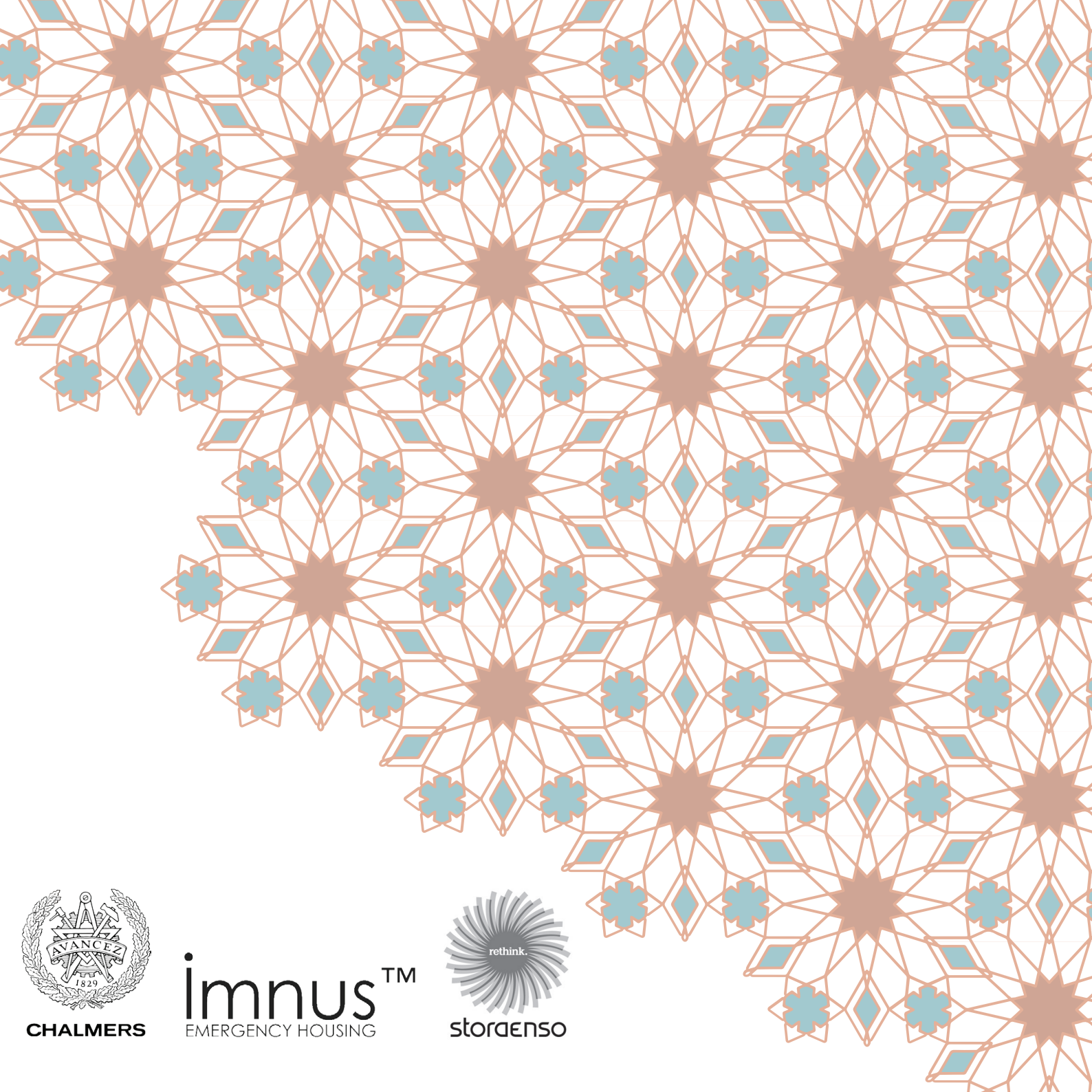
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FROM EMERGENCY SHELTERS TO HOMES

Design of paperboard housing exploring living conditions in post-disaster settlements

Jonas Lundgren and Francesca Tassi Carboni

Master's Programme Design for Sustainable Development
Department of Architecture, Chalmers University of Technology
Gothenburg, Sweden 2014

Abstract

Providing adequate post-disaster housing for refugees and displaced people is a challenging and critical issue, as world-wide aid resources are insufficient.

