCR 2015b)

The main advantages of T-shelters is that they are relatively spacious. Moreover, the production and assembly of T-shelters is less complicated compared to prefabricated shelter solutions. As competition between local contractors arise, some contractors started developing their own methods to make production easier and cheaper and providing employment opportunities among the local community. It is easy to assemble, dismantle and transport responding to the possibility of relocating requirements. It is also flexible as it can be extended and modified or subdivided using internal partitions to provide inhabitants with needed level of privacy, and it is provided with leg extenders making it easier to erect the structure on uneven land.

Nevertheless, T-shelters have a number of disadvantages. The production is still not fast enough to accommodate the population spikes needs. Therefore, tents are still needed. Another issue is that the Inverted Box Rib (IBR) corrugated sheet used for cladding the steel structure does not secure from leakage and dust. Also, the original design of the T-shelter included the construction of a porch that had to be canceled afterwards due to time requirements and cost. Beneficiaries were not satisfied because of reduced levels of privacy.

2.6.6 Rental Support Program

The flow of Syrian refugees to Jordan has put pressure on low-cost housing in the country and the urban infrastructure that is not being able to cope with the sudden ongoing increase in the demand for affordable house, which leads to tension between the refugees and the local community. One of the attempts to solve this issue is the rental support program that is being implemented in Irbid and Jerash Governorates (IFRC, UN-Habitat & UNHCR 2014).

The rental support program is in fact a number of projects that are happening in different areas supported by different donors and organizations. These organizations support landlords to complete unfinished housing projects in order to increase the number of housing affordable properties available for rental. Landlords are given a cash grant to finance the construction process and cover the rent for one refugee family for a specified period of time. The total cost per unit is US$ 2,500 of which US$ 1,400 is considered the rent for 12 months for one refugee family.

The project is funded by different donors, each has their own project timeline. Staff members from supporting organizations are responsible for ensuring the suitability of the property and they supervise the construction process. Also, they are responsible for all the legal processes. Organizations attempt to spread the word through a communication strategy that includes distributing leaflets, meeting with the local authorities and communities, and word of mouth. Interested landlords and property owners then approach the organizations. In total, the landlord would cover around 29% of the construction cost, the rest is covered by the supporting organizations.

The main advantages of this system is that it helps increase the number of housing units available for rent and reduce the pressure on the rental market, benefiting both the refugees and the local community, and it helps create employment opportunities. However, it is difficult to scale-up the project due to high labor and time requirements. Therefore, the current application scale does not significantly reduce the pressure on the rental market. There is also a risk of landlords breaking the deal after receiving the construction grant.

2.6.7 RE:BUILD

RE:BUILD is an innovative and revolutionary low-cost construction system developed by a collaboration between Pilosio Building Peace, architect Cameron Sinclair, and architect Pouya Khazaeli. RE:BUILD was developed to help with the Syrian Refugee crisis and the escalating need for shelter.
This construction system utilizes scaffolding tubes with natural materials that are available on-site, such as gravel and sand (figures 23,24,25). It can be used to construct any modular building that can be used as a home, clinic or school. The system is easy to construct and can be built by the refugees themselves as it requires little or no experience in the construction field. Structures built using this system are fast to construct and are considered a flexible, expandable, and environmentally friendly solution (Inhabitat 2012).

Figure 23: RE:BUILD construction system (Inhabitat 2012)

Figure 24: RE:BUILD construction system (Inhabitat 2012)

Figure 25: RE:BUILD construction system (Inhabitat 2012)

The system is composed of two main components: the scaffolding tubes that are connected together to form the main framework, and the filling that can be sand, gravel, or stone depending on the availability on-site. The flooring, on the other hand, is made of plywood panels covered with phenolic film and are imported from northern Europe. A layer of soil is added on the roof top to create a green roof. The structures are also equipped with a rainwater collection system.

2.6.8 Sandbag Classrooms

Castles of Sand is a project conducted by FAREstudio in Mbera refugee camp in Mauritania between 2012 and 2014. The project was a response to the need of constructing 60 classrooms with an approximate budget of 3,500 USD dollar per classroom. The structures were aimed to be of a transitional and temporary nature, in the same time are more comfortable and durable than the standard tents.

The design propsed b FAREstudio was based on the sandbag technique since transportation was difficult and the most available material on site was sand. The proposed design illustrated in figures 26,27 and 28, has loadbearing walls composed mainly of sandbags filled with sand and supported with chicken wire. The roofing system is a common roofing typology used in the area composed of steel trusses covered with truck tarpaulin. (FAREstudio 2014)

Figure 26: A classroom under construction (FAREstudio 2014)

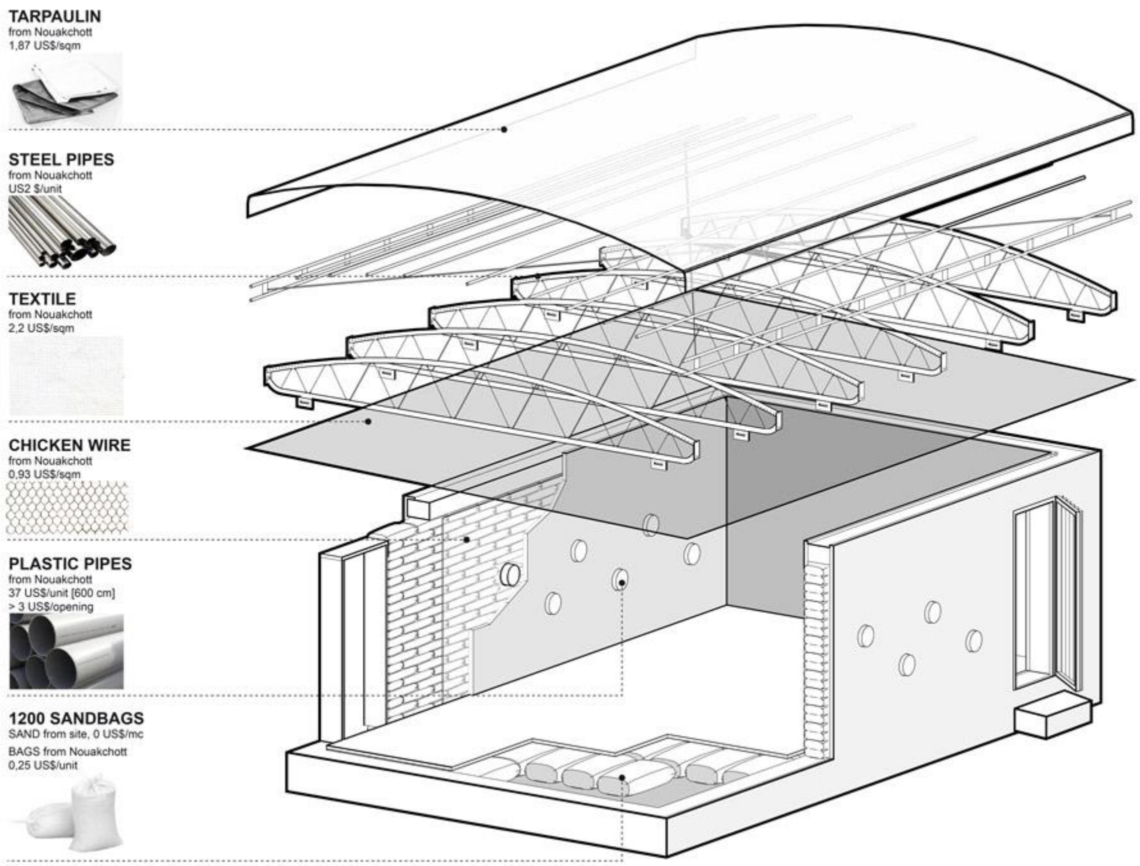

Figure 27: Construction system of Castles of Sand project (FAREstudio 2014)

Figure 28: Completed classrooms (FAREstudio 2014)

2.6.9 Incremental Housing - Villa Verde

Villa Verde is a social housing project design by Elemental Think Tank in Chile. The aim of the project was to construct a hundred housing units with a subsidy of $7,500. The budget only allowed for a building very tight houses. To overcome this problem and make use of the land area, Elemental proposed a housing typology where low-cost half of a housing unit is constructed (figure 29) allowing the residents to complete the constructions themselves gradually. With time, families started improving and expanding their housing units, each in response to their priorities and budget (figure 30).

Figure 29: Villa Verde half houses (Archdaily 2013)

Figure 30: Villa Verde completed houses (Archdaily 2013)

This incremental housing approach, according to Aravena, is a sustainable long-term solution for the housing shortages around the world triggered by the immigrants and refugee crisis. (Dezeen 2015b)

In the ABC of Incremental Housing (Elemental 2017), Aravena suggests 3 areas of development to be focused on when starting a project with limited resources:

“A. What is more difficult
B. What cannot be done individually
C. What will guarantee the common good in the future (Elemental 2017)”

Examples of the points listed above are designing the urban spaces in between the building plots, and building the structural frame that allows for future expansion.

2.6.10 Summary of Findings

- Three approaches of transitional shelters provision can be identified:
    - The top-down approach, which is most effective is cases of emergency when fast solutions need to be implemented. An example of that is Better Shelter and T-shelter in Azraq Camp
    - The bottom-up approach, which is often utilized after the emergency phase and when more durable solutions are required. Sandbag homes and Re:Build are good examples of that.
    - The incremental approach, which is a combination of the top-down and the bottom-up approaches. The concept lies in dividing the work

between the relevant organization and the beneficiaries. This approach is the base of Verde housing project in Chile.

- Utilizing on-site available materials is a common practice when it comes to shelter construction. Examples of that are sandbag construction and earth construction techniques.
- Steel construction and corrugated sheets are affordable solutions that enhance the security and privacy of the shelter, but they do not protect from dust and rain.
- Earth construction techniques are gaining popularity due to affordability and good thermal performance when compared to tents and steel shelters
- Cultural relevance is a very important aspect to be taken into consideration when designing transitional shelters. For this reason, it is often preferable to utilize local solutions and craftsmanship.
- Designing for thermal comfort is crucial. Enhancing the thermal comfort of the shelter starts with designing for a specific climate, optimizing the orientation, and adopting passive heating and/or cooling techniques that can be achieved with simple low-cost materials and configurations.

3 Chapter 3: Methodology

3.1 Overview

This chapter will introduce different research methodologies that have been used to investigate methods of enhancing shelter design in refugee camps. The advantages and disadvantages of each methodology will be presented in this chapter, as well as the selection of the most suitable research method for the questions at hand.

Various studies have been conducted to assess the performance of shelters in post-disaster situations in different areas worldwide. However, limited research was conducted in Iraq since the refugee camps are relatively new. Therefore, this chapter will present studies that were carried out in Iraq and in other areas around the world since, in many cases, the same methodology can be applied to various contexts.

3.2 Defining research parameters

It is worth mentioning that this paper presents a multi-disciplinary investigation. The issue under examination is multilayered. Therefore, the selected methodology has to be comprehensive covering a wide range of subjects. The scope of the investigation widens up to cover basic concepts related to post-conflict shelters and then narrows down to focus in depth of shelter enhancement strategies for Domiz camp.

Shelter enhancement, also has various aspects to be taken into consideration such as: materials availability, cost, speed of construction, thermal performance…etc. Some research choses to focus on one aspect more than the other, other research, on the other hand, aims to be more comprehensive.

This investigation is intended to be as comprehensive as possible to insure applicability in real life, with a focus on thermal performance.

3.3 Comparison of research methods applicable to this research

Extensive research has been carried out to investigate strategies to create successful and sustainable post-conflict temporary housing units that provide inhabitants with high living standards, and is in the same time, responsive to the context and the environment, requires reasonable amount of time to be constructed, and is cost efficient. Some of the papers presented looks at the topic from a wider angle and aims to present general recommendations and guideline to achieve that. Other, on the other hand, focus on a specific issue such as thermal performance. Since this research aims to cover general and specific, different papers are reviewed and presented on this chapter. The different methodologies presented are qualitative, quantitative or a combination of both.

3.3.1 Qualitative Research

Qualitative research involves exploring a topic by means of surveys, interviews, and/or observations to reach a general understanding. Qualitative research can be the base of further quantitative research.

Abulnour (2014) published a study that aimed to provide a set of recommendations to guide the provision, design, and construction of post-disaster temporary dwellings, to help decision makers and communities in producing housing units that provide acceptable living standards, in the same time, are cost and time efficient. The research methodology adopted by this study is a multi-disciplinary literature review. The study takes into consideration that there are various aspects to this subject that needs to be investigated such as the economic aspect, the socio-cultural aspect, the ecological aspect, and the technical aspect. Therefore, the researcher attempts to be as comprehensive as possible to include all the mentioned aspects in the investigation. Moreover, the study looks into examples and case studies of temporary shelters in different countries and assesses their successes and failures. The study results in a list of recommendations that are grouped according to the criteria they respond to. This research focuses on qualitative aspects, for this reason, literature review and case studies is considered a suitable research methodology.

Another recent investigation carried out by in 2013 aims to investigate the sustainability and cultural inadequacy problems of post-disaster shelters. The study explores the reasons why these problems occur and the most up-to-date strategies to overcome these issues. The methodology used to conduct this research is literature review. The researcher reviews recent studies that are relevant and reviews recommendations by different researchers. Based on that, guidelines for post-disaster temporary housing solutions are presented. (Félix, Branco, and Feio, 2013)

Hosseini et al (2015) presents a Multi-Criteria Decision Making model (MCDM), The Integrated Value Model for Sustainable Assessment (MIVES) model, to assess the sustainability of Temporary Housing Units (THUs) used in post-disaster situations. The model is generated to enable decision makers to select the most adequate and sustainable temporary housing typology. As a result, this will help reduce the negative impact of temporary housing economically, socially and environmentally. A sustainability index for each alternative is calculated by assessing a number of requirements, criteria, indicators, and subindicators of which each has a different priority and weight determined by a group of experts in previous studies. To test the proposed model, it was applied to determine the most sustainable alternative for post-disaster housing in Bam. Sustainability analysis was conducted on four temporary housing unit typologies the most sustainable option was determined. The study recommends that decisions-makers can modify indictor values depending on their requirements to improve the model and make it more relevant to different contexts.

An MSc thesis by Al Nimri (2014) looks into the issue of refugee camps on a larger scale and focuses on the planning and design of refugee camps. The thesis takes two refugee camps in Jordan, Al Zaatari and Al Azraq, as the man focus of the research. By means of field and empirical research along with literature review, the two planning and design models of the two camps are presented, analyzed, and compared. Based on the findings, a regeneration response plan is proposed to enhance the life and well-being of refugees in refugee camps.

Another MSc thesis (Gul 2015) focuses on Dara Sharakan Camp and Arbat Camp in Kurdistan region in Iraq. The study looks into the refugee camps as the cities of the future, and aims to develop urban planning strategy to transform the current camps into off-grid self-sustained cities. Moreover, a proposal for a possible shelter solution is proposed. The research is composed of two sections: field research and desk research. In the field research section, the researcher conducts a number of site visits to observe and document the current conditions of the camp under study. Interviews of UNHCR officials and refugees is conducted, as well as surveys. After that, the collected data is processed in the desk research section. Additionally, literature review and case studies are utilized.

Slater (2014) analyzed refugee camps in terms of their urban system. The balance between the needs of individuals and the need of the community in the case of refugee camps is discussed. Through literature review and analysis of case studies, the search highlights the strengths and weaknesses of different urban and shelter design practices applied worldwide. The study focuses on the case of Al Zaatari Camp in Jordan and analyses the current urban form and present shelter typologies. Combination of existing shelter typologies and introducing public spaces is part of the solution proposed by the researcher.

3.3.2 Quantitative Research

Quantitative research, on the other hand, deals with measurable data, and is most suitable when a hypothesis is tested with numerical figures, and results are presented in numbers, charts, and/or tables. The types of quantitative research applied to the research question at hand are experimental, digital simulation, and a combination of both.

Experimental research is used to test a certain hypothesis in a real-life setting or in a laboratory. Although this method results in high accuracy of the obtained data, it requires space, materials and tools and more man power making it less accessible to individual researchers. Also, the test is conducted under real-life conditions, the researcher does not have the ability to control the variables, which will often lead to more time requirements. Research through simulation, on the other hand, involves the creation of a physical or digital replica of reality. By doing so, the researcher is able to test a certain phenomenon holistically, taking into consideration all the variables as in reality. Results of research carried out by simulation is often close to real-life situation but it does not enable researchers to isolate and test specific factors to understand their relation. (Groat & Wang 2002)

Employing the simulation method in evaluating strategies to enhance post-conflict shelter was found in a research carried out by Borge-Diez et al. (2013). The paper argues that passive heating and cooling techniques are not being utilized to reduce energy consumption levels in low cost emergency shelters. The study sheds the light on the fact that in 2010 over 40 million people were forced to leave their homes for reasons such as conflict and natural disasters. Therefore, there's a big demand to improve the living situations of displaced people in emergency shelters. A case study is selected in Central America in Haiti where more than 100,000 buildings were destroyed as a result of an earthquake that hit the country in 2010. At the time the study was conducted, 1.3 million displaced people in Haiti were still living in tents and in transitional shelter. It is suggested that passive heating and cooling techniques have a great potential to improve the thermal performance and the living conditions of those transitional low-cost shelters. Two thermal simulation software were used to conduct the research: Energy plus and Design Builder. In this paper, a combination of three technologies is proposed as a solution: the layout distribution of the housing units, cool roof technology, and natural ventilation. The combination of these systems together resulted in a 50% drop in energy demand in peak hours, and a 40% drop in annual energy consumption levels.

A recent study (Cornaro et al., 2015) assesses of the thermal performance of emergency shelters and investigates the indoors environmental conditions. The assessment process help establish solutions to enhance the thermal performance of emergency shelters taking into consideration the materials that are often used for emergency shelters and the climatic conditions of the context they are placed in.

The research methodology used to carry out this investigation is a combination of experimental and digital simulation research methodologies. The shelter on which the tests were performed is a tent with a photovoltaic system produced by CHOSE (center of Hybrid and Organic Solar Energy). The tent is composed of a steel pole structure and a fabric. The tent prototype was assembled in an unpaved area near Rome where the monitoring campaign took place. Readings of internal air temperature, external air temperature, wind speed & humidity were documented over a week time in May 2013. Using the dynamic building simulation software IDA Indoor Climate and Energy 4.5, a model that reproduced the thermal performance of the tent was created. After that, a calibration process was implemented using the experimental data collected during the monitoring campaign, followed by testing the tent in two extreme climatic conditions using ASHRAE climatic data of Turin city to simulate extreme cold conditions, and Palermo city to simulate extreme hot conditions. A base case was created simulating the thermal performance of the tent before introducing any solutions. A number of simple solutions, that are easy to implement, were tested using the simulation model such as the addition of thermal insulation (aerogel pad) and tent floor treatment. Results show that the proposed solution are these solution helped improve the internal temperature slightly in winter, and reduce the internal temperature by 6°C in summer. The study recommends using the same method to test different thermal solutions and measure their impact.

Obyn, van Moeseke, and Virgo (2015) argue that it is crucial to establish a framework to assess the thermal performance of temporary shelters used in emergency situations. The paper discuss the challenges of creating an accurate simulation method for temporary emergency structures since many of the shelter typologies used in these situations are made of fabric materials and/or are highly subjected to a high percentage of air infiltration rate. The model was created out of multiple zones in order to simulate the thermal behaviors of the gap between the outer and inner skin of the tent. Also, the tent fabric was represented as a glazed surface to simulate its translucency properties. Moreover, the glazing was considered opened with a specific discharge coefficient to simulate the air tightness of the fabric. The computer simulation model was then calibrated with field experiments data carried out in Belgium Burkina Faso and in Luxenberg. The study resulted in an accurate simulation model that can be used to assess the thermal behaviors of the UNHCR family tent in different climatic conditions.

3.3.3 Mixed Method Approach

Due to the multidisciplinary nature of the research question at hand, a combination of qualitative and quantitative methods is also used. An example of the mixed method approach is a recent research (Albadra et al., 2017) that carried out to evaluate the thermal comfort in desert refugee camps focusing on Al Zaatari and Al Azraq refugee camps in Jordan. A combined quantitative and qualitative research methodology was utilized. The study argues that when measuring thermal comfort, thermal adaptation is often underestimated. For this reason, a survey based on the numerical ASHRAE scales was conducted, to measure and incorporate thermal adaptation. Moreover, results of the surveys are used to evaluate and identify priorities for the refugee community in terms of shelter thermal performance. The surveys were written in Arabic and fully explained to the families through interviews. Besides the social surveys, thermal surveys were conducting taking measurements of thermal parameters inside the shelters. Different numeric methods were used to analyze the data obtained from the surveys to determine the thermal comfort band, which was found to be ranging from 17.2°C to 28.4°C, showing the high adaptability of the refugee population. Results of the study shows that, although adaptation levels are higher during summer, thermal comfort of the population was reported higher during winter. In terms of shelter design, the highest priority for the refugee population was safety and security, then thermal comfort. The study also revealed that allowing the refugees to modify their shelters as they see fit is a very important aspect for achieving thermal comfort, as it allows them to create new configurations where they can maintain their privacy, and in the same time allow for ventilation. Such solutions have a affected their thermal comfort levels positively, specially during summer months.

Similarly, a combined research methodology was adopted by Dabaieh and Alwall (2018) in their recent research investigating the possibility of adopting a do-it-yourself approach for constructing shelter units for refugees. The research discusses the first phase of an on-going project focused on Syrian refugees in Sweden. The aim of the project is to utilize sustainable building strategies and materials with low ecological impact and involving the refugees in the construction process in the time spent waiting for their asylum process to be completed in Sweden.

Qualitative research in the form of surveys and interviews targeted to the refugee population was the starting point of the research. Results of the survey helped establish an understanding of the occupants needs, and their aspiration for their future homes. Also, this part of the research was important to understand the social and cultural customs. The data obtained from the surveys and interviews were considered the base for the following phase, referred to as “experimental living lab”. The research methodology of this phase can be described as participatory and action-oriented. During this phase, a prototype was built in collaboration with the refugees. Through the hands-on experiment, the construction process was assessed, as well as the refugees’ willingness to participate in the design and building of the prototype. Observations of the participatory focus group during the different stages of this research shows that involving the refugees in the construction is important to ensure that the shelter design is responding to their needs, and that social and cultural design aspects are taken into consideration. However, further research is needed to develop the technical and architectural requirements.