The objective of this thesis is to develop the design for an emergency shelter made in paperboard, focusing on the creation of dignified living conditions in a way that is both environmentally sustainable and economically feasible; a shelter which can be produced with high durability at reasonable cost. The project is performed in collaboration with *Imnus™ Emergency Housing*. *Re-board®* was selected as construction material, being rigid, lightweight and fully recyclable.

The design criteria are dictated by the analytic study of different aspects that could contribute to the optimization of the final product: life in refugee camps, essential qualities of a domestic environment, its spaces and functions, general requirements set by aid organizations and technical production requirements.

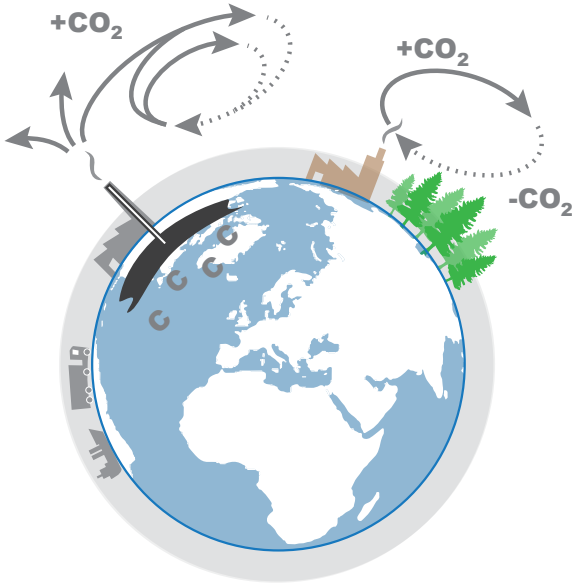
The thesis proceeded alternating research, design development and full scale realization, with the construction of three prototypes between January and June 2014.

The results support the appropriateness of paperboard housing solutions for early post-disaster response, prioritizing the aspects related to provision of privacy and structural stability, together with shelter adaptability to a diversity of cultural and social contexts.

Authors

Jonas Lundgren

With former experience as a teacher and project developer of a primary school extension in Ghana, in 2008 Jonas started Chalmers University at the bachelor program *Architecture and Engineering*, and followed it up with two parallel master programmes: *Structural Engineering and Building Technology* and *Design for Sustainable Development*. With an underlying interest for energy-efficient housing and deep involvement in Chalmers participation in *Solar Decathlon China 2013*, he has built up a future aim to work as an architect with zero-impact buildings. In his master thesis in civil and environmental engineering he concluded the benefits of using cellulose based materials in construction. This following thesis unites his interest of humanitarian work, technical material properties and sustainable architecture.

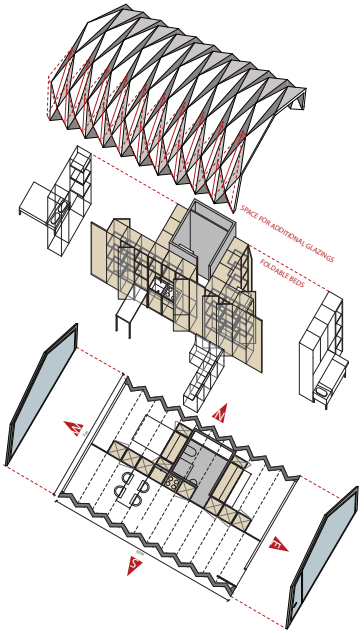


Master thesis "The Impact of Life Expectancy in LCA of Concrete and Massive Wood Structures".

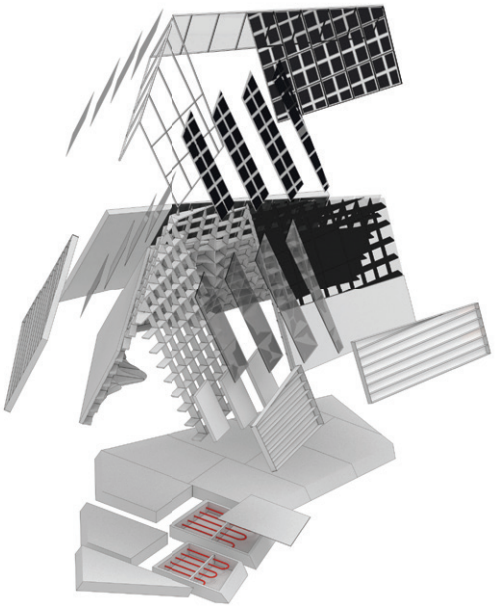
Halo. Solar-powered student housing, realized in Solar Decathlon China 2013.