3.4 Research Methodology Selection

The selected research methodology is a combination of qualitative and quantitative research. This investigation is multi-dimensioned. Therefore, each research methodology would be best suited to cover a certain part of the study. The stages of the research are described in Fig 31.

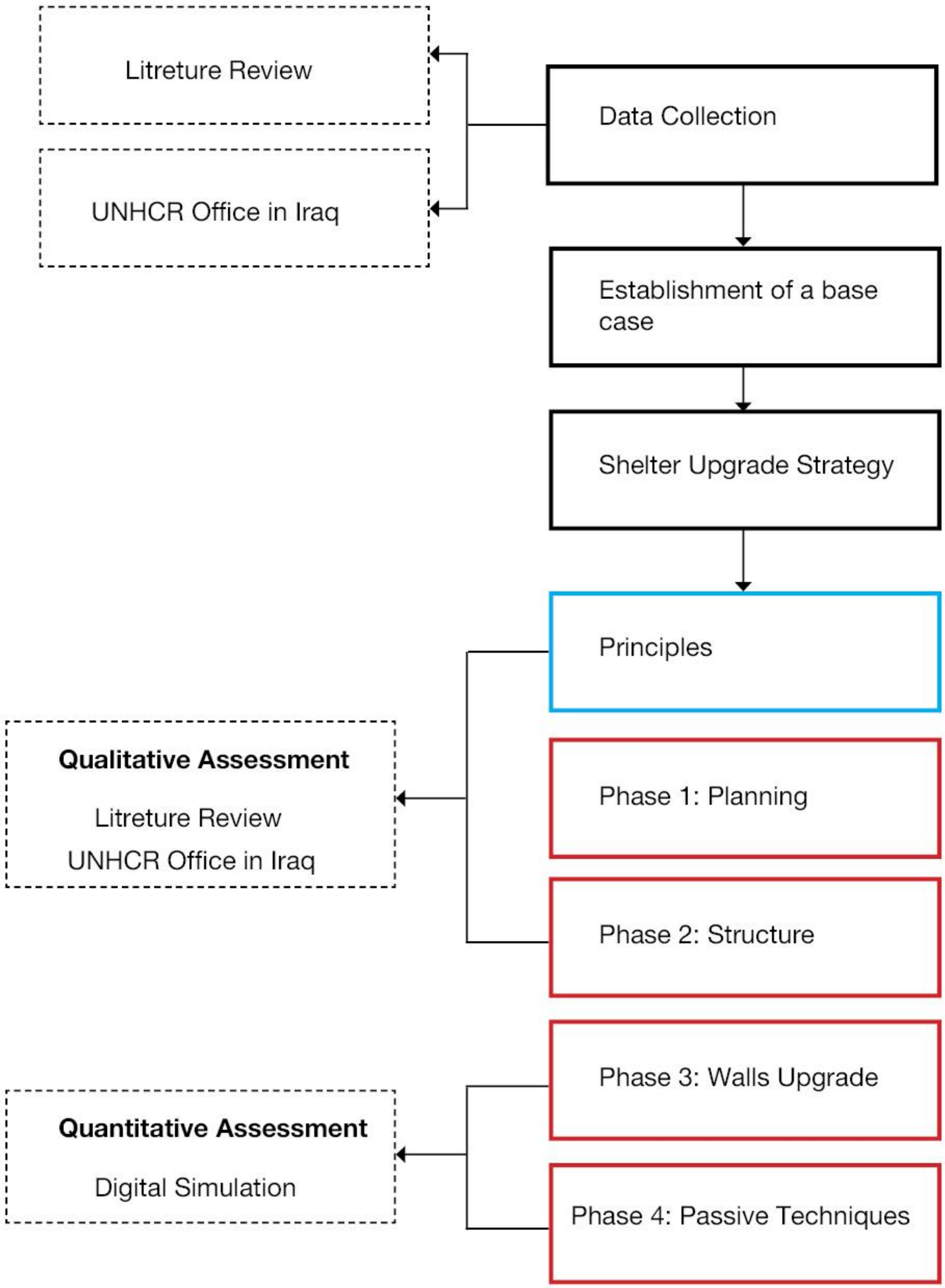

Figure 31: Research stages and methodology

3.5 Data Collection

Data collection will be conducted through two main sources:

3.5.1 Literature review

Literature review is the most suited method to cover the part of the study that investigates the general recommendations and design guidlines for transitional shelters, and looks into implemented examples to assess their successes and failures.

3.5.2 Contact with the UNHCR office in Iraq

Involvement of the UNHCR office in Iraq was seen as a crucial step since the beginning of this research. Communication between the author and the UNHCR office in Iraq was carried out via email. The first major involvement of the UNHCR office was in forming the research question. Domiz refugee camp was suggested as a potential case study. Also, a number of suggested areas of research was communicated to the UNHCR team as follows:

Feedback from the UNHCR was received on the 21st of December 2015, stating that Domiz refugee Camp is considered suitable and the specific area of research is shelter design and enhancement.

After the start of the research, a list of questions was prepared by the author and sent to the UNHCR team (refer to Appendix 1). The provided responses helped shape the base case shelter typology and direct the enhanced proposal.

3.5.3 Establishment of a base case

Based on the collected data through communication with the UNHCR office and literature review, a base case of a typical shelter typology in Domiz refugee camp is established.

3.5.4 Shelter Upgrade Strategy Proposal

A number of shelter enhancement strategies are proposed and assessed. Two approaches to assess the performance of the proposed enhanced design in comparison to the base case are utilized.

Qualitative Assessment

This approach is used to assess the general sustainability level of the design. Aspects assessed include provision approach, social and cultural adequacy, materials availability, Feedback from the UNHCR office is also an important tool to insure applicability and practicability of the proposal.

Quantitative Assessment

Unlike the social and contextual aspects of the proposed design, its thermal performance can be assessed with numerical data. The selected method to conduct the thermal performance assessment is digital simulation.

One of the advantages of research through digital simulation is enabling the researcher to easily control and alter the tested variables. Therefore, different scenarios can be simulated and tested in a very short time. Simulations are not dependent to external conditions. For example, the performance of the proposed shelter can be tested under different seasonal conditions in a short time, unlike experimental in which the researcher will have to take measurements over a yearly cycle. The tools required to conduct research with digital simulation is often limited to a computer and a simulation software, which are often widely accessible to researchers. Most of the digital simulation software are available with reduced process for students and researchers. Simulation can be conducted by an individual researcher. As a result, this method if favored by many.

4 Chapter 4: Results and Discussion

4.1 Overview

This chapter is designed to explain the 4 phases of the proposed shelter upgrade strategy, referred to as the Incremental Home Strategy, and assess the performance of the proposed shelter against the shelter typologies currently present in Domiz camp. First, each shelter typology currently being used in Domiz camp is explained. After that, phases of the proposed shelter upgrade strategy are presented. In the first phase, the optimum shelter orientation and clusters configuration is discussed. In phase two, recommendations on providing a durable structural frame is presented. After that, in phase three, a wall panel system is proposed as an alternative to the conventional solutions currently being utilized in Domiz camp. Finally, in phase four, the implementation of passive heating and cooling techniques is discussed. Two passive techniques are highlighted: the sunspace and the roof canopy. A qualitative assessment of phases 1 and 2 is presented by referring to the literature and relevant case studies prepared in chapter 2 of this research. Meanwhile, a quantitative assessment is presented in the last section for phases 3 and 4, where digital simulation is conducted to assess the thermal performance of the proposed strategies against the shelter typologies currently used in Domiz camp.

4.2 Shelter Typologies in Domiz Camp

This section is a review of the different shelter typologies currently present in the Domiz Camp according to the feedback received from the UNHCR office in Domiz Camp during October 2016. Moreover, supporting information and illustrations are derived from an interactive documentary film titled “Refugee

Republic" (Submarine Channel 2015), which received two awards in 2015, and was set in Domiz Refugee Camp. The documentary shows, through a series of photographs, written paragraphs, films, and illustrations, the everyday life of the people in Domiz Camp and describes thoroughly the shelter evolution and improvement process in the camp.

Currently, there is a total of 6,482 shelter units in Domiz camp, of which 5,056 are in Domiz 1 Camp, and 1,426 are in Domiz 2 Camp (figure 32). Four shelter typologies present in Domiz camp (table 1) which are as follows:

- The basic UNHCR tent
- Wooden or steel structure covered with tent fabric and/or blankets
- Steel structure covered with corrugated sheets
- Concrete blocks

Figure 32: Aerial view of Domiz camp (UNHCR)

Table 1: Shelter typologies in Domiz camp (UNHCR 2016, personal communication, 24 July)

Shelter Typology	**Number of Shelter Units**		
	Domiz 1	**Domiz 2**	**Total**
Standard UNHCR Tent	36	0	36
Wooden or steel structure covered with tent fabric and/or blankets	2170	26	2196
Steel frame covered with corrugated sheets	500	95	2232
Concrete blocks	2350	1305	3655
Total plots/shelters	5056	1426	6482

4.2.1 The basic UNHCR Tent

Once refugees are registered in the camp, they receive the standard UNHCR tent (figures 33 & 34). The total area of the standard family UNHCR tent is 23m^2 and is suitable for a family of 5 people. The family tents are considered a short-term solution and are designed for emergency situations. The life-span of the standard UNHCR tent is 1 year if maintained properly (UNHCR 2016e). One of the main issues with this shelter typology is that it is not resistant to wind and rain as shown in figures 35 and 36.

Figure 33: The standard UNHCR family tent for cold climates (UNHCR 2016e)

Figure 34: Standard UNHCR tents in Domiz Camp (UNHCR 2016, personal communication, 04 October)

Figure 35: Example of a flooded tent in Baghdad (UNHCR Iraq 2015)

Figure 36: UNHCR tents blown away by a wind storm in Domiz camp (Anderson 2013)

4.2.2 Wooden or steel structure covered with tent fabric and/or blankets

After living in the camp for some time, it’s common to see the refugee population undertaking upgrade measures to enhance their shelter and gain more privacy and more space. People either replace their tent or create an additional structure using wooden sticks to build the main structure that is covered with the tent fabric, blankets, and plastic sheeting as illustrated in figure 37.

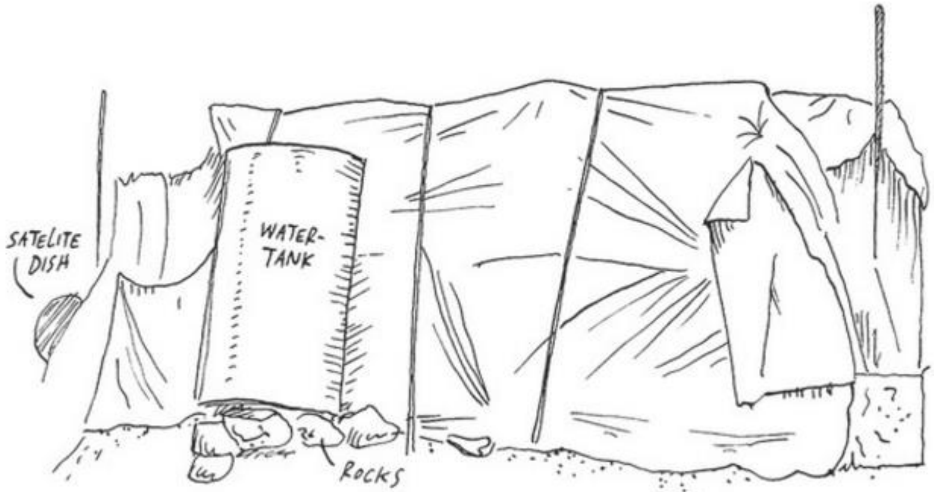

Figure 37: Drawing of a wooden frame shelter in Domiz camp (*Submarine Channel 2015*)

Due to the vulnerability of these structures, which one may refer to as huts and are easily blown away by winds stronger than the average daily breeze, the next upgrade is replacing the wooden structure with a steel structure that is more stable and durable (figure 38) .

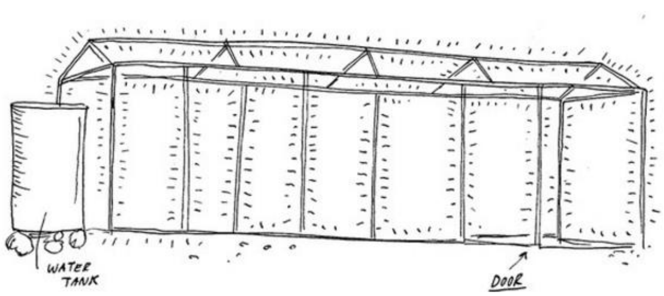

Figure 38: Drawing of a steel frame shelter in Domiz camp (*Submarine Channel 2015*)

It's important to highlight that in this stage of shelter typology evolution, refugees try various combinations. Therefore, forms of hybridization emerge as shown in figures 39 and 40. One of the risks of this behavior, is the possibility of over exhausting the structures and loading them with materials that are heavier than their capacity, resulting in the risk of shelter collapse (Slater 2014).

Figure 39: Example of a hybrid shelter typology found in Domiz Camp (Submarine Channel 2015)

Figure 40: Example of a hybrid shelter typology found in Domiz Camp (Submarine Channel 2015)

4.2.3 Steel Structure covered with corrugated sheets

The next step in shelter typology evolution in Domiz camp is replacing the fabric and blanket covers with corrugated steel sheets which are an available and cost effective solution that is common in the context of refugee camps. Figures 41 and 42 show examples of corrugated steel sheets used as a shelter cover in Domiz camp.

Figure 41: Example of a corrugated steel sheet shelter in Domiz Camp *(Submarine Channel 2015)*

Figure 42: Example of a corrugated steel sheet shelter in Domiz Camp (Submarine Channel 2015)

4.2.4 Concrete Blocks

The most advanced shelter typology being implemented in Domiz camp is the concrete blocks shelter as shown in figure 43. According to the UNHCR (2016), this typology is the most preferable alternative for the refugees. The main advantage of this shelter typology is that it provides the best protection and safety in comparison to fabric shelters. It also give the refugees the possibility of having proper subdivisions inside the space and create separated rooms to obtain more privacy for family members.

The cost of upgrading a shelter to concrete blocks is $2500, which is covered by the refugees themselves. This cost covers the building of the shelter excluding the kitchen and wash facilities. In an economy where 15% of the refugee population are unable to fulfill their basic needs with their income, and 65% are able to fulfill their basic needs partially, and only 20% are comfortable in covering their basic needs, affording this amount of money is still challenging for the refugee population (UNHCR 2014 economy).

Figure 43: Concrete blocks shelters in Domiz camp *(*UNHCR 2016, personal communication, 04 October*)*

4.3 Proposed Shelter Upgrade Strategy – The Incremental Home

The proposed shelter upgrade strategy, described in figure 44, follows an incremental approach adopted from the ABC of Incremental Housing published by Elemental Think-tank and Alejandro Aravena for which he won the Pritzker prize of Architecture in 2016. The instrumentality approach is considered a solution to deal with the scarcity of means and limitations of resources. The conventional approach in low-cost housing may lead to compromising the quality of life of the occupants. Meanwhile, following an incremental approach initially leads to providing parts of the structure, but creates an adequate framework that allows for future growth to be carried out by the occupants. This approach is explained in details in section 2.6.9 of this research. In the proposed upgrade strategy, the role of the UNHCR and other NGOs is gradually reduced to be replaced by the involvement of the refugees themselves. Phasing the upgrade measures is also a way to enable the refugees to pay by installments and spread the cost over a longer period of time depending on each refugee's financial ability. It is suggested that the initial investment of the shelter upgrade should focus on the upgrade aspects that require technical abilities and skilled labor and cannot be undertaken by the refugees on their own. The proposed plan is comprehensive and is based on the assumption that new units are to be constructed. However, the upgrade strategies are categorized into 4 phases to ensure flexibility of application. It is possible to adopt the plan starting from phase 1. Phase 2, on the other hand, can be a continuation of phase 1 or can be the starting point of the upgrade plan in situations where phase 1 is not possible, and so on.

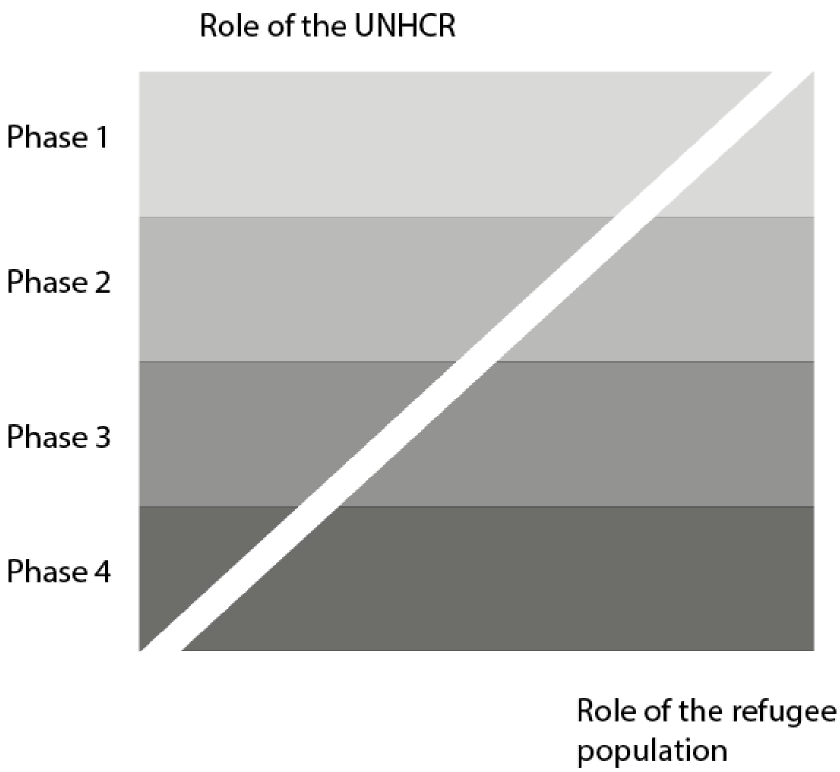

Figure 44: Diagram of the Incremental Home upgrade strategy (source: Author)

4.4 General principles of The Incremental Home strategy

This section sheds the light on the general principles that form the overall framework of the upgrade strategies presented in detail in section 4.2.

4.4.1 Responsiveness to the current practice in the camp

It is important to stress on the fact that the Domiz camp had passed the emergency phase. The need for shelters that can be erected very fast is no longer a priority. All the refugees in the camp now have the basic needs and it is time for enhancement and upgrade which can be done in at a slower pace.

The current upgrade that is taking place in Domiz camp is being done by the refugees themselves. After attaining official authorization from the Board of Relief and Humanitarian Affairs (BRHA), the refugees undertake the cost of materials and labor. The role of the UNHCR staff is to monitor the process and assess the needs of the refugees during the upgrade process. Moreover, Most of the construction workers are from the refugee community. Furthermore, an interview with Firas Al Khatib, one of the refugees living in Domiz Camp, featured on Refugee Republic Documentary (Submarine Channel 2015) is another evidence of the applicability of the proposed bottom-up approach. In the interview, he explains how shortage in tents in Domiz Camp caused as many as three family to occupy one single tent. As a result, a Do-It-Yourself approach was established in the camp. Firas started a construction materials shop in the camp where he sells tarpaulin and wooden slats. In no time, all the materials were sold out and refugees started constructing their own shelters.

Based on the above data, a bottom-up approach where the role of the refugee population increases with time is seen suitable for Domiz Camp.

4.4.2 Allow For Incremental Enhancement

The proposed upgrade strategies allow for incremental application. For this reason, simple techniques and local sourcing is preferred to precast imported solutions. The aim of incremental implementation is to provide flexibility in terms of budget. If solutions can be broken down into phases and can be implemented separately, every refugee family can upgrade based on what they can afford.

Another reason is that each family might have different priorities in terms of what they need to upgrade. Therefore, the benefits of each upgrade strategy should be communicated to the refugees and the decision on what to implement should be left for them to make. For example, some may consider internal divisions a priority, while others would want to enhance the thermal insulation first. Moreover, allowing for incremental implementation leaves room for personalization, providing the refugees with a deeper sense of belonging to these shelters in comparison to imposed pre-fabricated units.

4.4.3 Refugees Empowerment

In order to be able to scale-up a project of that sort, it is crucial to ensure knowledge transfer from the UNHCR team to the refugee community to enable them to build their own shelters. This thesis proposes establishing a training center in Domiz camp through which the refugees are provided with the needed knowledge and tools. A similar solution is currently being explored by the UNHCR innovation program (2016) in three refugee camps in Ghana where shelter has been a major concern. A training center, also referred to as a “tools library”, was established in these refugee camps where the refugees are able to borrow the construction tools they need, and to get the necessary training and technical assistance. Moreover, the training center provides community meeting opportunities which encourages spreading the knowledge through peer education (UNHCR Innovation 2016).

4.4.4 Modularity

One of the aspects that is taken into consideration in the proposed shelter is modularity. Modular design is an effective approach to lower the cost of manufacturing by reducing the diversity of design elements and enabling mass production. Also, the replacement of damaged parts is much easier with a modular design approach. Moreover, modularity of the shelter configuration makes future expansion and modification of the shelter easier, as a result giving the refugees a better opportunity to personalize their shelters. Taking into account the need to transfer knowledge due to the bottom-up approach, modular design is easier to learn and pass the knowledge from one individual to the other.

4.4.5 Allow for disassembly and relocation

Despite the fact that in many cases, refugee camps become permanent settlements with time, they are still considered a temporary setting, and unpredictable circumstances might occur at any time. Therefore, the ability to disassemble and relocate the shelters is an added advantage.

4.4.6 Design for long-term sustainability

The proposed strategies take into account the long-term sustainability aspect. On an environmental level, preference is given towards construction materials that can be sourced on site, to reduce both the cost and environmental impact of the transportation processes. Moreover, the proposed solutions attempt to utilize natural materials and allow for disassembly and re-use to avoid waste in the long-term, keeping in mind that these shelters can be temporary.