Francesca Tassi Carboni

After graduating with a degree in *Architectural Science* from the University of Parma in Italy and doing an internship at the studio *Flores Prats* in Barcelona, Francesca started the master program *Design for Sustainable Development* at Chalmers University. There she developed two projects of paper houses, as temporary and nomadic interventions to apply in urban voids and on rooftops. The projects explore the minimal space of living and the potential of paper as a strong construction material that could offer a broad range of solutions at a low price. She approaches the thesis as an experience that will enhance her architecture ethics, problematizing the possibility of architecture to be a vehicle of social sustainability and improvement of the living conditions for affected populations around the world.



Foldable origami paper shelter 2013.



Seed 2.0. Solar-powered housing in cardboard. Chalmers entry for Solar Decathlon Europe 2014.

Involved companies

Imnus™ Emergency Housing

The master thesis is performed in collaboration with three students at the master program Entrepreneurship and Business Design at Chalmers School of Entrepreneurship. With their company Imnus™ Emergency Housing they develop a concept that improves living conditions for people in emergency situations and delivers light, flat packaged and fully recyclable housing modules. The company was founded in Gothenburg in 2013 in a partnership with Encubator AB and Stora Enso Re-board AB.

Stora Enso Re-board

The material that have been chosen the shelter construction is Re-board®, a lightweight and strong paperboard formed by external rigid layers and a fluted core. Manufactured by Stora Enso Re-board in Norrköping, Sweden, its main field of application is as interior furniture or fair booths and displays. Today is being tested also an outdoor version of the material with a moisture proof surface. Re-board® has a small climate impact and can be recycled as paper in normal waste paper streams, because of the utilization of water based adhesives.

Chalmers University of Technology

In December of 2013 Imnus™ contacted the Department of Architecture to start a collaboration with two master thesis students that could follow the design development of the product. The work with the company constituted an important part of the thesis, that was carried on independently from the academic research.

Acknowledgements

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Master thesis coordinator

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CEO Stora Enso Re-board AB

Luis Iglesias & Lisa Kihlström

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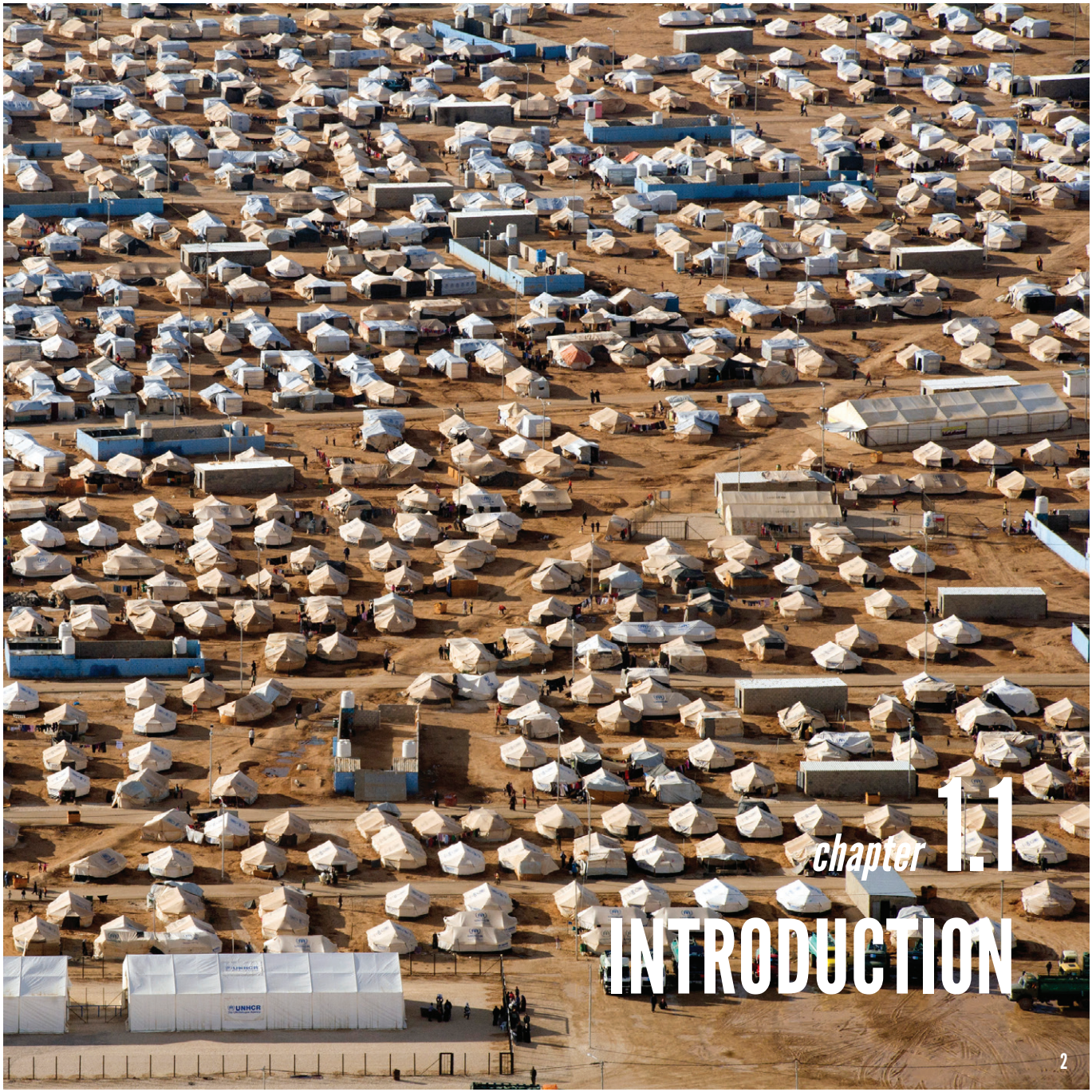


chapter 1.1

INTRODUCTION

Preamble

Any given year, millions of people lose their homes and belongings in natural disasters and conflicts. In 2012 the international community faced the planet's worst refugee crisis in many years. Every day, on average, 3,000 people become refugees. Today 45.2 million people worldwide are considered as forcibly displaced due to persecution, conflict, generalized violence and human rights violations. The data trends indicate that number of refugees will continue to rise in the coming decade. The average lifespan of a refugee camp is close to 17 years, with some Palestinian refugee camps still running after more than 50 years (UNHCR, 2012a).

Emergency aid and business opportunities

Catastrophic events are not just the pure concern of the population involved, but they mobilize and involve a growing sector of professionals and organizations worldwide, opening new business opportunities for emergency relief and natural disaster services. The United Nations High Commissioner for Refugees (UNHCR) and the Red Cross (IFRC) represent the largest customers of emergency relief solutions existing in the world. Both organizations have supply stockpiles in strategic positions around the globe with the capacity to provide immediate assistance in case of need. In the case of the UNHCR, it owns stockpiles in Copenhagen and Dubai and is now in a capacity to mobilize emergency response within 72 hours to respond to the immediate needs of 500,000 people in a humanitarian aid. Therefore a very large space is needed to store the products to deliver, implying the necessity of reducing the volume of the packages (UNHCR, 2009).

Post-disaster housing solutions

In case of a disaster a fast solution to resettle the victims is needed. The main options for settlements are dispersed settlements in host families in rural or urban contexts, and grouped settlements in collective centres or camps. Due to the large amount of people in need, it is often difficult to provide permanent housing solutions immediately at the first post-disaster stage (Corsellis & Vitale, 2005).

For families that have been displaced because of a natural disaster or man-made conflict, the process to construct a more durable home may not be possible due to their temporary status or it would require substantial time. Similarly a disaster may be of large magnitude resulting in a need of large-scale shelter provision. This cannot be met through the regular construction industry, which is typically geared to incremental construction over time. In such situations, there is a need for individual household solutions that have been pre-engineered to provide the sufficient relief. The solutions need to be adaptable in terms of both materials and technologies used, to enable the affected population to transition back into more durable homes (IFRC, 2011).

Humanitarian organizations have minimum requirements: the units must be intended for fast development and be durable, low cost, easy to assemble and transport. The comfort and the design of the shelter itself are the last requirements to fulfil, and for this reason many examples do not succeed in providing the essential qualities that are expected in a domestic environment.