On an economical level, the proposed bottom-up approach aims to help the internal economy of the camp to grow. According to the UNHCR 2014 economic report on the refugee camps in Kurdistan region, the main source of income for 54% of the refugee population is Cash for Work activities (CFW). Examples of CFW activities is cleaning and maintaining the camp, mass communication within the refugee population, and hygiene promotion. On the other hand, 22% of the refugee population depend mainly on wage labor outside the camp. Most of the refugees working outside the camp work in the construction industry either with the government or with the private sector. This may include working on roads or on new refugee camps. Therefore, training the refugees and providing them with an opportunity to participate in the construction process, will not only help them build their own shelters, but also increase their chances to be employed in the construction industry in Duhok (UNHCR 2014 economy).

On a social level, involving the refugees in the construction process and allowing them to make decisions concerning their homes is an important aspect to enhance their sense of belonging, ensure their dignity and prepare them to be less dependent on external aid. Also, when the refugees make the decisions, the solutions will be according to their traditions, customs and cultural needs making them sustainable from a social point of view.

4.5 Phases of The Incremental Home strategy

In the ABC of Incremental Housing (Elemental 2017), it is stated that when adopting an incremental approach, it is important start with the most difficult and complex aspects, in which a specialist must be involved. Examples of these aspects are urban design of the development and the provision of the structural frame under which further developments can be implemented. Based on that, the proposed upgrade strategy is divided into 4 phases: planning, structural frame, walls covering upgrade, and passive cooling and heating strategies. The complexity and technicality of the suggested solutions are the highest in phase one, therefore, the role of the UNHCR team is also the highest in this phase. Gradually, the implementation of the solutions gets simpler allowing the refugees to take more of the responsibility. Below is an elaborate description of each of the phases.

4.5.1 Phase 1: Planning

The first phase focuses on recommendations on the optimum units' orientation and clusters' configurations. Although these recommendations can be implemented with very little or no cost, they have an impact on later stages on the performance of the shelter and occupants comfort. Decisions made at this stage require technical knowledge, therefore the role of the UNHCR is maximized while the role of the beneficiaries is minimized. As explained in section 4.2, in situations where the implementation of phase 1 is not possible, due to space limitations or in the case of pre-existing shelters, the upgrade strategy can start from phase 2.

Orientation

The optimum orientation of a building allows for effective harnessing of the sun energy, and ensures maximum solar exposure during the under heated periods and minimum solar exposure during the overheated periods. Analysis done using the Autodesk weather tool (figure 45) shows that the favorable orientation of a roughly orthogonal building occur along the north-south axis with an offset of 10 degrees.

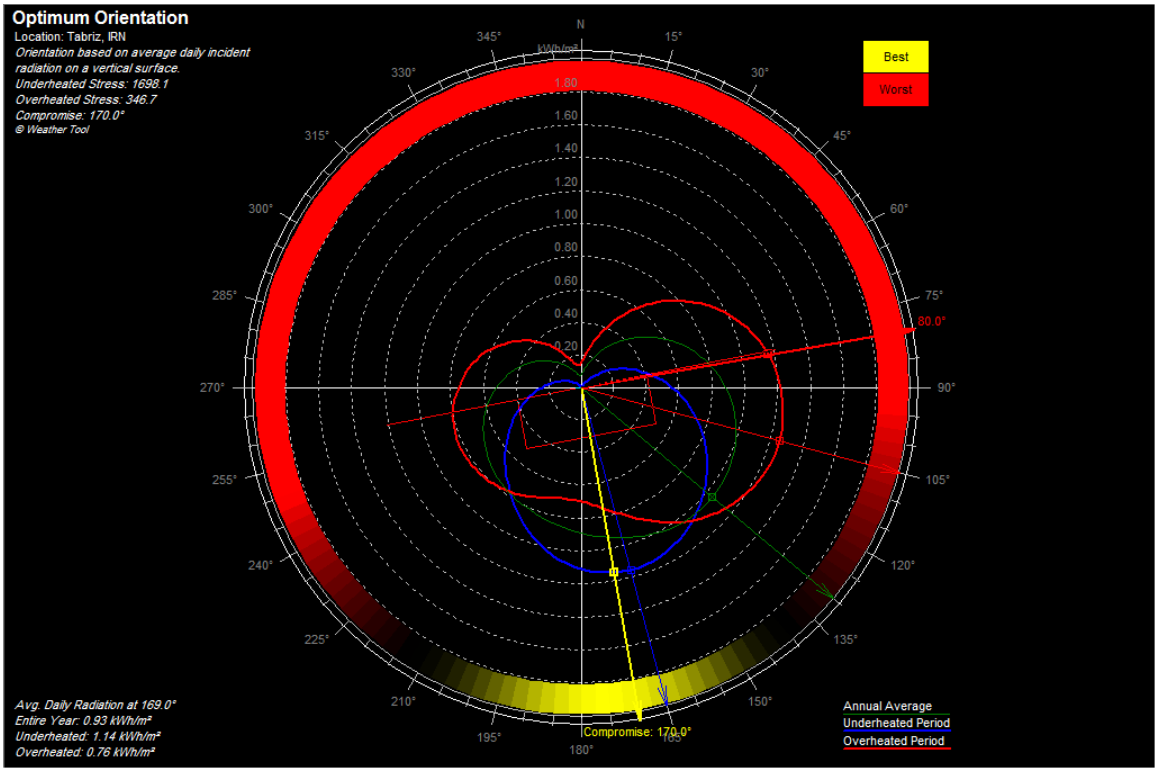

Figure 45: Optimum building orientation in Tabriz city (Autodek Weather Tool)

Cluster layout and configuration

The layout and configuration of the units is an important factor affecting the way the shelter units respond to the sun and wind. Placing the units too close to each other leads to shading the south facing façade, which reduces the shelter's capacity to harness the solar energy. Moreover, not leaving an adequate distance between the units increases the risk of fire spread. According to Corselis et al. (2005), the recommended spacing between the units should be twice the height of the shelter units as shown in figure 46. It's worth mentioning that in some situations the limited availability of land within refugee camps makes it hard to apply this guideline. However, research by IFSEC (2008) shows that in some refugee camps this aspect is not taken into consideration although there's no shortage in land.

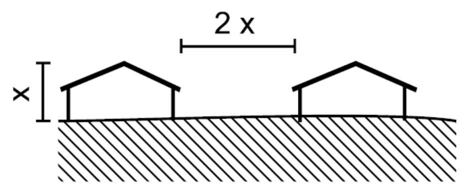

Figure 46: recommended width of a firebreak (Corselis et al. 2005)

Another issue to be taken into consideration when designing clusters is the strong winds that sometimes lead to sand storms causing major respiratory diseases, or blowing away shelters that are not secured. When designing transitional shelters, it is important to avoid shelter configurations that creates a channeling effect and increases the effect of strong winds. A layout that encourages wind dissipation in winter is preferable (figure 47), while still allowing the prevailing wind in summer to flush the spaces and provide cooling during the over-heated periods.

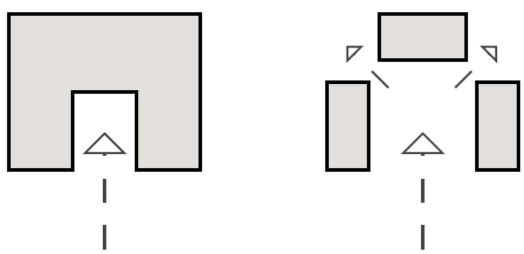

Figure 47: Dissipating wind force through planning (Corselis et al. 2005)

Figure 48 and 49 illustrate how wind speed and direction are typically distributed in Tabriz city in Iran, the closest city to Duhok of which the weather data is available (refer to section 4.8 for details on weather data used). The wind rose indicates that the prevailing wind blows from the north and east in winter, when the average temperature of the wind is below 0°C (figure 50). In summer, on the other hand, the prevailing wind blows from the north-east.

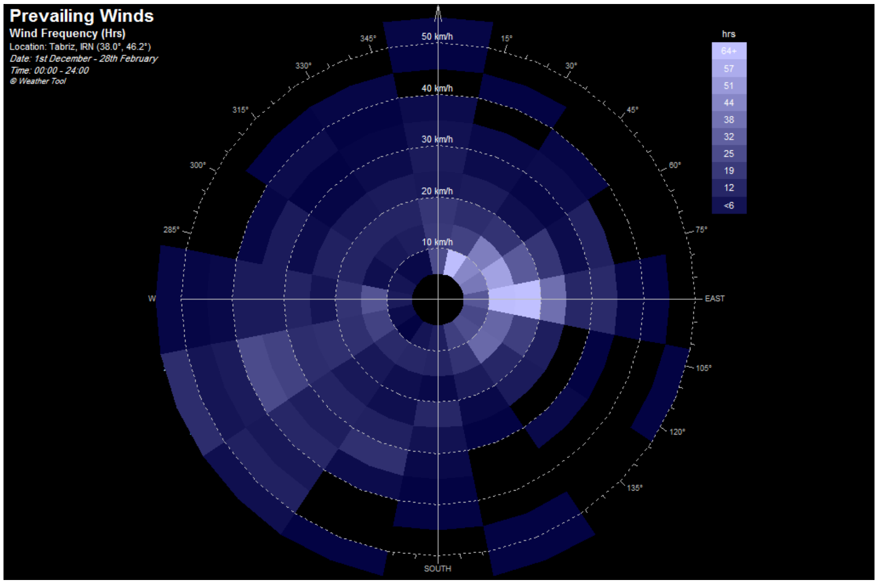

Figure 48: Prevailing wind direction in Tabriz city in winter (Autodek Weather Tool)

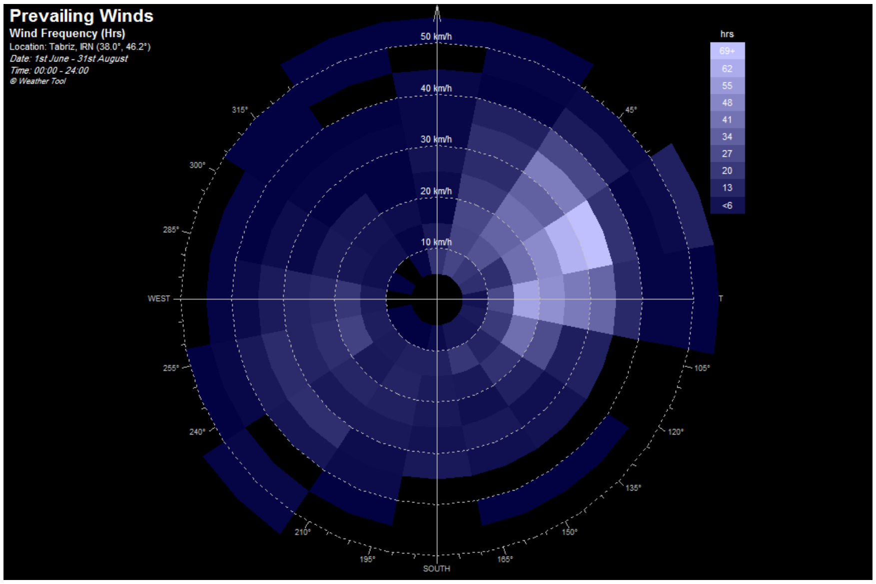

Figure 49: Average temperature of wind in Tabriz city in summer (Autodek Weather Tool)

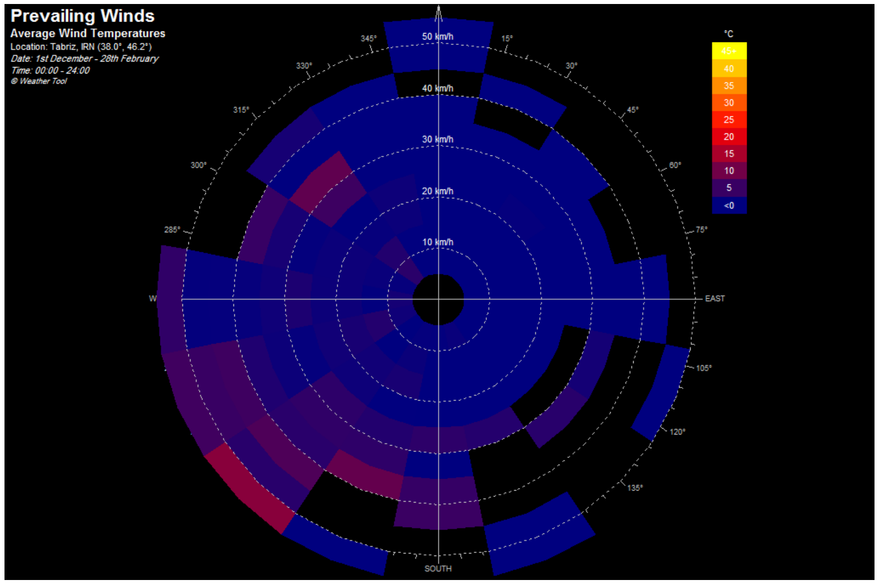

Figure 50: Average temperature of wind in Tabriz city in winter (Autodek Weather Tool)

Taking all these factors into consideration, the final proposed shelter-layout is illustrated in figure 51.

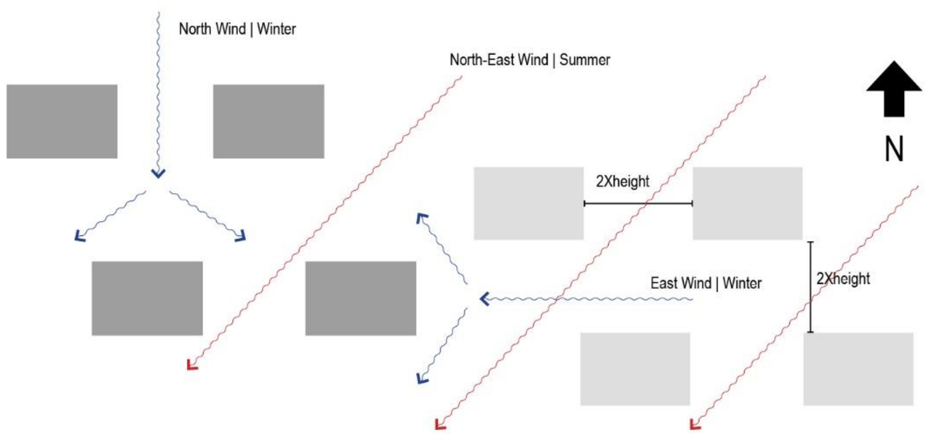

Figure 51: Proposed shelters-layout

4.5.2 Phase 2: Structural Frame

According to the Humanitarian Charter and Minimum Standards in Humanitarian Response, if materials for a complete shelter are not available and cannot be provided to the refugees, the priority shall be given to the provision of the base structural support with roofing materials. Although the resulting structure may not be adequate for providing security and protection from climatic conditions, it provides the basic shelter that can be upgraded at a later stage (Sphere Project, 2011).

Adopting a similar approach, it is proposed to utilize the initial investment in shelter upgrade in establishing a durable and stable structural framework, on which the refugees themselves, after this stage, can upgrade. The aim of this phase is to prevent structures from collapsing or being blown away by wind, and prevent rain from penetrating the shelter.

Due to the organic nature of shelter construction practices in the camp, a case-by-case assessment is required to evaluate the current structural system, if available. A new structural system can be built, or the current system can be upgraded by enhancing the joints. Moreover, a detailed structural design should be undertaken by a specialized structural engineer. For this reason, this section of the study covers only general recommendations without going into specific details.

General recommendation on the structural frame

A. The proposed structure, illustrated in figure 52, is a 4mx6m galvanized steel portal frame. The system is modular allowing for future expansion and accommodation of various configurations.

B. The columns are attached to pad foundations, which are dug directly under the columns and filled with concrete by hold down bolts and column base plates. The type of foundation also depends on the soil conditions at the specific site where the shelter will be constructed. For this reason, this decision can be made by specialists under the UNHCR supervision after investigating the soil conditions.

C. Flooring is raised above ground level by 30 cm in order to prevent rainwater from entering the living spaces. In addition to its role in protection from rainwater and flooding, insulating the floor from the ground enhances the thermal performance of the shelter.

D. A gable roof with a 20-30° inclination is proposed, as it receives the least wind stress in comparison to steeply pitched and low-pitched roof (figure 53) (Corselis et al. 2005).

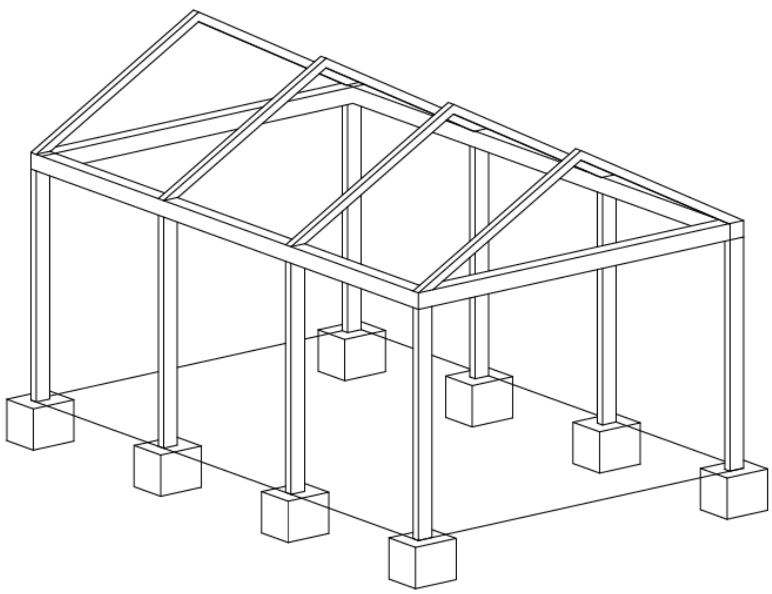

Figure 52: Proposed structural frame

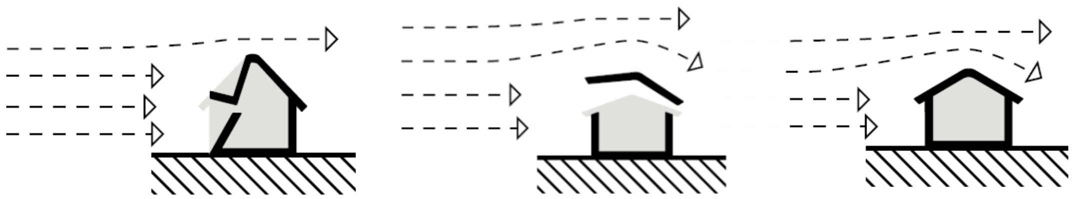

Figure 53: Steeply pitched roofs receive a high wind load (left), low-pitched roofs receive high suction (center), and a roof angled at 20°–30° receives the least wind stress *(Corselis et al. 2005)*

E. To ensure that the shelter is resistant to wind, the roof elements must be securely attached to the walls to ensure that wind loads are transmitted to the ground rather than causing the roof to blow off. Figure 54 shows the recommended joint using patch plates, bolts, and metal straps.

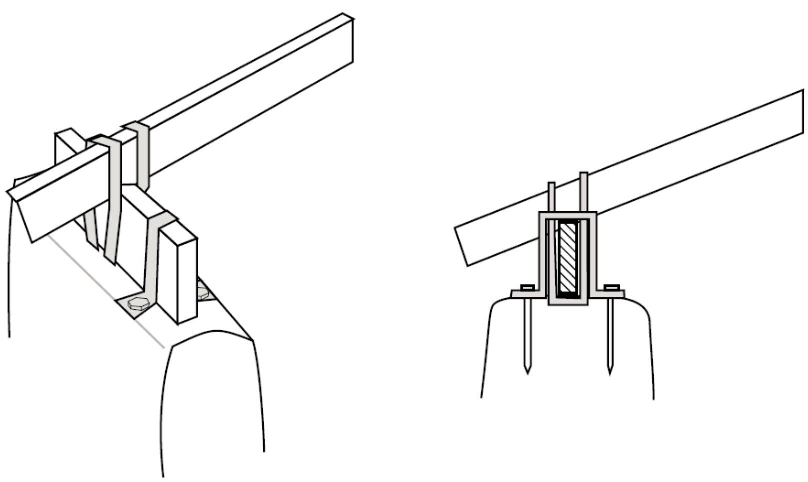

Figure 54: Recommended roof trusses fixing detail (Corselis et al. 2005)

4.5.3 Phase 3 Walls Covering Upgrade

Most of the shelters that are in need for upgrade strategies have some basic envelope materials such as tent fabric, blankets or corrugated steel sheets.

After the construction of the structural frame, these materials can be utilized when the shelter is first occupied until the refugees are able to invest in the next upgrade solutions, which is the proposed wall panel system illustrated in figures 55 and 56. According to the UNHCR office in Domiz camp, the only materials available for construction in Domiz camp are sand, cement, concrete blocks, and corrugated steel sheets for roofing. Therefore, building with sand can be considered a suitable solution for Domiz camp. Besides its availability, sand is a free material that is available on site and does not require any transportation making this solution cost effective. Additionally, sand has low thermal conductivity, 0.25 Wm/K for dry sand (Hamdhan and Clarke 2010), concrete between 0.1-1.8 depending on its density, much lower than steel 16 Wm/K (Engineering Toolbox 2016)

The proposed wall panel system is composed of layers of metal mesh and UNHCR tarpaulin, which is the same material used for the standard UNHCR tents. Following the same module of the structural system, the wall panels can be pre-fabricated and stored as a wall panel kit along with the required number of bolts needed to fix the panel on the structural frame. After fixing the proposed wall panel cover, the gap is filled with sand that is sourced on site. The process of fixing the wall panels and filling them with sand can be done incrementally, since the wall panel can also function without filling it with sand. A layer of tarpaulin material forms an internal roofing, while the external roof is covered with corrugated steel sheets.