Problem statement

"The right to adequate housing [...] is intended to ensure that everyone has a safe and secure place to live in peace and dignity."

(UN OHCHR & UN-Habitat, 2005)

Natural and man-made disasters cause much more than just physical damage and destruction of property to those who live in affected areas. The affected population is reminded of the fragility of human existence and will endure a tough emotional recovery, facing a loss of comfort, security and control over their surrounding environment. In this scenario it is even more important to acknowledge the necessity for the physical housing unit to provide qualities beyond the minimum of living requirements, creating a space that could be called home. A place appropriate to feel safe in, enabling an expression of identity, customs and traditions. Without a home with a predictable daily life people are left with no grounding and may just disintegrate into sickness, numbness, melancholia, or even suicide (Markovitz, 1995). Access to a safe and healthy shelter is essential to a person's physical, psychological, social and economic well-being and should be a fundamental part of national and international action (UN, 1992).

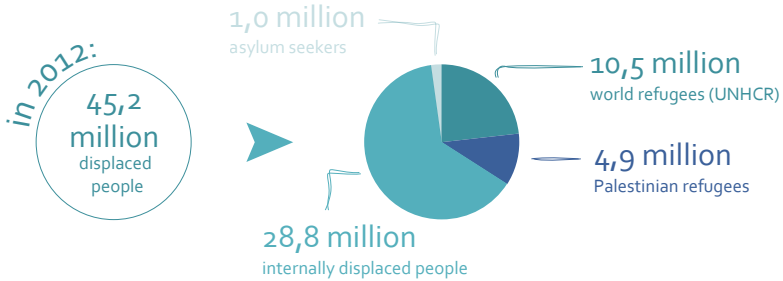
Passive recipients

In case of a disaster, the recipients of aid are often instinctively recognized as "victims". This definition portrays people as passive and incapable of bringing about change, emphasizing weakness and limitations derived from the dramatic event. A socially heterogeneous class of individuals, independently from gender, age, belonging to fractions, regions or states, which may be friendly or hostile. They all receive the same care and the same kind of support for their physical maintenance such as shelter, security, health and food. The lack of familiar signs in the new settlement creates a confusion of roles, provoking the questioning of one's already threatened and traumatized identity (Agier, 2002). Also the exclusion of refugees from the decision making process in creating emergency shelters leads to conflicts in camps, and often to the partial abandonment of the shelter facilities (Subasinghe, 2013).

Scarcity of aid

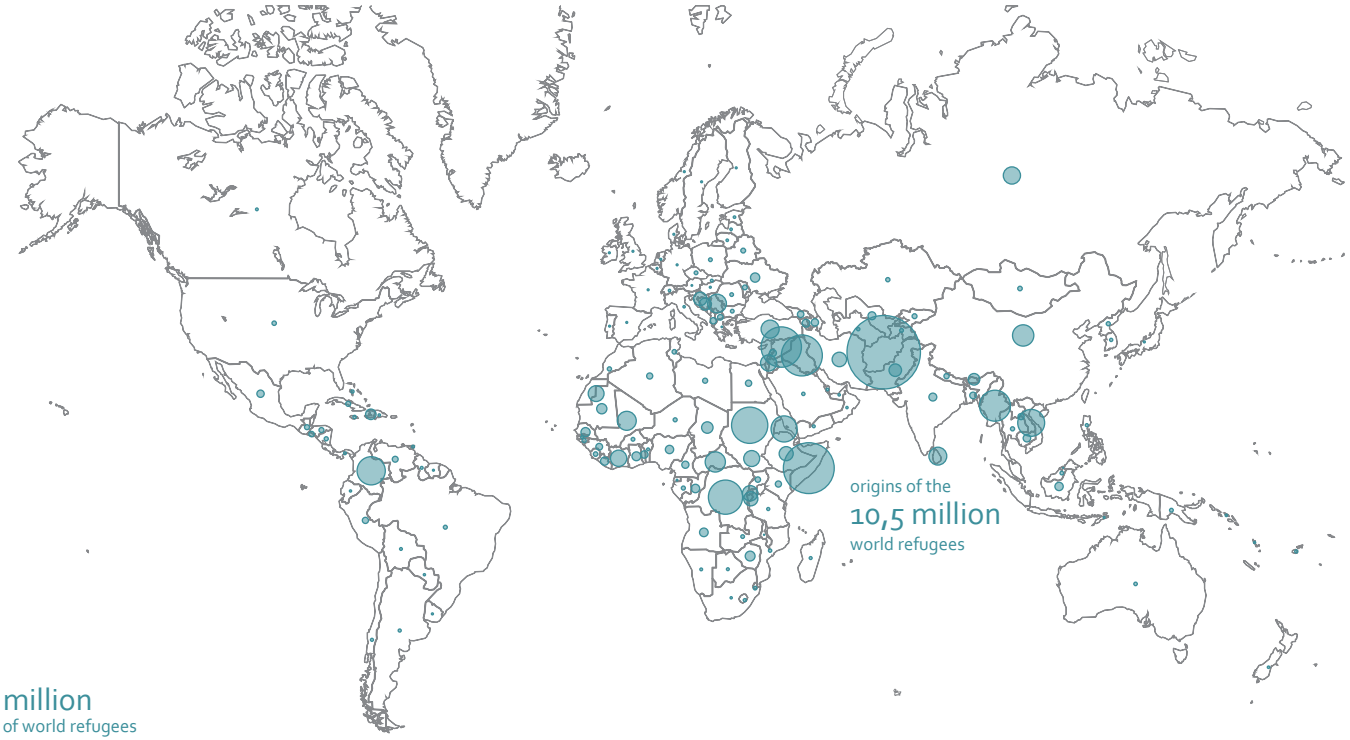
Emergency response solutions appear in many cases to be insufficient to meet user demands. Often tents break in strong winds and rainfalls, with water leaking inside because of missing drainage. The shelter inhabitants experience a feeling of no safety in a dense compound with unfamiliar neighbors. Considering the healing process of traumatized people, the appearance of shelters is often seen as sterile and is missing the feeling of home and personal ownership. Many shelters lack of proper ventilation or thermal control. In general a proper solution for hygiene, sanitation and food storage is missing, causing contamination and spread of diseases.

Solving these deficiencies is difficult because of financial resource limitations and urgency of response. Planning long-term for temporary settlements is a complex undertaking that addresses a diversity of cultural and social contexts, for example the uncertainty in duration of conflicts or possibilities in rebuilding communities affected by natural disasters.

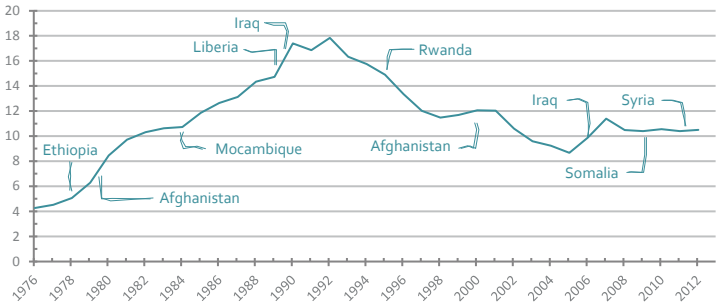


46% of refugees are children

80% is hosted in developing countries



million
of world refugees



top 5 refugee origins

Afghanistan	2,6 million
Somalia	1,1 "
Iraq	0,7 "
Syria	0,7 "
Sudan	0,6 "

top 5 host countries

Pakistan	1,6 million
Iran	0,9 "
Germany	0,6 "
Kenya	0,6 "
Syria	0,5 "

(UNHCR, 2012a)

Research questions

Based on the problem statement we see that general post-disaster housing solutions are designed to fulfil technical requirements instead of addressing the needs of the final users. Considering that the design of ordinary dwellings is user oriented, it should be possible to have the same perspective when developing emergency shelters. We state that there is a strong need of architectural studies to provide functional and pragmatic solutions. In relation to this, we have developed one main research question:

How to enable dignified living conditions for displaced people in post disaster housing in a way that is both economically feasible and environmentally sustainable?