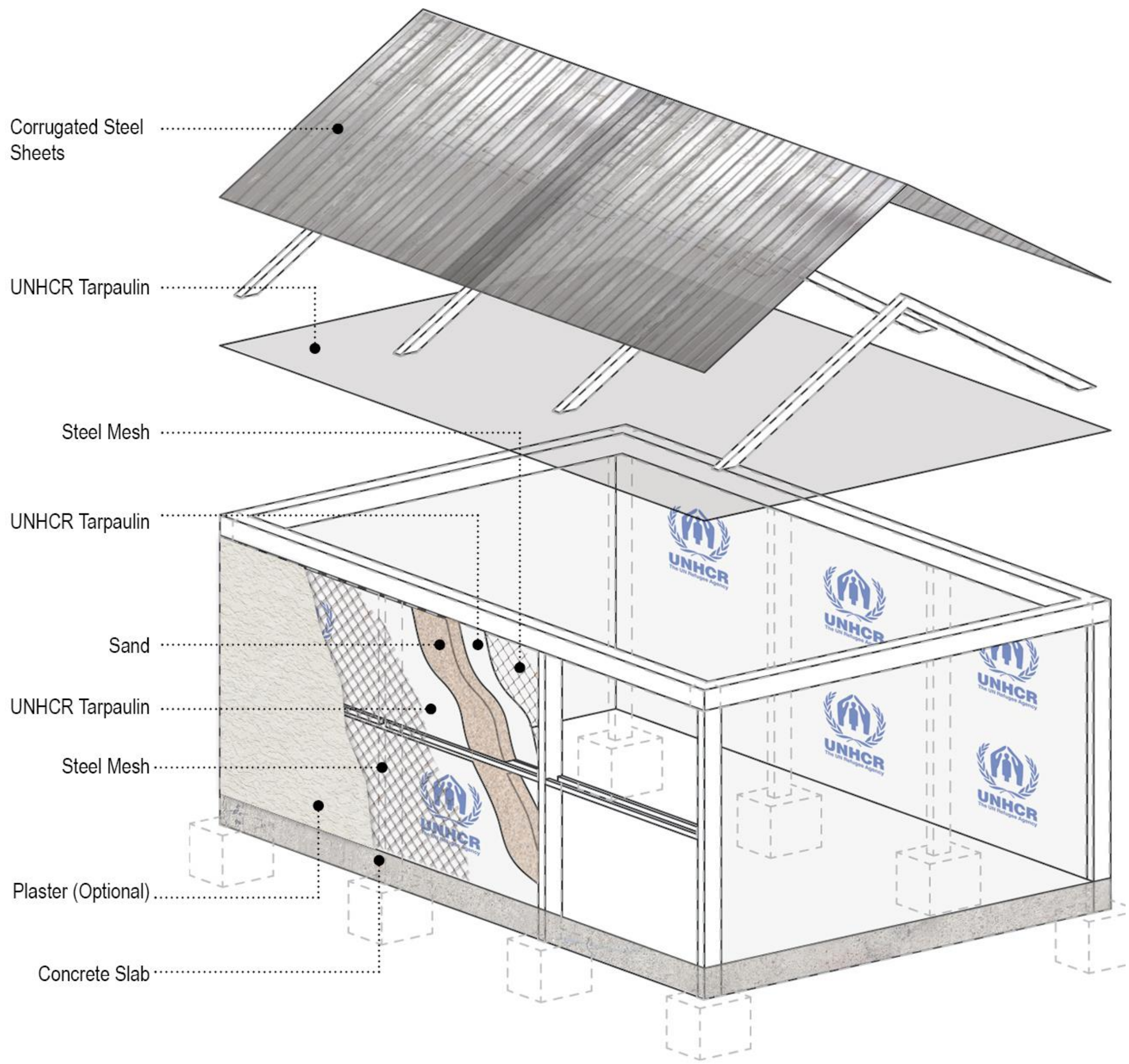

Figure 55: proposed wall and roofing system

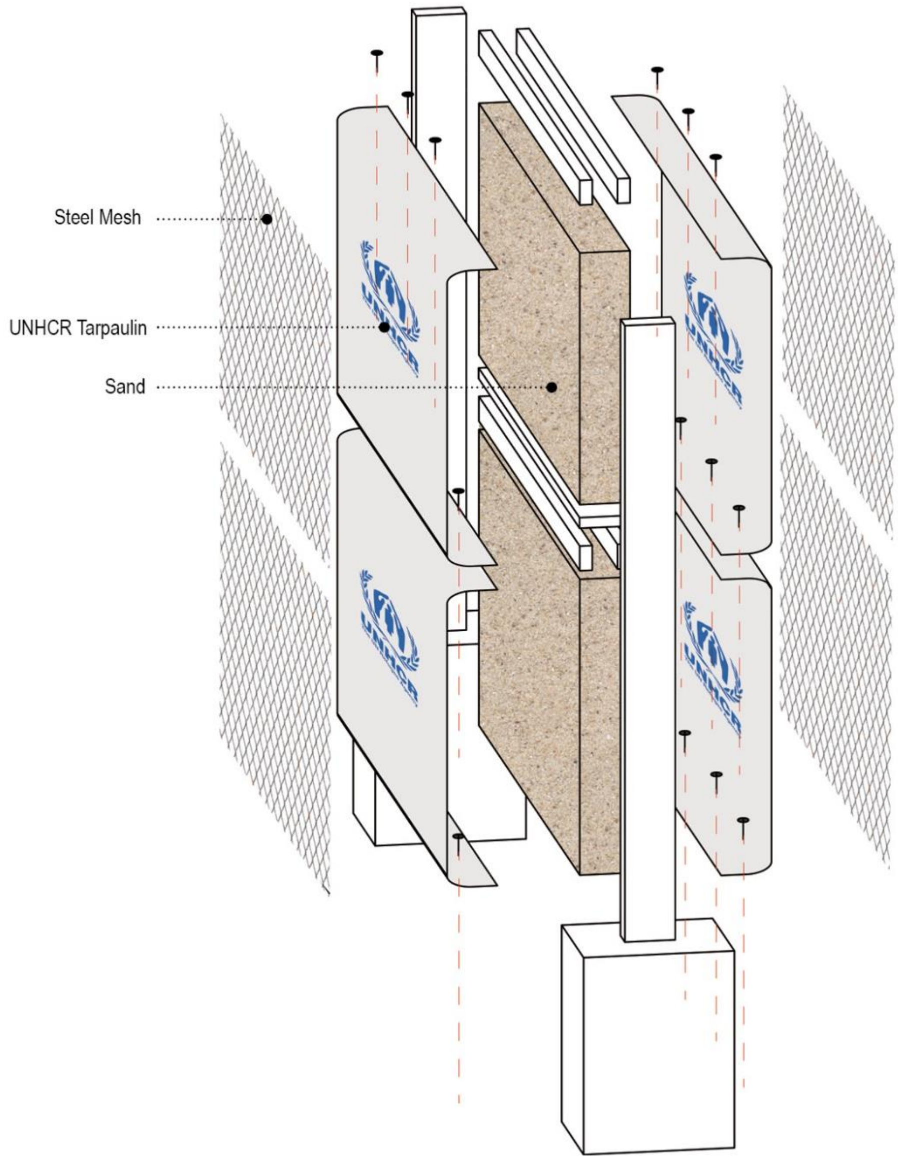

Figure 56: Exploded perspective view of the proposed wall panel system

Following the same modular system of the structural frame, this solution allows for various layout configurations, according to each family’s needs and budget. Figures 57 illustrate few of the possible layout configurations that can be achieved.

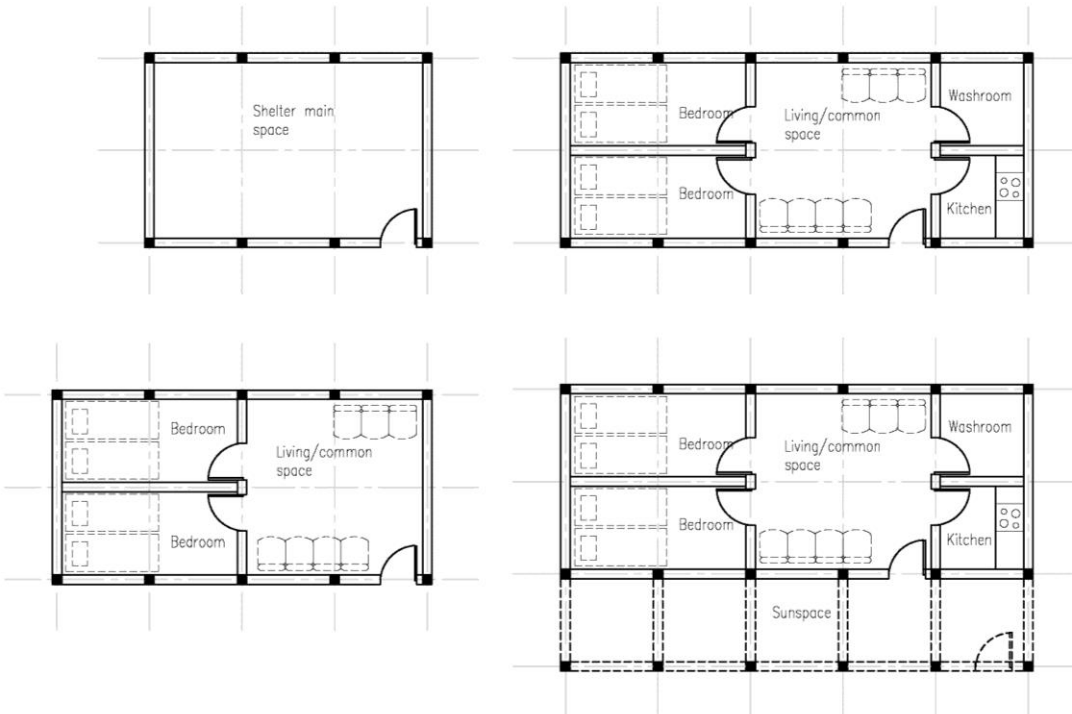

Figure 57: Examples of possible layouts

In this phase, the role of the UNHCR is limited to utilizing the production and distribution of the wall panel kit in the market. However, installing the system and filling the panel with sand can be fully done by the beneficiaries, as it requires little technical knowledge and can be undertaken by unskilled labor.

This solution is inspired by the sandbag construction method. However, a common problem with sandbag construction, especially when using burlap sandbag, I that it is not water resistant. If water penetrates the sandbag, the sand fill becomes heavier leading in a risk of a structural damage, and it loses its thermal properties. Moreover, the sandbag might rot with time. In the proposed wall panel, the UNHCR tarpaulin material is used instead. The UNHCR tarpaulin is an available material and very common to be used in refugee camps. According to UNHCR standards, the tarpaulin is resistant to water and rain penetration (UNHCR 2016). Moreover, a layer of plastic sheeting can be added to ensure water resistance. Another advantage for this configuration over a conventional sandbag construction is that these panels are non-load bearing elements. Therefore, it is safer to be handled by unskilled labor, the beneficiaries themselves, than a conventional sandbag construction. Also, this provides flexibility in terms of the thickness of the walls. A typical sandbag wall is around 40 cm in width, meanwhile, the proposed panel is 20 cm.

Other variations of this solution can be produced. Figures 58 and 59 show two options of how the wall panel is assembled. In option A, the 20cm wall panel is composed of a sand layer covered by layers of tarpaulin and steel mesh. In option B, on the other hand, two sand layers are utilized with a 5cm air cavity in the middle to enhance the thermal insulation. The two options will be tested in sections 4.10.6 and 4.10.7.

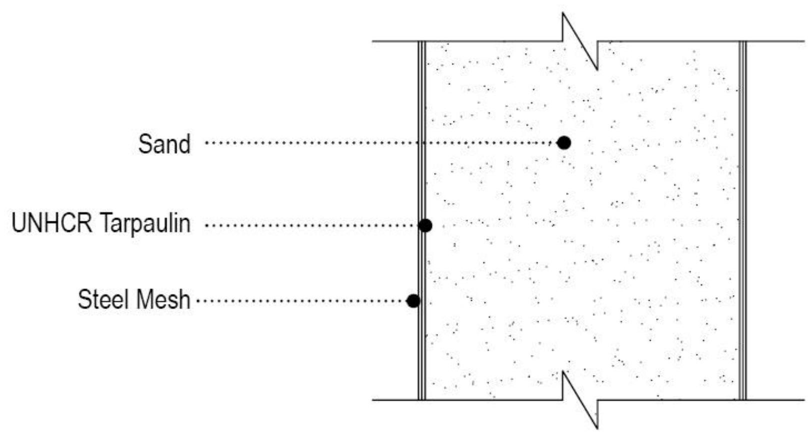

Figure 58: Wall panel system option A

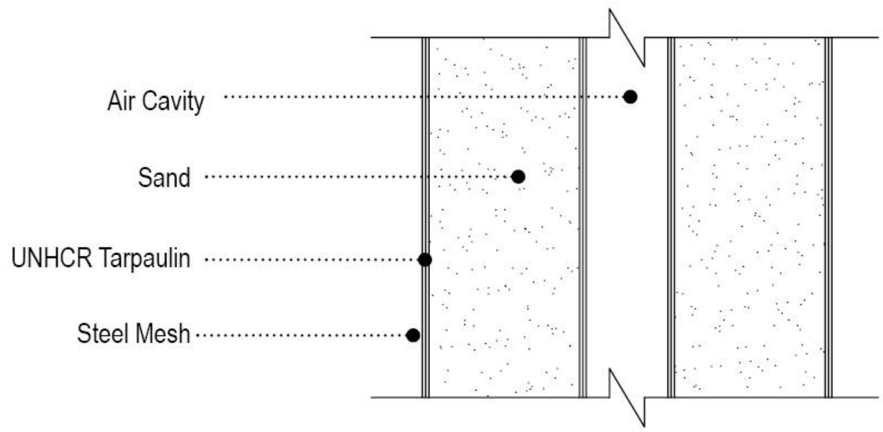

Figure 59: Wall panel system option B

4.5.4 Phase 4 passive heating and cooling techniques

The last phase of the upgrade strategy highlights passive heating and cooling techniques that can help improve the thermal performance of the building. In this phase, the knowledge on how to implement the strategies should be transferred to the users through training sessions, and the decision is for them to make on what they see as a priority.

4.5.4.1 The sunspace

The sunspace is one of the passive heating strategies that utilizes indirect heat gain. The sunspace is a south facing room that is composed of an extension of the structural frame covered with plastic sheeting (figure 60), a material that is available and affordable in the camp. Double sheeting can also be used to increase its thermal insulation.

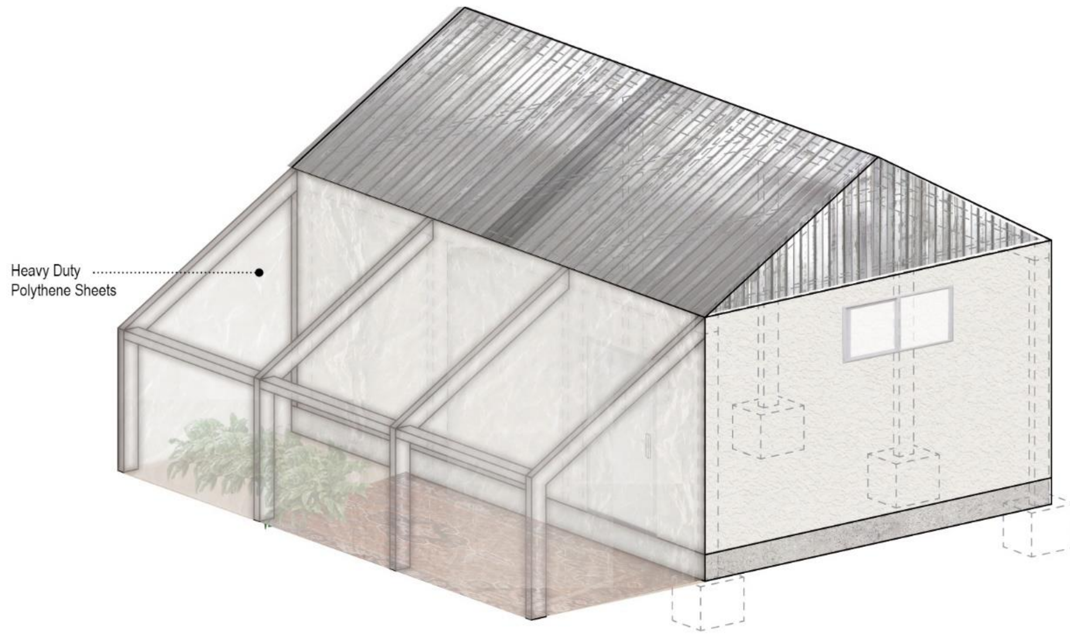

Figure 60: Addition of a sunspace to the shelter

Due to the greenhouse effect, the sunspace will trap the sun heat from direct solar exposure providing a warm space during daytime. Also, when combined with thermal mass, the heat is transferred to the adjacent main shelter space.
The proposed sunspace becomes a semi-private space that allows for the use of transparent materials to allow sun to penetrate the space without compromising privacy. This is considered an advantage of using a sunspace for heating rather than direct heat gain. This additional room can also be utilized for carrying out domestic activities such as cooking and washing, or as an additional living area used during daytime in winter. Also, the sunspace can be used as a greenhouse to grow plants. It is worth mentioning that families in Domiz camp have planted home gardens as a way of beautifying their homes, providing their basic food needs, and giving them a deeper sense of belonging

(figure 61). This practice is being encouraged and promoted by the camp management, and providing a better opportunity for home gardening by adding the sunspace can be considered an added advantage.

Using materials such as plastic sheeting and simple fixing detail enables the beneficiaries to remove the plastic sheeting during summer to avoid over-heating.

Figure 61: Home gardening practices in refugee camps in Kurdistan (UNHCR 2016)

4.5.4.2 The Roof Canopy

The roof canopy is composed of a layer of tarpaulin that is added on top of the corrugated steel sheets roofing by fixing hooks leaving an air gap in between (figure 62). The roof canopy helps shade the roof in summer to reduce the heat gain through the roof. Providing openings on the sides and on the upper part of the canopy encourages air flow through the canopy which helps further reduce heat gain through the roof. The system is simple to assemble and can be removed in winter when heat gain is needed. The same shading strategy can be adopted to cover the sunspace structure that is opened in summer to create a shaded summer veranda.

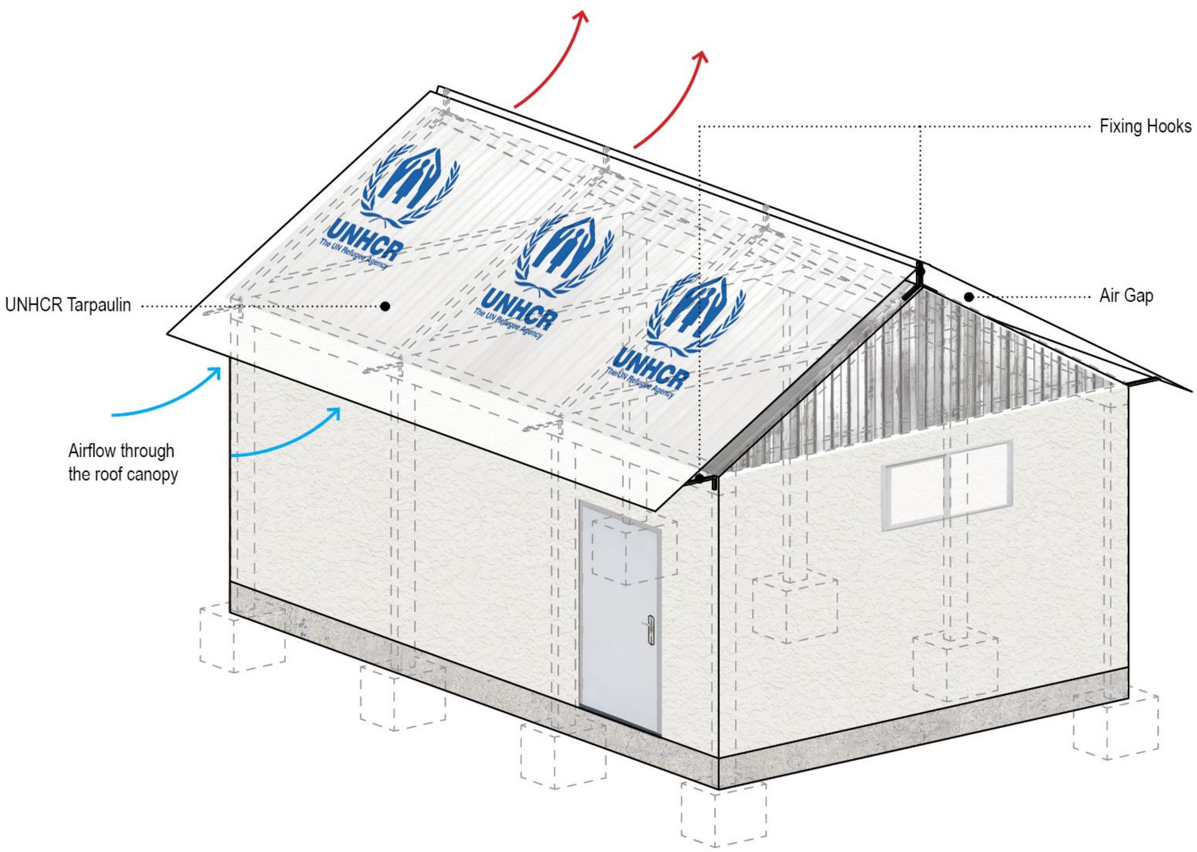

Figure 62: Proposed roof canopy

4.6 Digital Simulation

This section is intended to assess the thermal performance of the current shelter typologies and compare them to the proposed upgraded shelter through digital simulation using IES-VE software. The research aims to conduct energy simulations to assess the thermal performance of the shelter typologies currently present in Domiz camp, as well as the proposed strategies. The first section covers the general input data for the simulation models such as the geographical location, weather data, the occupancy density, and the thermal template followed by detailed explanation of the construction template of each scenario.

4.7 Base Model Input

The climate in northern Iraq is semi-arid, with cold winters and hot dry summers. The northern part of Iraq where Duhok city is located is a mountainous region that experience very cold winters and occasional heavy snows. The air temperature in Duhok drops to as low as 1°C in winter. During summer months, on the other hand, the temperature goes up to around 36°C (figure 63).

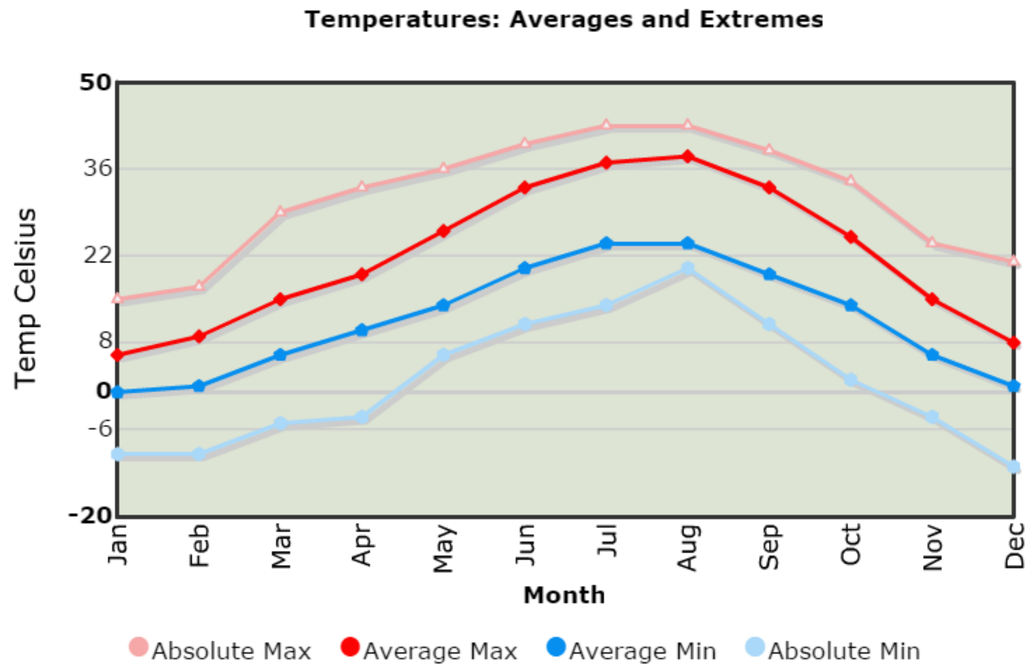

Figure 63: Average and extreme annual temperatures in Duhok city (Weather2 2016)

As shown in figure 64, from October to April, Duhok experiences rainfall ranging from 62 mm in October at the start of the wet season, and reaching the highest in April where precipitation level can reach 101 mm (Weather2, 2016).

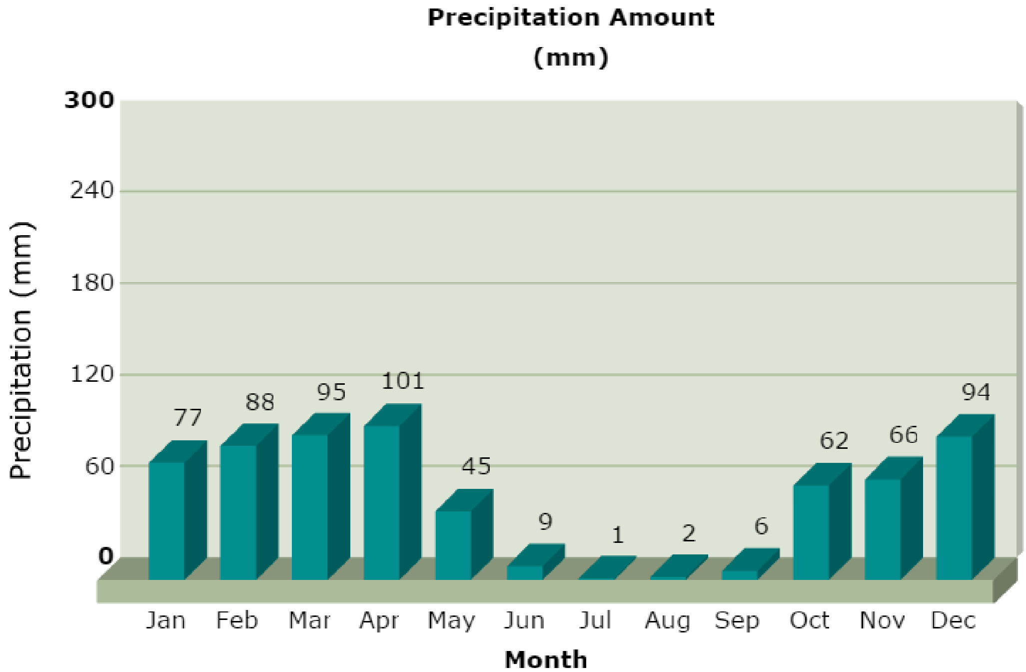

Figure 64: Precipitation in Duhok city (Weather2 2016)

4.8 Location and Weather Data

Using IES-VE APLocate tool, the location of Domiz camp was set as shown in figure 65. Since the weather data for Duhok city in Kurdistan is not available, the weather data for Tabriz city in Iran is used instead. Tabriz is the closest city to Duhok geographically and in terms of climate similarity. Therefore, the weather file of Tabriz is used for the thermal simulation purposes in this study as an approximate representation of the climatic conditions in Duhok. Also, Tabriz weather data is automatically selected by the software as the nearest available weather data to the specified location.

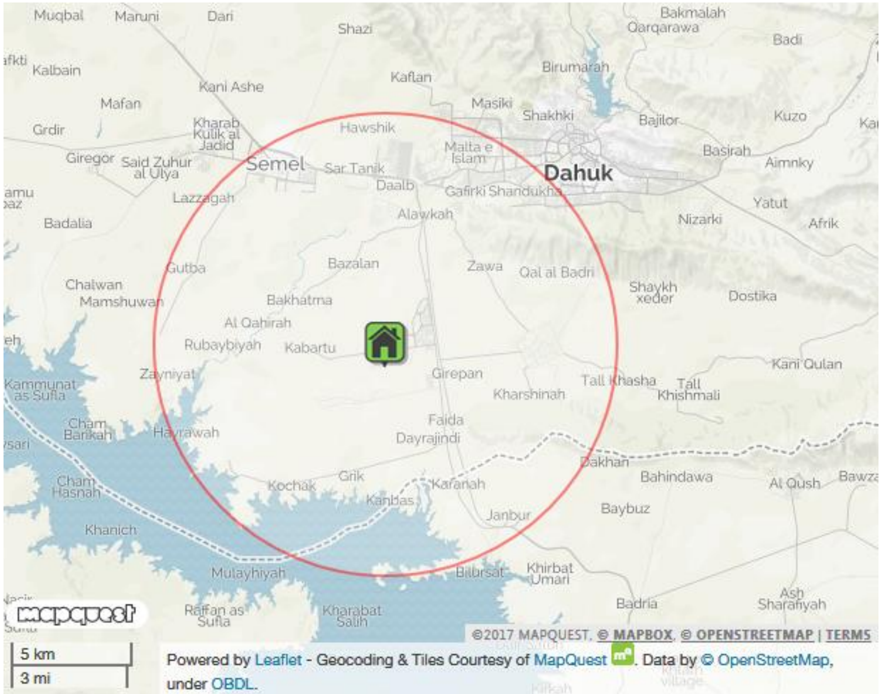

Figure 65: Location of Domiz camp set-up using IES-VE APLocate tool (IES <VE> 2017)

In the IES-VE software, a thermal template is created. The mechanical cooling and heating systems are set as on continuously. The set point of the heating system is 19°C, and for the cooling system is 23°C. Although there are no active cooling or heating systems in the shelter unit under study, setting on the cooling and heating systems make it possible to simulate the cooling and heating loads required to maintain the internal condition within the comfort zone. Therefore, the heating and cooling loads are indications of the thermal comfort levels. This method is used to enable comparison between the different simulation scenarios. The occupancy density is assumed to be 0.2 person/m², following that of the standard UNHCR family tent.

4.9 Simulation Scenarios

Table 2 provides an overview of the simulations scenarios covered in this research. Sections 4.9.1, 4.9.2, and 4.9.3 provide a detailed description of each scenario and a view of the construction template used in each.

Table 2: Simulation matrix

Scenario	U-Value (W/m²K)	Shelter Typology 1 | Base Case	Shelter Typology 2	Shelter Typology 3	Shelter Typology 4	Proposed Shelter | Phase3A	Proposed Shelter | Phase3B	Proposed Shelter | Phase 4	Proposed Shelter | Phase 5	The Hybrid Solution
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Parameter										
Wall										
UNHCR tarpaulin	5.6	●	●							
Corrugated steel sheet	5.9			●						
Concrete blocks	1.7				●					
Filled wall panel	1.31						●			
Improved wall panel	1.04							●	●	●
Floor										
UNHCR tarpaulin	4.5	●	●	●						
Concrete slab	2.83				●	●	●	●	●	●
Roof										
UNHCR tarpaulin	5.6	●	●							
Corrugated steel sheet	7.1			●	●	●	●	●	●	●
Passive Techniques										
None	NA	●	●	●	●	●	●			
Sunspace	NA							●		●
Double roof	NA								●	●

4.9.1 Scenario A

Scenario A is considered the base case, representing the shelter typology 1 explained in section 4.4.1, the standard UNHCR family tent. The modelling was fully based on description provided by the UNHCR. A base model is created as shown in figure 66 which is extracted from the simulation model of the base case.

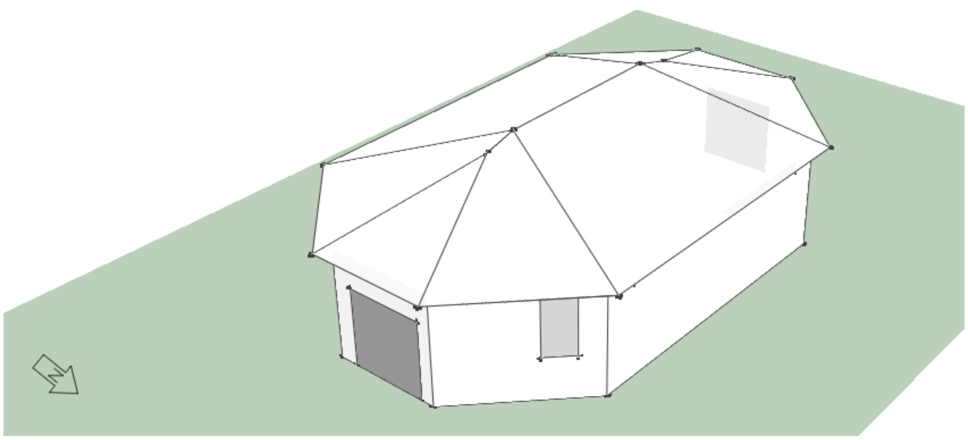

Figure 66: Model of scenario A (IES-VE & Author)

In scenario A, the external walls, ground cover, and roof cover are all assumed to be of the UNHCR tarpaulin material. The U-value of the material is set to be 5.5 W/m²K, which is an indicative value based on literature (Obyn, van Moeseke & Virgo, 2015 and Manfield, 2000). Properties of the windows is set as heavy- duty polythene sheets that has a U-value of 1.2 W/m²K (Eartheasy, 2014).

4.9.2 Scenarios B, C, and D

Scenarios B, C and D are representations of shelter typologies 2, 3 and 4, respectively, as explained in sections 4.1.2-4.1.4. It's important to highlight that there are no accurate references to create a model for these cases, because shelter construction of these typologies is an organic process that varies from one family to the other resulting in a spectrum of typologies and building materials. Moreover, there are shelter units that are a combination of different structural systems and building materials. For this reason, testing the thermal performance of possible materials requires simplification of shelter typologies. Therefore, a hypothetical shelter is created on which simulations of cases B, C, and D will be conducted (figure 66). The shelter is a simple rectangular structure with a gable roof of 30° slope and a covered area of 24 m^2, similar to that of a standard UNHCR family tent, assuming that approximately families occupy the same area even after the enhance their shelters. The height of the shelter unit in 2.4m^2 based on the minimum architectural standards for habitable spaces (Neufert et al. 2000). One door and two windows for ventilation are assumed.

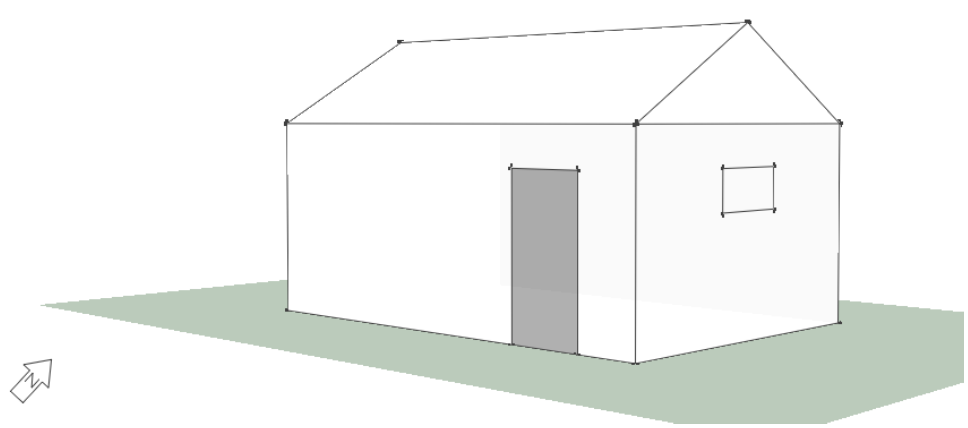

Figure 67: Model of scenario B, C and D (IES-VE & Author)

Scenario B, illustrated in figure 68, is similar to the base case in terms of the materials used. Ground cover, walls, and roofing are all tarpaulin with a U-value of 5.5 W/m²K.

Figure 68: Scenario B – shelter typology 2

In Scenario C, the ground cover remains as the tarpaulin material, however, the walls and the roof are upgraded to corrugated steel sheets with a U-value of 7.1 W/m²K (figure 69).

Figure 69: Scenario C – shelter typology 3

In Scenario D (figure 70), concrete blocks are used for the walls. The flooring is a concrete slab, and the roofing remains as a corrugated steel sheet.

Figure 70: Scenario D – shelter typology 4

4.9.3 Scenarios E to H

Scenarios E to H are simulations of proposed enhancement strategies of phase 3 as explained in section 4.5.3, and phase 4 as explained in section 5.5.4 The same model used for scenarios A-D is used with a different construction template (figure 71).

In scenario E, the flooring and the roofing remains the same as in scenario D. However, the walls are specified as option A of the proposed wall panel, which is composed of layers of tarpaulin and sand in between. The total U-value of the walls in this scenario is 1.3 W/m²K. In scenario F, option B of the proposed wall panel is used which introduces an air cavity in the middle reducing the U-value to 1.04 W/m²K. The thermal performance of the sunspace is tested in scenario G (figure 72), and the effect of adding a roof canopy is assessed in scenario H (figure 73).

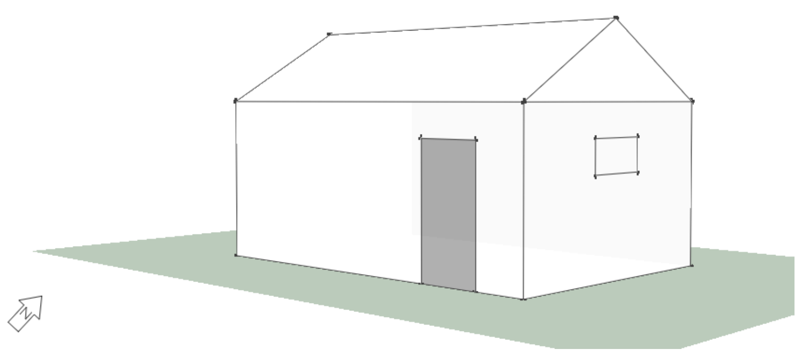

Figure 71: Model of scenario E and F (IES-VE & Author)

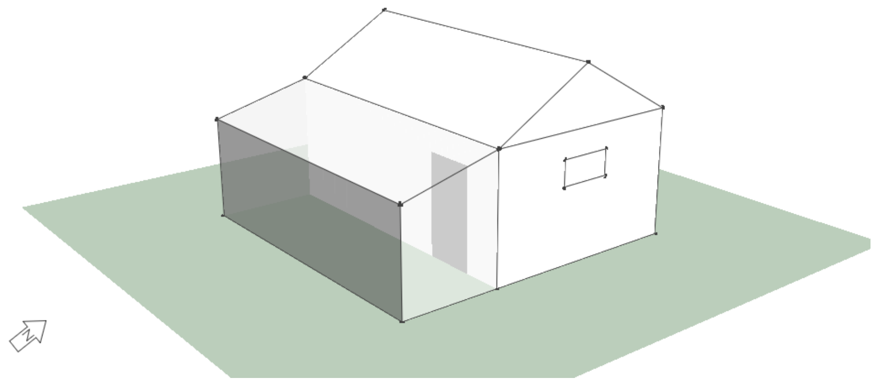

Figure 72: Model of scenario G (IES-VE & Author)

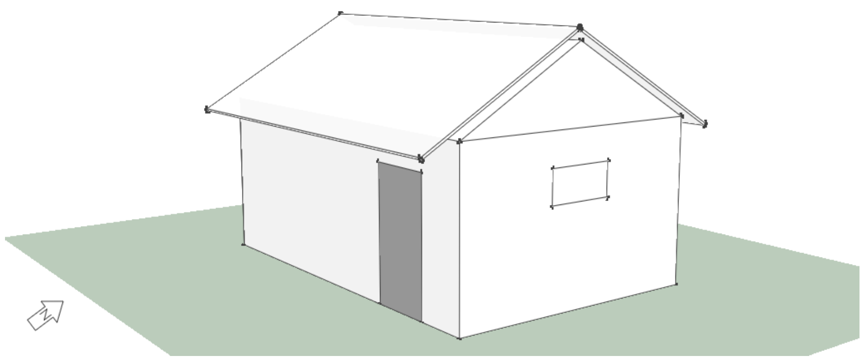

Figure 73: Model of scenario H (IES-VE & Author)

4.10 Simulation Results

In this section, results of the simulations are presented and discussed. The thermal performance of each scenario is discussed by reviewing the heating and cooling loads of each scenario as an indication of the thermal comfort levels inside the shelter and as a means of comparison between the different scenarios.

4.10.1 Simulation Results of Scenario A – The Baseline Case

From table 3 and figure 74 that show the cooling and heating loads of scenario A per month, it is clear that the heating loads are significantly higher than the cooling loads. The total annual heating and cooling loads of scenario A is 27.39MWh of which 84% is heating load and 16% is cooling loads. This significant difference between the heating and cooling loads is due to the extreme cold temperature experienced in Domiz camp. The amount of energy needed to maintain the internal air temperature within the comfort zone is at its highest during January. Meanwhile, during June and September, cooling and heating loads drop to the minimum indicating the highest thermal comfort levels experienced in the camp.

Table 3: Monthly cooling and heating loads of baseline case; scenario A (IES <VE> & Author 2017)

Month	**Cooling Loads (MWh)**	**Heating Loads (MWh)**	**Heating & Cooling Loads (MWh)**
Jan	0.0000	5.0020	5.0020
Feb	0.0000	3.9714	3.9714
Mar	0.0025	2.9021	2.9046
Apr	0.0302	1.7470	1.7772
May	0.3209	0.7678	1.0887
Jun	0.7216	0.2655	0.9871
Jul	1.2192	0.0497	1.2689
Aug	1.2050	0.0597	1.2647
Sep	0.6593	0.2621	0.9214
Oct	0.1652	1.2004	1.3656
Nov	0.0055	2.6716	2.6771
Dec	0.0000	4.1587	4.1587
Total	**4.3294**	**23.0581**	**27.3875**

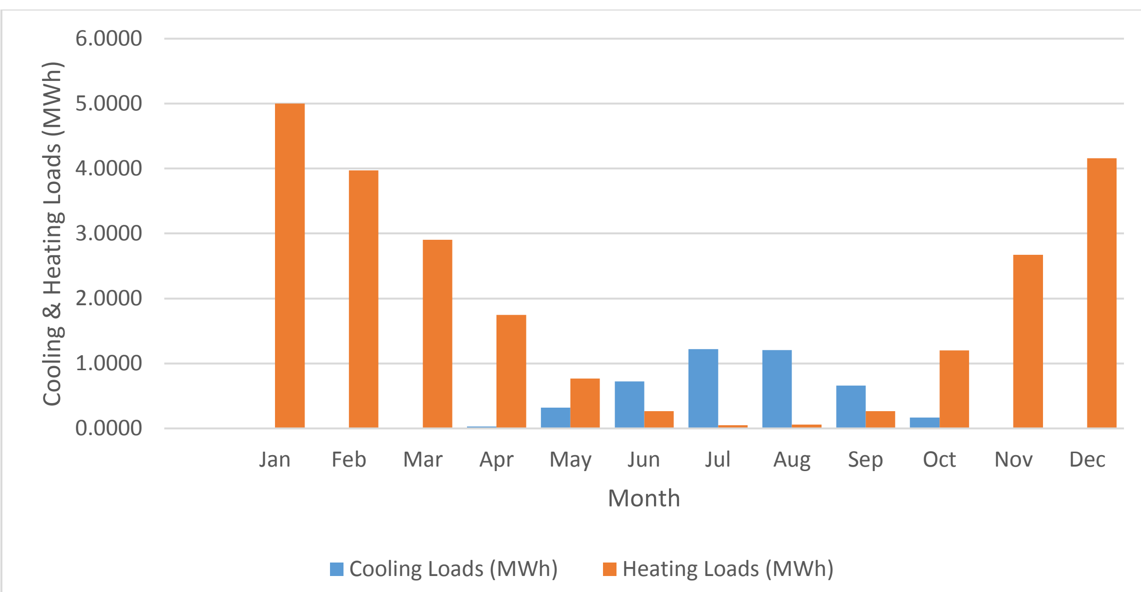

Figure 74: Monthly cooling and heating loads of baseline case; scenario A (IES <VE> & Author 2017)

4.10.2 Simulation Results of Scenario B

Scenario B is similar to scenario A in terms of the construction template used for the simulation. The flooring, walls, and roofing are all made of tarpaulin. Moreover, both shelter typologies have the same floor area which is approximately 24 m^2. However, when comparing the heating and cooling loads of scenario B in comparison to the baseline case, a 33% increase in cooling loads and a 27% increase in heating loads is identified as shown in table 4 and figure 75.