We have subdivided this main question into three underlying questions:

Human needs

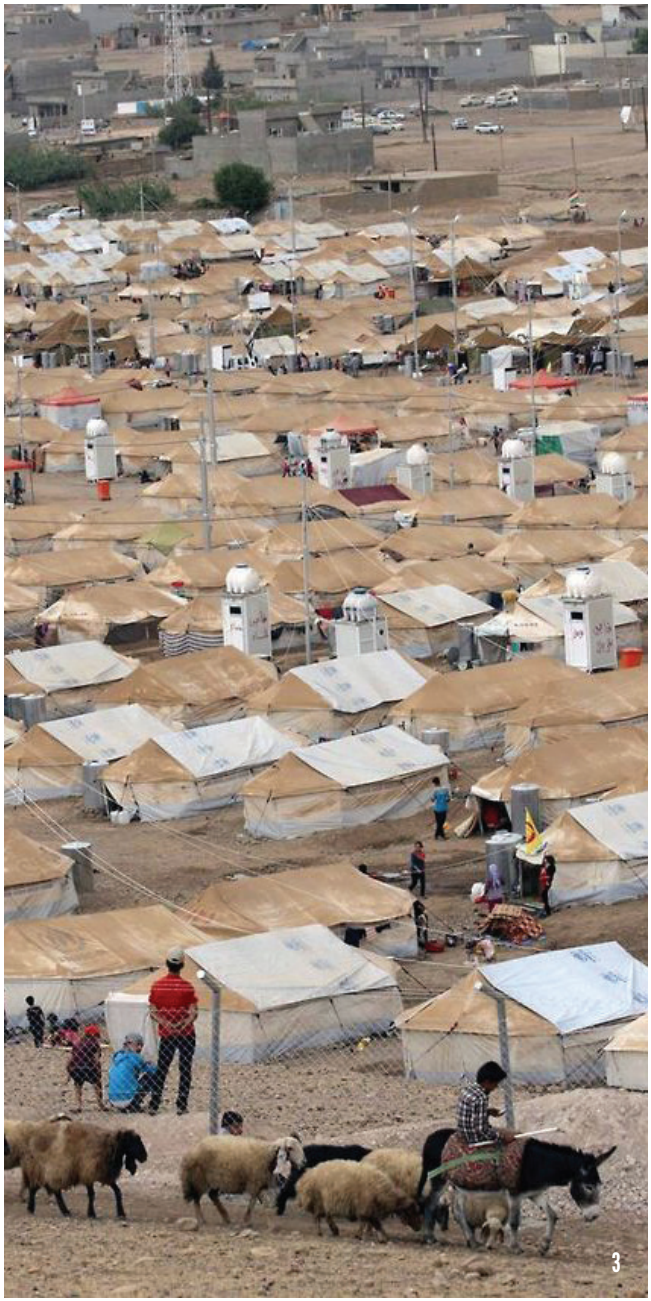
With regard to restrictions in cost, what human living needs should be prioritized to improve subjective well-being of displaced people?

Appropriateness

Is it possible to reach an optimized design that still addresses a diversity of cultural and social contexts?

Paperboard housing

Is it possible to achieve a stable and safe shelter with a paper material?



Kawergost refugee camp in Irbil, Iraq.

Delimitations

Implementing a post-disaster shelter project demands academic research with a realistic mindset. Disaster response is a complex issue that involves many different aspects, such as providing immediate assistance to the victims, assessing damage and planning temporary settlements. Because of the limitation in time, for our project we will concentrate on the housing unit and its residents. Logistics and settlement planning are still important factors to consider but will be described briefly in the following research chapter.

The collaboration with Imnus™ and Stora Enso set the prerequisites of the design to use Re-board as the main material. Other materials can be employed for supported structure and waterproofing, but the aim will be to explore design solutions in paperboard, and properties of alternative materials will not be investigated.

Emergency settlements are spread around the world where weather and climate are varying from tropical wet to cold semi-arid. The difference in temperature can vary from +40°C, causing overheating, to -20°C, demanding the integration of an additional heating system. The specific solutions required to adapt the shelter to these climatic variations are outside the scope of this thesis, but adaptability in ventilation for indoor air exchange will be regarded in the final design proposal.