Table 4: Monthly cooling and heating loads of scenarios A and B (IES <VE> & Author 2017)

Month	**Cooling Loads (MWh)**	**Cooling Loads (MWh)**	**% to the baseline case**	**Heating Loads (MWh)**	**Heating Loads (MWh)**	**% to the baseline case**
	Scenario A (baseline case)	**Scenario B**		**Scenario A (baseline case)**	**Scenario B**	
Jan	0.0000	0.0000	0%	5.0020	6.3931	28%
Feb	0.0000	0.0000	0%	3.9714	5.0522	27%
Mar	0.0025	0.0045	80%	2.9021	3.6647	26%
Apr	0.0302	0.0442	46%	1.7470	2.2276	28%
May	0.3209	0.4380	36%	0.7678	0.9761	27%
Jun	0.7216	0.9509	32%	0.2655	0.3313	25%
Jul	1.2192	1.6056	32%	0.0497	0.0626	26%
Aug	1.2050	1.6022	33%	0.0597	0.0756	27%
Sep	0.6593	0.8906	35%	0.2621	0.3323	27%
Oct	0.1652	0.2316	40%	1.2004	1.5135	26%
Nov	0.0055	0.0082	49%	2.6716	3.3718	26%
Dec	0.0000	0.0000	0%	4.1587	5.2763	27%
Total	**4.3294**	**5.7759**	**33%**	**23.0581**	**29.2771**	**27%**

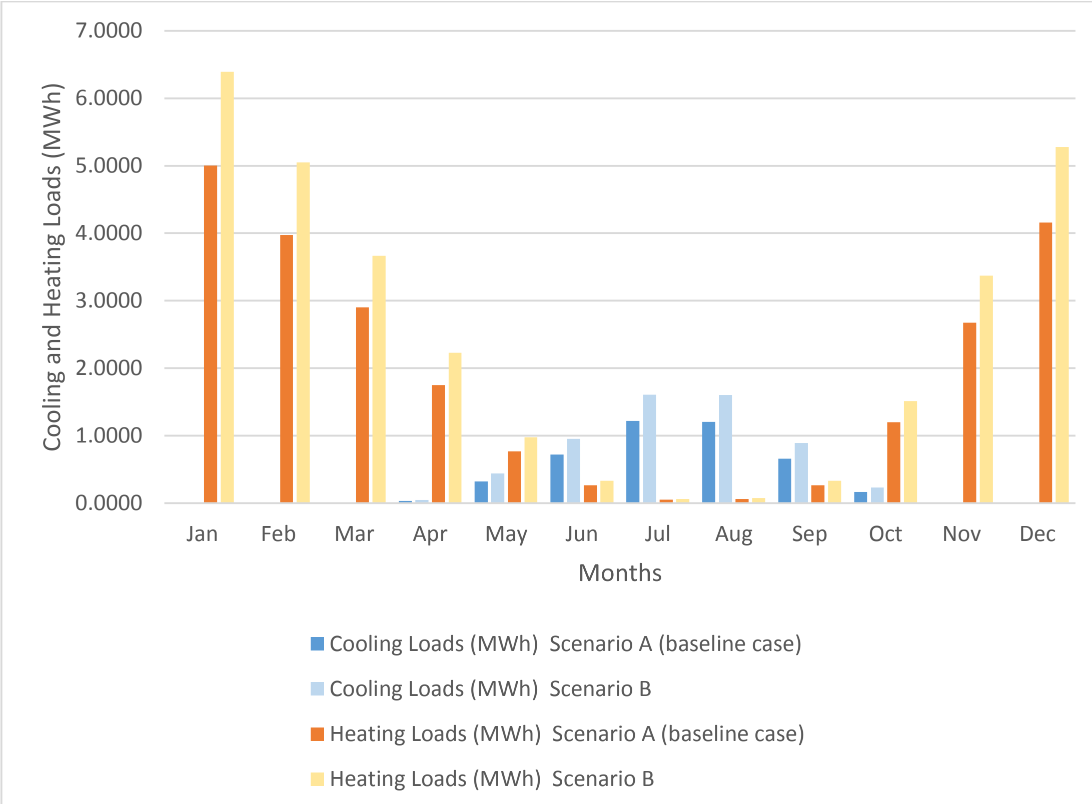

Figure 75: Monthly cooling and heating loads of scenarios A and B (IES <VE> & Author 2017)

The reason behind the observed increase in energy requirements is due to the increase in the external surface area between the two scenarios, which leads to a higher rate in heat gain and loss. Since the external surfaces of both scenarios have poor insulating qualities with a U-value of 5.5 W/m²K, the increase in surface area resulted in a noticeable increase in energy demands. Since both shelter typologies in scenarios A and B utilize the same material, the UNHCR tarpaulin, the upgrade from scenario A to B is usually driven by the need to create additional space and enough headroom inside the shelter. Scenario B represents an upgrade from an emergency shelter to a transitional shelter of a more permanent nature, therefore, the walls in scenario B are higher than those of scenario A. The height of the tent in scenario A is 1.5m at the edges which limits the usability of the space (UNHCR 2016e). Meanwhile, in the upgraded shelter of scenario B, the minimum height of the space is as per the minimum architectural standards, which is between 2.2 and 2.4 (Neufert et al. 2000). This has led to an increase in the volume of the shelter and resulted in an increase in energy requirements. Moreover, the geometry of the roof is different between the two scenarios. The roof in scenario A represents a hipped roof, while the roof in scenario B is a gable roof which has led to an increase in the overall volume of the shelter.

To be able to increase the area and the height of the shelter while minimizing the increase in heating and cooling loads, it is recommended to add internal partitions. When only parts of the shelter are occupied, smaller rooms would require less energy to cool or heat.

4.10.3 Simulation Results of Scenario C

In scenario C, the walls and roof cover are assumed to be made out of corrugated steel sheets, while the ground cover remains as a tarpaulin cover.

Replacing tarpaulin with corrugated steel sheets is generally considered an upgrade, however, results of the simulation show that it leads to an increase in the cooling and heating loads. When compared to the baseline case, the cooling loads of scenario C are 37% higher, and the heating loads are 31% higher (figure 76 and table 5).

Table 5: Monthly cooling and heating loads of scenarios A and C (IES <VE> & Author 2017)

Month	Cooling Loads (MWh)	Cooling Loads (MWh)	% to the baseline case	Heating Loads (MWh)	Heating Loads (MWh)	% to the baseline case
	Scenario A (baseline case)	Scenario C		Scenario A (baseline case)	Scenario C	
Jan	0.0000	0.0000	0%	5.0020	6.5870	32%
Feb	0.0000	0.0000	0%	3.9714	5.2064	31%
Mar	0.0025	0.0049	96%	2.9021	3.7709	30%
Apr	0.0302	0.0464	54%	1.7470	2.2983	32%
May	0.3209	0.4527	41%	0.7678	1.0071	31%
Jun	0.7216	0.9819	36%	0.2655	0.3429	29%
Jul	1.2192	1.6550	36%	0.0497	0.0652	31%
Aug	1.2050	1.6456	37%	0.0597	0.0786	32%
Sep	0.6593	0.9164	39%	0.2621	0.3437	31%
Oct	0.1652	0.2388	45%	1.2004	1.5598	30%
Nov	0.0055	0.0086	56%	2.6716	3.4690	30%
Dec	0.0000	0.0000	0%	4.1587	5.4280	31%
Total	**4.3294**	**5.9503**	**37%**	**23.0581**	**30.1568**	**31%**

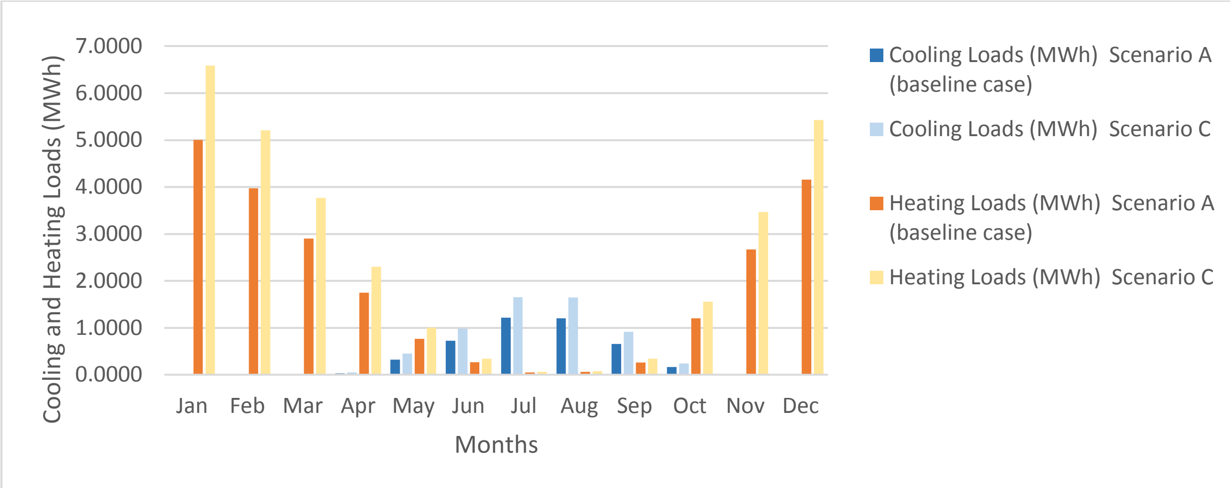

Figure 76: Monthly cooling and heating loads of scenarios A and C (IES <VE> & Author 2017)

The reasons behind this increase is the difference in the geometry of the shelter leading to a bigger volume which requires more energy for cooling and heating. Moreover, corrugated steel sheets have very high thermal conductivity and a U-value of 5.9 W/m²K. Despite the poor thermal performance of the corrugated steel sheets, they have other advantages when compared to the baseline case such as durability, higher water resistance, increased sound absorption qualities providing the occupants with more privacy. Moreover, one of the most important advantages of the corrugated steel shelters over the standard tents is the enhanced safety levels as it enables the occupants to add a door and a lock (The Guardian 2017c). To overcome this problem, when steel sheets are used in shelters provided by the UNHCR or other NGOs, it is often combined with a layer of thermal insulation, such as T-shelters in al Azraq camp (UNHCR 2015b). However, when the refugees themselves are upgrading their shelters, the limited budget and resources does not always enable them to resort to this option.

4.10.4 Simulation Results of Scenario D – Concrete Shelter

Results of the simulation show that a considerable improvement was achieved when using concrete blocks. When compared to the baseline case, the cooling loads of scenario D are 25% lower, and the heating loads are 21% lower (table 6 and figure 77).

Table 6: Monthly cooling and heating loads of scenarios A and D (IES <VE> & Author 2017)

Month	**Cooling Loads (MWh)**	**Cooling Loads (MWh)**	**% to the baseline case**	**Heating Loads (MWh)**	**Heating Loads (MWh)**	**% to the baseline case**
	Scenario A (baseline case)	**Scenario D**		**Scenario A (baseline case)**	**Scenario D**	
Jan	0.0000	0.0000	0%	5.0020	4.1273	-17%
Feb	0.0000	0.0000	0%	3.9714	3.2499	-18%
Mar	0.0025	0.0015	-40%	2.9021	2.3604	-19%
Apr	0.0302	0.0204	-32%	1.7470	1.3686	-22%
May	0.3209	0.1864	-42%	0.7678	0.4566	-41%
Jun	0.7216	0.5450	-24%	0.2655	0.1141	-57%
Jul	1.2192	1.0178	-17%	0.0497	0.0083	-83%
Aug	1.2050	1.0137	-16%	0.0597	0.0107	-82%
Sep	0.6593	0.3965	-40%	0.2621	0.0686	-74%
Oct	0.1652	0.0755	-54%	1.2004	0.8019	-33%
Nov	0.0055	0.0026	-53%	2.6716	2.1767	-19%
Dec	0.0000	0.0000	0%	4.1587	3.4301	-18%
Total	**4.3294**	**3.2594**	**-25%**	**23.0581**	**18.1733**	**-21%**

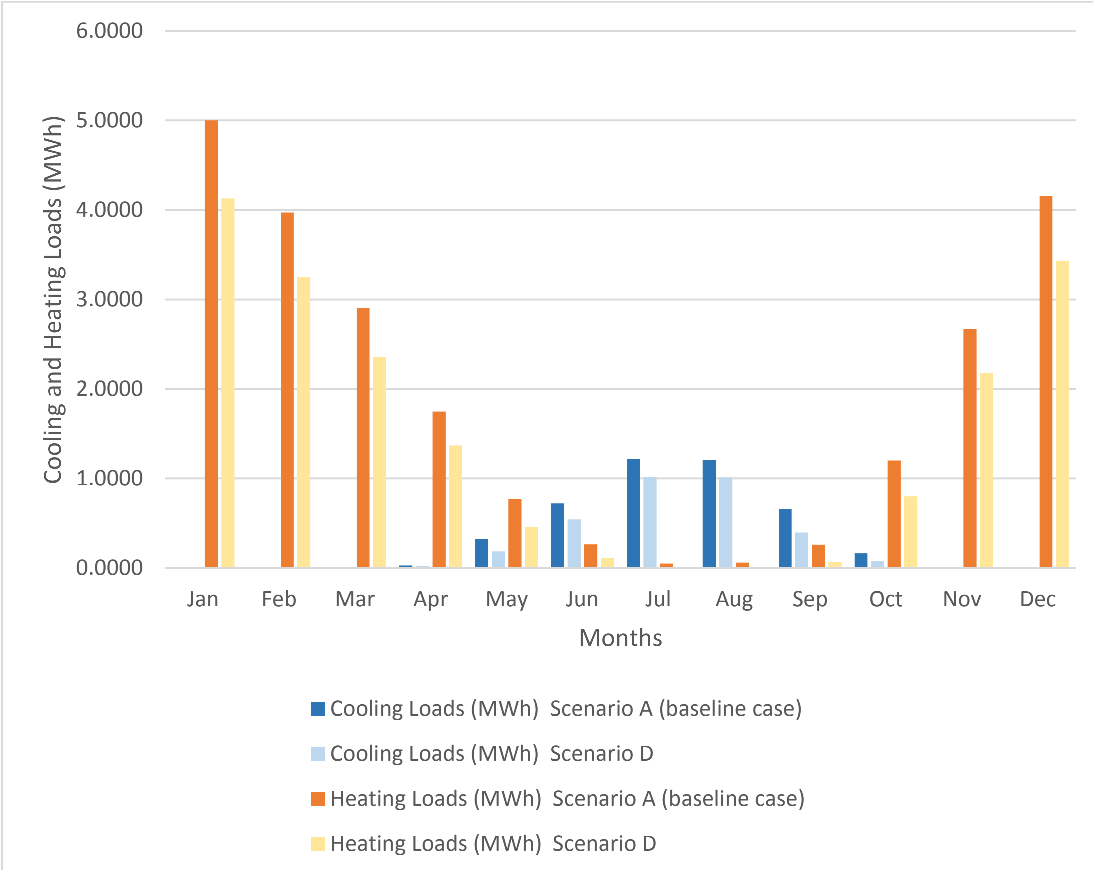

Figure 77: Monthly cooling and heating loads of scenarios A and D (IES <VE> & Author 2017)

These results are aligned with the data received from the UNHCR office in Iraq stating that the concrete shelter is the most satisfactory shelter typology currently implemented in Domiz camp. The reported drop in the heating and cooling loads is due to the low U-value of concrete (1.7 W/m²K) in comparison to all the other materials used in shelter typologies A-C. Adding to that, the concrete is characterized with a high thermal mass enabling it to store the heat and reduce temperature fluctuations.

4.10.5 Comparison between shelter typologies of Domiz camp

When comparing the 4 shelter typologies (figure78) currently present in Domiz camp in terms of their thermal performance, it is concluded that some of the upgrade strategies carried out by the refugees may influence the thermal performance of the shelter negatively. The tarpaulin shelter (scenario B) and the corrugated steel shelter (scenario C) caused a 28% and a 32% increase in the annual heating and cooling loads respectively (table 7 and figure 79). Nevertheless, these two shelter typologies are highly present in the camp as they offer other advantages in comparison to the standard tent.

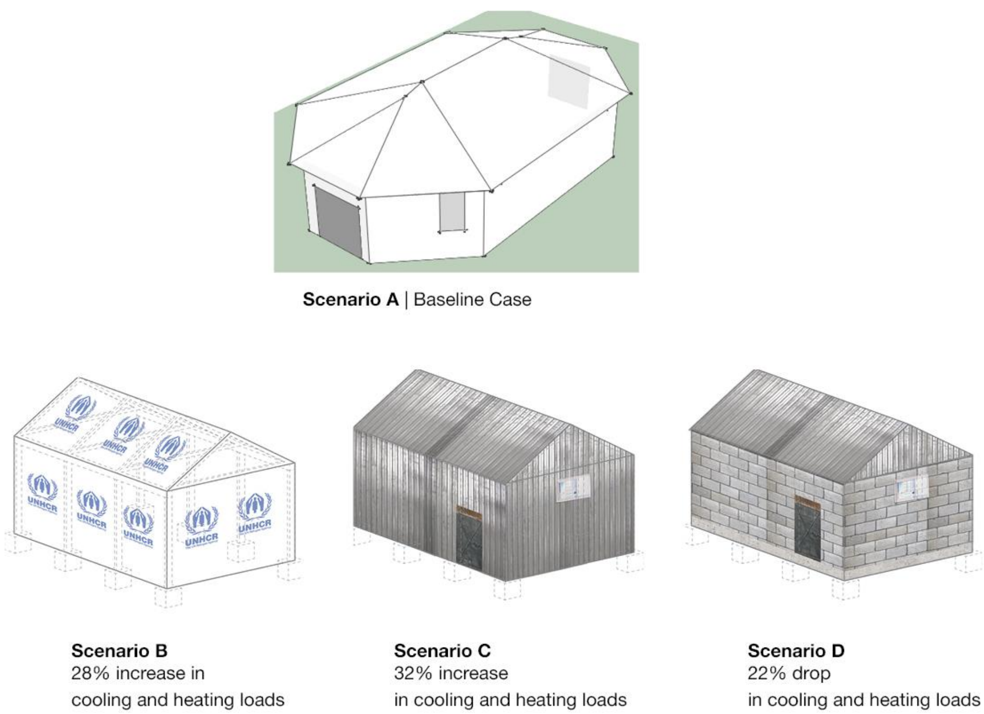

Figure 78: Comparison between shelter typologies in Domiz camp

This upgrade mostly driven by the refugee's need of more space and adequate headroom that allows the users to perform all their daily activities comfortably. Other factors play an important role in the shelter upgrade process, such as the privacy and safety levels achieved by each shelter typologies. Also, scarcity of resources plays an important role in the emergence of these two typologies. To offset the degradation in the thermal performance of these two shelter typologies (scenarios B and C), it is recommended to introduce internal partitions when increasing the area of the shelter, making it easier for the occupants to heat or cool only the occupied parts of the shelter at any time during the day. Also, when using corrugated steel sheets, thermal insulation can be used to enhance the thermal performance of the shelter.

These findings highlight that the concrete shelter (scenario D) is the only upgraded shelter that provides the refugees with the required levels of safety, privacy, and thermal comfort, stressing the need for alternative cost-effective and labor-inclusive solutions.

Table 7: Total cooling and heating loads of scenarios A-D (IES <VE> & Author 2017)

Scenario	**Cooling Loads (MWh)**	**% to the baseline case**	**Heating Loads (MWh)**	**% to the baseline case**	**Total Loads (MWh)**	**% to the baseline case**
A (Baseline case)	4.3294	_	23.0581	_	27.3875	_
B	5.7759	33%	29.2771	27%	35.0530	28%
C	5.9503	37%	30.1568	31%	36.1071	32%
D	3.2594	-25%	18.1733	-21%	21.4327	-22%

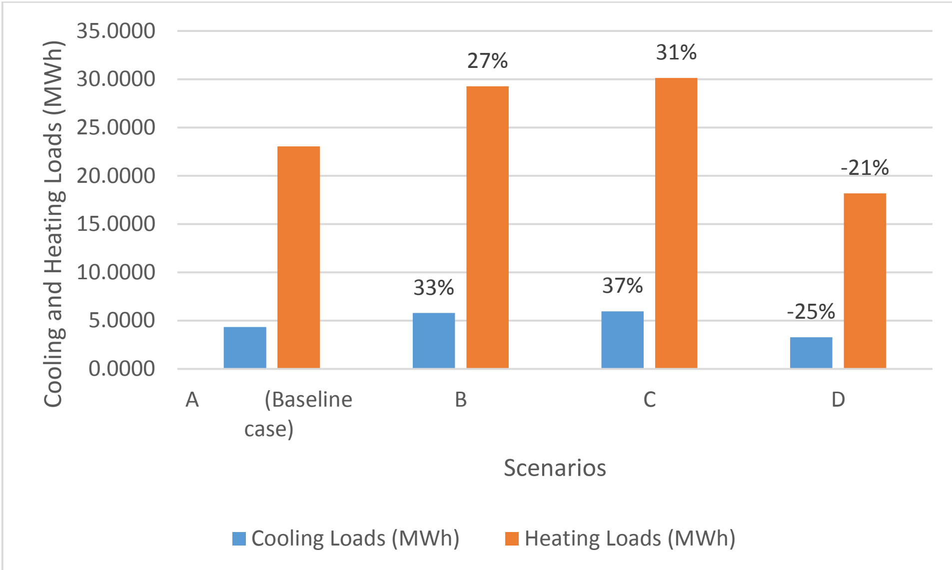

Figure 79: Total cooling and heating loads of scenarios A-D (IES <VE> & Author 2017)

4.10.6 Simulation Results of Scenario E – Proposed Shelter Phase 3 Option A

As explained in details in section 4.5.3 of this research, two options of a wall panel system are proposed as an alternative to conventional building materials and systems used in Domiz camp. The first option of the proposed wall panel is composed of layers of tarpaulin filled with sand in between. Thermal simulations of this option show that the thermal performance of the shelter is significantly better than that of the baseline case. In comparison to the baseline case, the cooling loads of scenario E dropped by 27%, and the heating loads dropped by 25% (table 7 and figure 78). This drop was achieved due to the decrease in the U-value of the building envelop when using the proposed wall panel (1.3 W/m²K), which increased the thermal resistance of the shelter, enhancing its thermal performance throughout the year.

Table 8: Monthly cooling and heating loads of scenarios A and E (IES <VE> & Author 2017)

Month	**Cooling Loads (MWh)**	**Cooling Loads (MWh)**	**% to the baseline case**	**Heating Loads (MWh)**	**Heating Loads (MWh)**	**% to the baseline case**
	Scenario A (baseline case)	**Scenario E**		**Scenario A (baseline case)**	**Scenario E**	
Jan	0.0000	0.0000	0%	5.0020	3.9371	-21%
Feb	0.0000	0.0000	0%	3.9714	3.0981	-22%
Mar	0.0025	0.0019	-24%	2.9021	2.2551	-22%
Apr	0.0302	0.0215	-29%	1.7470	1.3087	-25%
May	0.3209	0.1840	-43%	0.7678	0.4387	-43%
Jun	0.7216	0.5255	-27%	0.2655	0.1073	-60%
Jul	1.2192	0.9768	-20%	0.0497	0.0085	-83%
Aug	1.2050	0.9708	-19%	0.0597	0.0107	-82%
Sep	0.6593	0.3820	-42%	0.2621	0.0689	-74%
Oct	0.1652	0.0781	-53%	1.2004	0.7684	-36%
Nov	0.0055	0.0029	-47%	2.6716	2.0777	-22%
Dec	0.0000	0.0000	0%	4.1587	3.2711	-21%
Total	**4.3294**	**3.1435**	**-27%**	**23.0581**	**17.3503**	**-25%**

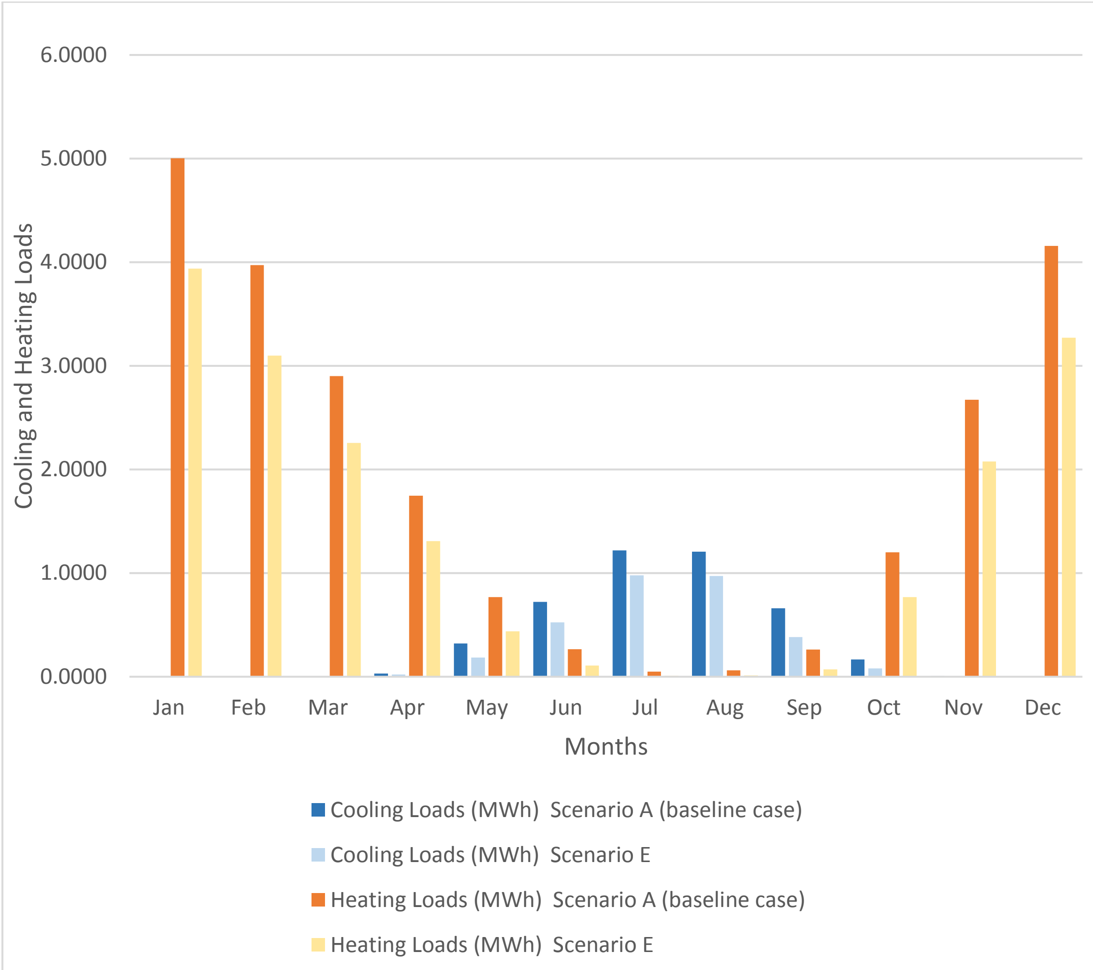

Figure 80: Monthly cooling and heating loads of scenarios A and E (IES <VE> & Author 2017)

4.10.7 Simulation Results of Scenario F - Proposed Shelter Phase 3 Option B

In scenario F, option B of the proposed wall panel is used which introduces an air cavity in the middle reducing the U-value to 1.04 W/m²K. Results of the simulation show a 29% drop in cooling loads and a 28% drop in heating loads when compared to the baseline case as shown in table 9 and figure 81.

Table 9: Monthly cooling and heating loads of scenarios A and F (IES <VE> & Author 2017)

Month	**Cooling Loads (MWh)**	**Cooling Loads (MWh)**	**% to the baseline case**	**Heating Loads (MWh)**	**Heating Loads (MWh)**	**% to the baseline case**
	Scenario A (baseline case)	**Scenario F**		**Scenario A (baseline case)**	**Scenario F**	
Jan	0.0000	0.0000	0%	5.0020	3.7843	-24%
Feb	0.0000	0.0000	0%	3.9714	2.9778	-25%
Mar	0.0025	0.0021	-16%	2.9021	2.1686	-25%
Apr	0.0302	0.0221	-27%	1.7470	1.2595	-28%
May	0.3209	0.1831	-43%	0.7678	0.4270	-44%
Jun	0.7216	0.5123	-29%	0.2655	0.1042	-61%
Jul	1.2192	0.9451	-22%	0.0497	0.0087	-82%
Aug	1.2050	0.9376	-22%	0.0597	0.0109	-82%
Sep	0.6593	0.3744	-43%	0.2621	0.0698	-73%
Oct	0.1652	0.0792	-52%	1.2004	0.7456	-38%
Nov	0.0055	0.0030	-45%	2.6716	1.9992	-25%
Dec	0.0000	0.0000	0%	4.1587	3.1440	-24%
Total	**4.3294**	**3.0589**	**-29%**	**23.0581**	**16.6998**	**-28%**

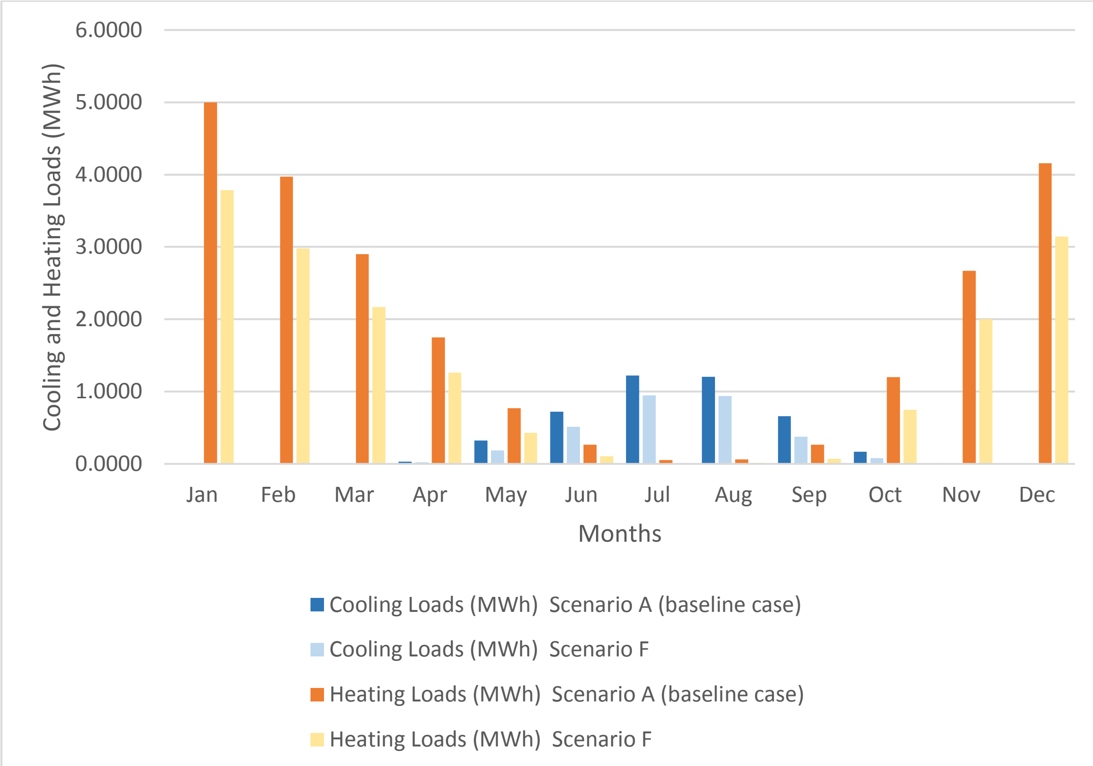

Figure 81: Monthly cooling and heating loads of scenarios A and F (IES <VE> & Author 2017)

4.10.8 Comparison between Options of the Proposed Wall Panel

When comparing the two options of the proposed wall panel, with and without the air cavity, it is clear that both options provide a significant improvement in the thermal performance of the shelter when compared to the baseline case. When compared to the baseline case, scenario E, which is option A of the propped wall panel, led to a 25% drop in the annual heating and cooling loads. Option F, which is option B of the proposed wall panel, led to a 28% drop in the annual heating and cooling loads (table 10 and figure 82). It is important to highlight that both options have a better thermal performance even when compared to the concrete shelter, scenario D, which led to a 22% drop in the annual heating and cooling loads.

Table 10: Total cooling and heating loads of scenarios A-D (IES <VE> & Author 2017)

Scenario	**Cooling Loads (MWh)**	**% to the baseline case**	**Heating Loads (MWh)**	**% to the baseline case**	**Total Loads (MWh)**	**% to the baseline case**
A (Baseline case)	4.3294	_	23.0581	_	27.3875	_
E	3.1435	-27%	17.3503	-25%	20.4938	-25%
F	3.0589	-29%	16.6998	-28%	19.7587	-28%

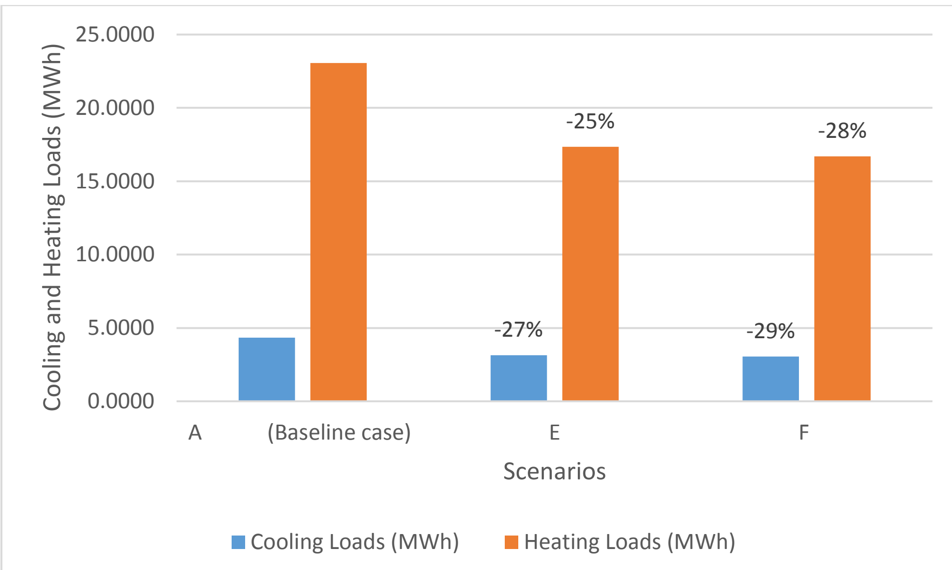

Figure 82: Total cooling and heating loads of scenarios A-D (IES <VE> & Author 2017)

These findings highlight the potential of utilizing available and low cost materials and building techniques to create efficient shelters for the refugees. Although introducing an air cavity in the wall panel improved its thermal performance, the improvement percentage is not significant. For this reason, one may argue that the improvement achieved by adding the air cavity, does not justify duplicating the amount of material needed to create the panel. Also, complexity of the construction technique is not preferable since this upgrade phase will be undertaken by the refugees themselves. Taking all these aspects into consideration, scenario E, is selected by the author as the preferred option, on which further enhancement strategies are tested in the nest sections.

4.10.9 Simulation Results of Scenario G – The Sunspace

In scenario G, a sunspace was added to the south of the main shelter space. The walls and roof of the sunspace are composed of a single layer of plastic sheeting. Two openings were added on the wall separating the main space of the shelter and the sunspace, to create an air flow between the two spaces. Due to the greenhouse effect, the sunspace traps the heat gained by direct exposure to the sun throughout the day. Hot air from the sunspace flows through the ventilation openings to the main shelter space, and cool air flows from the main space to the sunspace. This continuous air flow helps increase the internal air temperature of the shelter in winter which is evident in the significant drop in heating loads (32%) as shown in table 11 and figure 83.

During summer, on the other hand, the addition of the sunspace resulted in an undesirable heat gain, which is demonstrated in June and August as no reduction in the cooling loads was observed. Moreover, a 1% increase in cooling loads was reported in July. For this reason, it is important that the sunspace become a temporary solution rather than a permanent one. Since the proposed sunspace is composed of an extended structure covered with plastic sheeting, one solution is removing the plastic sheeting during summer and storing the material until needed.

Table 11: Monthly cooling and heating loads of scenarios A and G (IES <VE> & Author 2017)

Month	Cooling Loads (MWh)	Cooling Loads (MWh)	% to the baseline case	Heating Loads (MWh)	Heating Loads (MWh)	% to the baseline case
	Scenario A (baseline case)	Scenario G		Scenario A (baseline case)	Scenario G	
Jan	0.0000	0.0000	0%	5.0020	3.7290	-25%
Feb	0.0000	0.0000	0%	3.9714	2.8616	-28%
Mar	0.0025	0.0023	-8%	2.9021	1.9972	-31%
Apr	0.0302	0.0235	-22%	1.7470	1.0759	-38%
May	0.3209	0.2380	-26%	0.7678	0.3103	-60%
Jun	0.7216	0.7228	0%	0.2655	0.0689	-74%
Jul	1.2192	1.2365	1%	0.0497	0.0059	-88%
Aug	1.2050	1.2109	0%	0.0597	0.0078	-87%
Sep	0.6593	0.5648	-14%	0.2621	0.0531	-80%
Oct	0.1652	0.1008	-39%	1.2004	0.5992	-50%
Nov	0.0055	0.0032	-42%	2.6716	1.8549	-31%
Dec	0.0000	0.0000	0%	4.1587	3.1992	-23%
Total	**4.3294**	**4.1028**	**-5%**	**23.0581**	**15.7630**	**-32%**

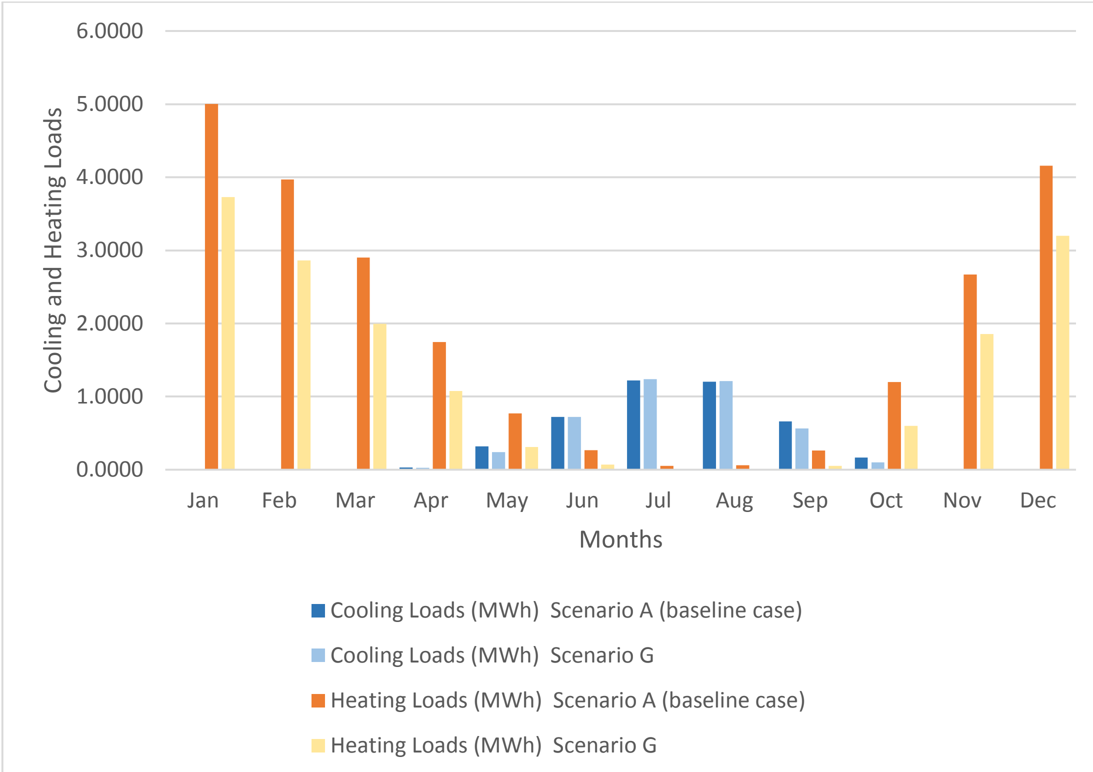

Figure 83: Monthly cooling and heating loads of scenarios A and G (IES <VE> & Author 2017)

4.10.10 Simulation Results of Scenario H – Adding the Roof Canopy

Unlike the vertical surfaces of any building, the roof is constantly exposed to direct solar radiation throughout the day. Therefore, maximum heat gain occurs through the roof as illustrated in figure (x). In Domiz camp, materials and resources limitations leaves the refugees with corrugated steel sheets as the only solution for shelters roofing. As mentioned previously, corrugates steel sheets have high thermal conductivity, resulting in high heat gain through the roof. In addition to shading the roof, the proposed roof canopy acts as a double roofing system encouraging air flow between the tarpaulin layer and the roofing. The airflow helps further reduce the heat gain through the roof which is clear in the results of the simulation. However, during winter, maximum heat gain is needed as internal air temperatures are significantly lower than the comfort levels. Results of the simulation show a 20% drop in heating loads when compared to the baseline case, unlike scenario E which leads to

Table 12: Monthly cooling and heating loads of scenarios A and H (IES <VE> & Author 2017)

Month	**Cooling Loads (MWh)**	**Cooling Loads (MWh)**	**% to the baseline case**	**Heating Loads (MWh)**	**Heating Loads (MWh)**	**% to the baseline case**
	Scenario A (baseline case)	**Scenario H**		**Scenario A (baseline case)**	**Scenario H**	
Jan	0.0000	0.0000	0%	5.0020	3.9376	-21%
Feb	0.0000	0.0000	0%	3.9714	3.1846	-20%
Mar	0.0025	0.0000	-100%	2.9021	2.3682	-18%
Apr	0.0302	0.0000	-100%	1.7470	1.3845	-21%
May	0.3209	0.0467	-85%	0.7678	0.4641	-40%
Jun	0.7216	0.3110	-57%	0.2655	0.1196	-55%
Jul	1.2192	0.7488	-39%	0.0497	0.0048	-90%
Aug	1.2050	0.6980	-42%	0.0597	0.0046	-92%
Sep	0.6593	0.1958	-70%	0.2621	0.0417	-84%
Oct	0.1652	0.0098	-94%	1.2004	0.7892	-34%
Nov	0.0055	0.0000	-100%	2.6716	2.1245	-20%
Dec	0.0000	0.0000	0%	4.1587	3.4023	-18%
Total	**4.3294**	**2.0101**	**-54%**	**23.0581**	**17.8259**	**-23%**

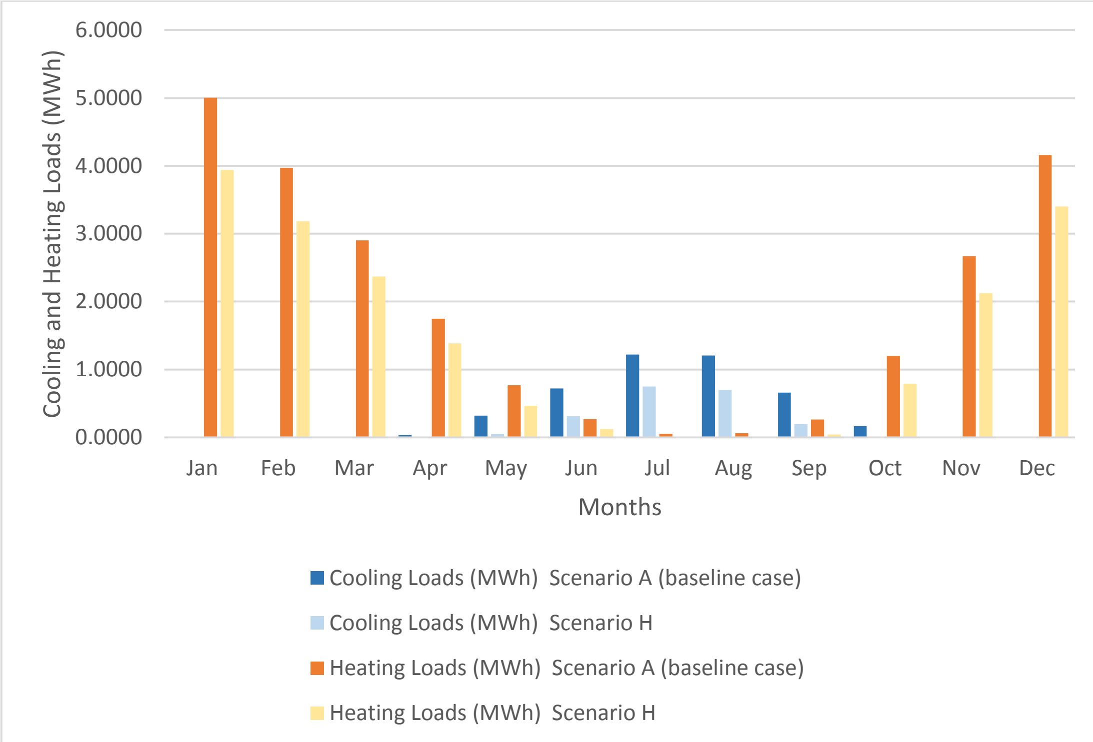

Figure 84: Monthly cooling and heating loads of scenarios A and H (IES <VE> & Author 2017)

4.10.11 Comparison between scenarios E,G, & H

As shown in table13 and figure 85, the most significant drop in cooling loads was recorded in scenario H, when the roof canopy was added. A 54% reduction in cooling loads was achieved by adding the roof canopy. Meanwhile, the most substantial decrease (32%) in heating loads was achieved by adding the sunspace. Since both the roof canopy and the sunspace are temporary solutions that can be implemented only when needed, a hybrid solution can be derived out of scenarios E, G, and H.

Table 13: Total cooling and heating loads of scenarios E-H (IES <VE> & Author 2017)

Scenario	Cooling Loads (MWh)	% to the baseline	Heating Loads (MWh)	% to the baseline	Total Loads (MWh)	% to the baseline
A	4.3294	_	23.0581	_	27.3875	_
E	3.1435	-27%	17.3503	-25%	20.4938	-25%
G	4.1028	-5%	15.7630	-32%	19.8658	-27%
H	2.0101	-54%	17.8259	-23%	19.8360	-28%

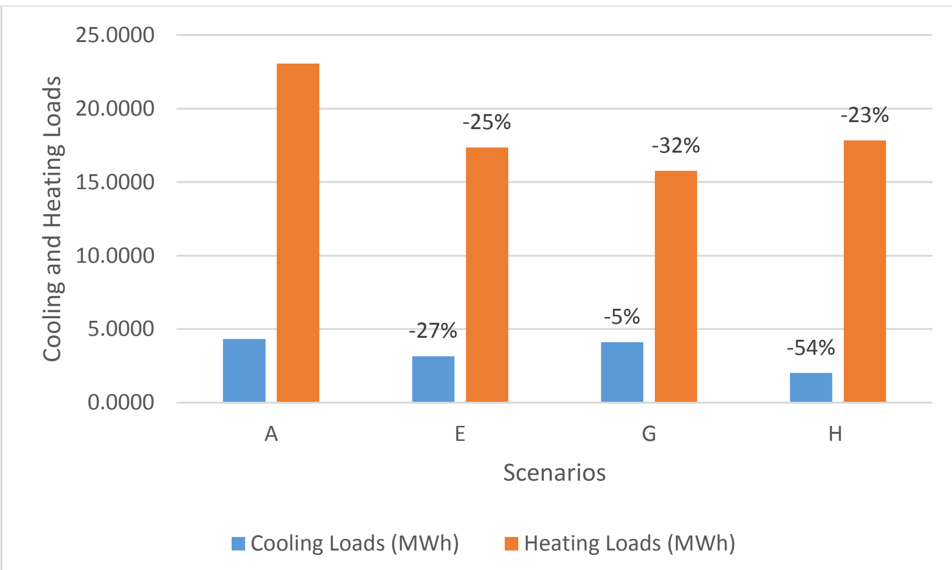

Figure 85: Total cooling and heating loads of scenarios E-H (IES <VE> & Author 2017)

4.4.4.11 Scenario I - The hybrid solution

By comparing the heating and cooling loads of scenarios G and H, a hybrid solution can be derived by highlighting which scenario to implement in each month to achieve the most significant drop in heating and cooling loads. As illustrated in table 14, the sunspace should be fully closed from January till April, and from September till December. During these months, the addition of the sunspace resulted in a considerable reduction in the heating loads. Meanwhile, between May and August, the sunspace must be fully opened and ventilated to avoid overheating. Also, the roof canopy is added to achieve a further drop in cooling loads.

Table 14: selection of which scenario to implement in each month

Month	**Selected Scenario**	**Cooling Loads (MWh)**	**Heating Loads (MWh)**	**Total Loads (MWh)**
Jan	G	0.0000	3.7290	3.729
Feb	G	0.0000	2.8616	2.8616
Mar	G	0.0023	1.9972	1.9995
Apr	G	0.0235	1.0759	1.0994
May	H	0.0467	0.4641	0.5108
Jun	H	0.3110	0.1196	0.4306
Jul	H	0.7488	0.0048	0.7536
Aug	H	0.6980	0.0046	0.7026
Sep	G	0.5648	0.0531	0.6179
Oct	G	0.1008	0.5992	0.7
Nov	G	0.0032	1.8549	1.8581
Dec	G	0.0000	3.1992	3.1992
Total		**2.4991**	**15.9632**	**18.4623**

As shown in table 15, implementing the hybrid solution results in a 42% drop in cooling loads, and a 31% drop in cooling loads when compared to scenario A, the baseline case.

Table 15: Monthly cooling and heating loads of scenarios A and I (IES <VE> & Author 2017)

Month	Cooling Loads (MWh)	Cooling Loads (MWh)	% to the baseline case	Heating Loads (MWh)	Heating Loads (MWh)	% to the baseline case
	Scenario A (baseline case)	Scenario I (hybrid)		Scenario A (baseline case)	Scenario I (hybrid)	
Jan	0.0000	0.0000	0%	5.0020	3.7290	-25%
Feb	0.0000	0.0000	0%	3.9714	2.8616	-28%
Mar	0.0025	0.0023	-8%	2.9021	1.9972	-31%
Apr	0.0302	0.0235	-22%	1.7470	1.0759	-38%
May	0.3209	0.0467	-85%	0.7678	0.4641	-40%
Jun	0.7216	0.3110	-57%	0.2655	0.1196	-55%
Jul	1.2192	0.7488	-39%	0.0497	0.0048	-90%
Aug	1.2050	0.6980	-42%	0.0597	0.0046	-92%
Sep	0.6593	0.5648	-14%	0.2621	0.0531	-80%
Oct	0.1652	0.1008	-39%	1.2004	0.5992	-50%
Nov	0.0055	0.0032	-42%	2.6716	1.8549	-31%
Dec	0.0000	0.0000	0%	4.1587	3.1992	-23%
Total	**4.3294**	**2.4991**	**-42%**	**23.0581**	**15.9632**	**-31%**

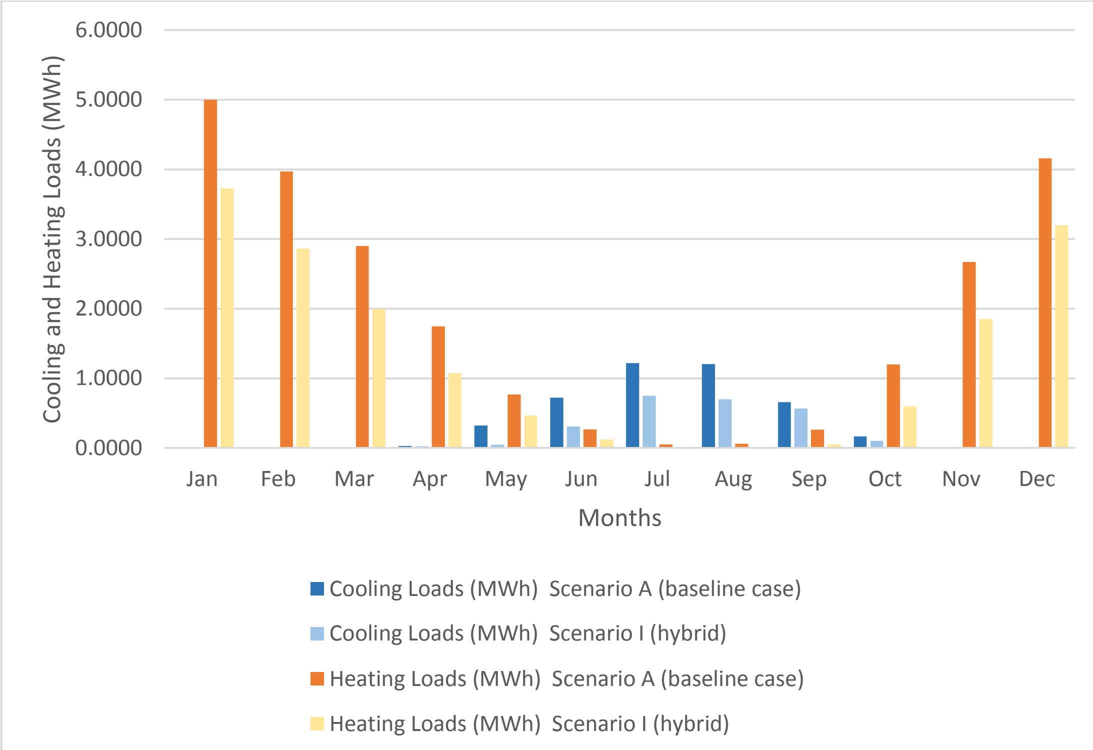

Figure 86: Monthly cooling and heating loads of scenarios A and I (IES <VE> & Author 2017)

4.10.12 Comparison between all scenarios

Table 16 and figure 87 show a comparison between all scenarios in terms of the annual cooling and heating loads. Results of the simulation show that the most substantial drop in the annual heating and cooling loads, 42% and 31% respectively, was achieved in scenario I. due to the following:

- The use of the proposed wall panel (section 4.5.3), which is composed of two layers of tarpaulin filled with 20cm thickness of sand sourced from the site, supported by a steel mesh from both sides. This configuration results in a U-value of 1.3 (W/m²K), which is lower than any of the U-values achieved by other shelter typologies in Domiz camp.

- The use of the sunspace as a passive heating strategy from January till April, and from September till December. During these month, the roof is completely exposed to maximize solar heat gain.
- The use of a layer of tarpaulin to shade the roof (a roof canopy) between May and August to reduce heat gain through the roof. During these months, the sunspace is opened and ventilated to avoid over-heating.

Table 16: Total cooling and heating loads of all scenarios (IES <VE> & Author 2017)

Scenario	**Cooling Loads (MWh)**	**% to the baseline case**	**Heating Loads (MWh)**	**% to the baseline case**	**Total Loads (MWh)**	**% to the baseline case**
A (Baseline case)	4.3294	_	23.0581	_	27.3875	_
B	5.7759	33%	29.2771	27%	35.0530	28%
C	5.9503	37%	30.1568	31%	36.1071	32%
D	3.2594	-25%	18.1733	-21%	21.4327	-22%
E	3.1435	-27%	17.3503	-25%	20.4938	-25%
F	3.0589	-29%	16.6998	-28%	19.7587	-28%
G	4.1028	-5%	15.7630	-32%	19.8658	-27%
H	2.0101	-54%	17.8259	-23%	19.8360	-28%
I	2.4991	-42%	15.9632	-31%	18.4623	-33%

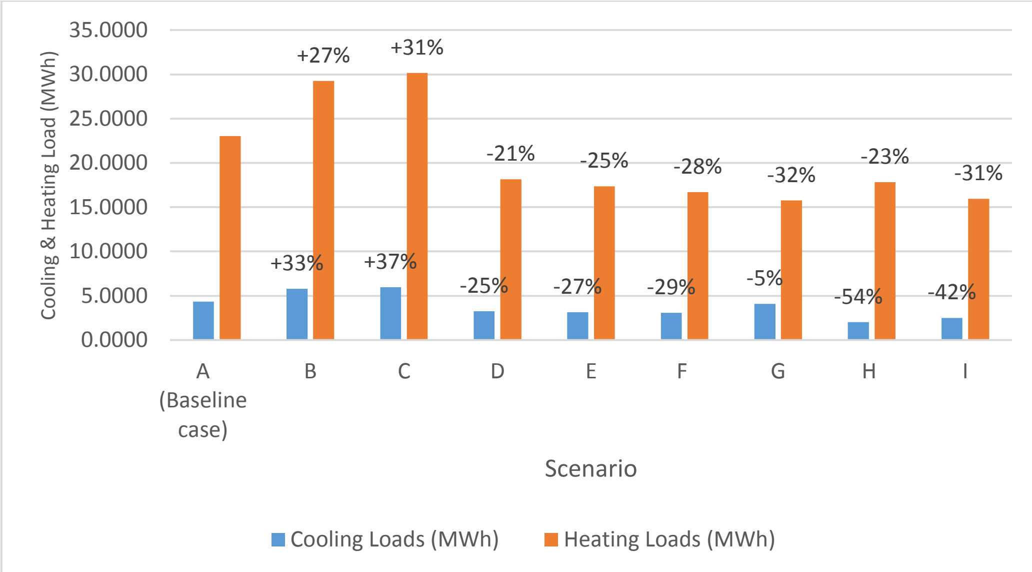

Figure 87: Total cooling and heating loads of all scenarios (IES <VE> & Author 2017)

5 Chapter 5: Conclusions & Recommendations

5.1 Conclusion

This research was carried out to explore sustainable strategies to upgrade shelters in refugee camps, focusing on Domiz refugee camp in Iraq. The Domiz camp was selected as a suitable case study for this research upon correspondence with the UNHCR team in Iraq, which also stated that shelter upgrade is considered a priority in Domiz camp and a research in this area would be beneficial.

Literature review was conducted to examine refugee camps shelter design typologies, common building materials, and design guidelines. Moreover, several successful case studies of shelters that can be applicable in the context of refugee camps were presented and assessed. Through the case studies, three approaches to shelter provision were identified: the top-down approach, the bottom-up approach, and the incremental approach. Also, it was concluded that utilizing on-site materials is being successfully used in building refugees shelter due to affordability and availability. Also, the importance of designing with thermal comfort and cultural relevance in mind was evident.

A review of the context of Domiz camp shows that the camp is located within a semi-arid climate zone, with cold winters and hot dry summers.
Results of the research show that Domiz camp had passed the emergency phase, therefore, the speed of construction is no longer a priority.

Furthermore, a detailed description of the current shelter typologies present with Domiz camp was provided by the UNHCR office in Iraq, stating the number of units under each shelter typology, materials used, and issues of concern.

Based on the above, a shelter upgrade strategy was proposed. The shelter upgrade strategy, referred to as The Incremental Home Strategy, is composed of four phases in which the role of the UNHCR and other NGOs is maximized in the first phase, gradually being overtaken by the involvement of the beneficiaries, the refugee population, by the end of phase 4. The Incremental Home strategy is an attempt to utilize the building capacity of the people by facilitating an organized and balanced approach of roles distribution. The upgrade strategy starts with the aspects that are technically challenging and require expertise and skilled labor, which is where the role of professionals and specialists from different organizations is needed. Gradually, the tasks become easier in terms of implementation and knowledge transfer to enable the people to take control and be the decision makers. The first phase is the planning phase, focusing on the optimum shelter orientation and clusters' configuration. The second phase discusses the provision of the structural frame that is rain and wind resistance providing a durable base for future upgrade. The third phase is the wall covering upgrade phase, in which a wall panel system is proposed as an alternative to current practices. The proposed wall panel is composed of layers of steel mesh, tarpaulin, and sand combined in two different configurations referred to as proposed wall panel option A, and proposed wall panel option B. The main difference between the two options is that option B introduces an air cavity layer to decrease the U-value of the system. The last phase suggests the addition of passive cooling and heating techniques. Two different techniques are suggested: the sunspace and the roof canopy.

For phases 1 and 2, qualitative assessment is utilized by referring to the literature, comparing to case studies and referencing to information provided by the UNHCR. In phases 3 and 4, on the other hand, quantitative assessment is used to test the thermal performance of the proposed solutions. Digital simulation was selected as the method best suited to conduct the quantitative assessment due to its accessibility for the researcher and ability to test multiple scenarios within the time frame of this study.

A total of 8 simulations were conducted using IES VE software to assess the thermal performance of the current shelter typologies in Domiz camp, of which the UNHCR tent is considered the base case, against the proposed solutions. Heating and cooling loads of each scenario indicated the amount of energy needed to maintain the internal temperature within the comfort zone.

Results of the simulation illustrate the following:

- Due to the cold climate of Kurdistan region, the heating loads constitute 84% of the total heating and cooling loads in the baseline case, the UNHCR tent.
- When upgrading the tent into the tarpaulin shelter (scenario B), a 33% increase in cooling loads and a 27% increase in heating loads is observed. This increase is mainly due to the increase in the external surface area of the shelter due to an increase in shelter height which increase heat loss during winter, and heat gain during summer.
- When upgrading the tent into a corrugated steel shelter (scenario C), the cooling loads are increased by 37%, and the heating loads are increased by 31% higher. Similar to scenario B, scenario C has a larger external surface area increasing the heat loss/gain. Also, corrugated steel has poor thermal insulation qualities.
- When upgrading the tent into a concrete shelter (scenario D), a significant improvement in the thermal performance of the shelter is achieved. In scenario D, heating loads drop by 21%, and cooling loads drop by 25%. This considerable improvement is due to the drop in U-value of the walls, and to the high thermal mass properties of the concrete.

- Among the shelter typologies present in Domiz camp, the concrete shelter is considered the most thermally-efficient solution.
- In scenario E, Using option A of the proposed wall panel led to a 27% drop in cooling loads and 25% drop in heating loads, illustrating that this solution is more effective than all the shelter typologies of Domiz camp.
- In scenario F, Using option B of the proposed wall panel, which has an air cavity, led to a 29% drop in cooling loads and 28% drop in heating loads. Which is slightly better than results achieved by implementing option A.
- When compared to option A of the proposed wall panel, option B is more complex to build, requires double the amount of material due to introducing an air cavity in the system, and offers a small improvement in the thermal performance of the shelter. For this reason, option A is selected by the author as a base upon which the sunspace and the roof canopy are tested.
- Adding a sunspace (scenario G) led to a significant drop in heating loads (32%). Meanwhile, cooling loads dropped only by 5% due to undesirable heat gain during summer.
- Adding the roof canopy (scenario H) led to a significant drop in cooling loads (54%). Meanwhile, heating loads dropped by 23% from the base case but increased heating load compared to scenario E (eliminating the roof canopy) due to undesirable heat loss during winter.
- Since both the roof canopy and the sunspace are temporary solutions that can be implemented only when needed, a hybrid solution (scenario I) is derived out of scenarios E, G, and H.
- In scenario I, the hybrid solution, the sunspace is used from January till April, and from September till December. During the rest of the year, the sunspace is opened and ventilated to avoid undesirable heat-gain in summer. The roof canopy is installed between months May throughout

August to reduce heat gain through the roof. Scenario I led to 42% decrease in cooling loads, and 31% decrease in heating loads.

- The study illustrates the potential of utilizing low-cost available materials in a simple system to achieve a significant improvement in the thermal performance of the shelter, even when compared to the concrete shelter which is considered the most successful shelter typology in Domiz camp.

5.2 Recommendations for Future Studies

Knowledge transfer from specialists to the refugee population is an essential part of the 'The Incremental Home Strategy'. Therefore, it is recommended to conduct further studies on the implementation of training programs in Domiz camp.

Also, further structural analysis can be conducted to specify exact sizing of structural elements and the most successful size and configurations of the proposed wall panel. Furthermore, a detailed Bill of Quantity can be produced on which a feasibility study is conducted to compare the cost of implementing this option to the cost of other shelter typologies. Moreover, future research can be carried out to investigate possible insulation materials that can be added to improve the performance of the roofing system. Also, a prototype of the proposed shelter can be built, on which experimental assessment can be conducted. Finally, future work could focus on transforming the findings and the proposed solutions into a simplified illustrated version in the form of a manual or a booklet making these solutions and findings accessible for the refugee population, since this research is aimed not only as a guide for camp administration, but also as a guide to the refugee population, providing them with solutions and giving them the option to implement what they see mostly needed so each one can respond according to their needs.

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Appendix 1

Feedback received from the UNHCR office in Iraq on 4th July 2016

1. Specify the percentage of each of the following shelter typologies currently present in Domiz Camp

Categories	Domiz 1 camp	Domiz 2 camp
Standard UNHCR tent	**36**	**0**
Wooden structure covered with tent fabric and blankets/ plastic sheets	**450**	**0**
Steel frame covered with tent fabric and blankets	**1720**	**26**
Steel frame covered with corrugated sheets	**500**	**95**
Concrete blocks	**2350**	**1305**
Total plots/shelters	**5,056**	**1426**

2. Are there shelter typologies other than the mentioned above? If yes, please specify. No

3. What is the most convenient building material in terms of cost and availability?

Cement, sand and concrete blocks. As for the roof, sandwich panel is preferable.

4. Who is responsible of doing the construction work?

- The refugees themselves: Yes, after attaining official authorization from BRHA, self-upgrading by the refugees.

- UNHCR staff: Monitoring and needs assessment.

- Skilled labour from the city hired by the UNHCR: Usually the labours from the refugee community.

5. Who is covering the construction cost?

   Self-upgrading by the refugees, the refugees undertaking the cost of materials and labour fees.

6. Is there a specific budget allocated for each family/shelter unit?

   Around 2000-2500USD to upgrade the tent shelter into a concrete blocks shelter with concrete base (the cost does not include the upgrading of the WASH facilities and kitchens).

7. What is the most successful type of shelter being implemented in Domiz camp?

   Concrete blocks built up shelters with a concrete slab.

8. What are the biggest needs of refugees when it comes to shelter?

   Built up shelter by concrete blocks is the first need that improves the shelter from protection point of view. Having two separated rooms for families to give more privacy for family members.

9. What are the priorities/types of solutions you would like to see coming out of this study?

Summary:

To upgrade the following cases and/or substandard shelters in the camp:

- Wooden structure covered with tent fabric and blankets/ plastic sheets.
- Steel frame covered with tent fabric and blankets.
- Steel frame covered with corrugated sheets
- Tent with attached wooden frame with plastic sheet.

10. Can you give examples where such solutions have been implemented successfully or not and why?

GRC has conducted the shelters upgrading of 1066 shelters in Gawilan camp successfully:

- In terms of logistic support and implementation it was very fast, well organized regarding the delivery of the materials to the PoCs.
- Proper coordination between the BRHA TU and related NGO in terms of standard shelters, design and monitoring the construction.
- The PoCs received 200 $ cash for work/ monetization, majority of the community received cash even like a tentative income.
- Vast majority of the refugees/community were satisfied regarding the quality of the materials.