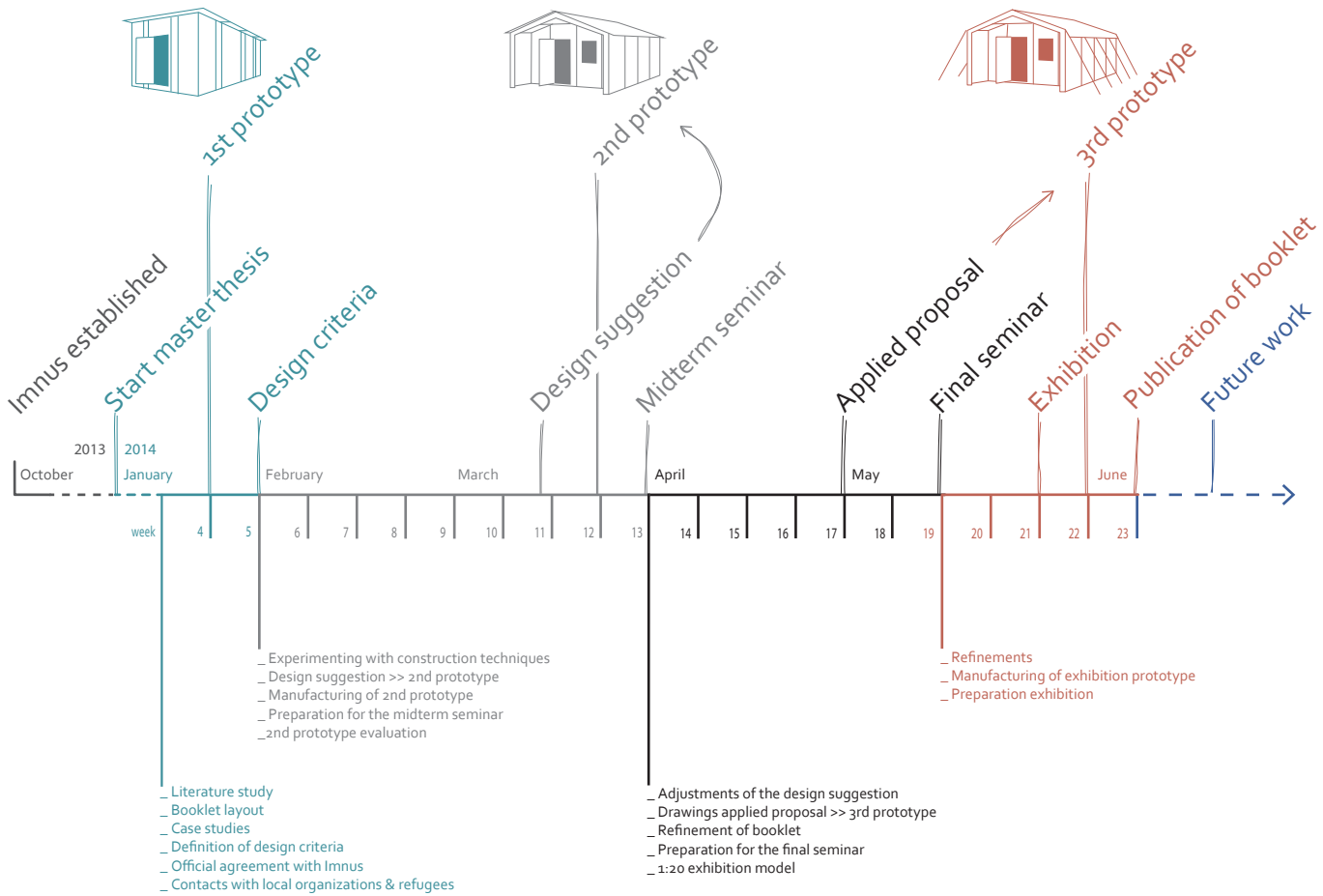
Methods

The thesis proceeded with continuous alternation between research and design. The initial stage of academic research provided a basic knowledge regarding the field of post-disaster response solutions. The design phase started by translating organizational, company and residential requirements into design criteria. The design was developed by the use of several tools, from hand-made sketching to parametric digitalization, but during the process the emphasis will be put on physical modelling. Interviewing a Palestinian family who lived for one year in a refugee camp enriched our knowledge about living conditions in emergency shelters and offered a useful input to the elaboration of the design proposal.

The close collaboration with Imnus™ provided the advantage of instant feedback regarding the feasibility of design solutions and allowed the realization of full scale prototypes. We considered production and business requirements as a fundamental part of real product development process instead of mere design limitations. Nonetheless, to allow architectural independence in exploring, limitations in cost were followed to a certain extent in the development of the final design proposal.

The prototyping process constituted the starting point for a full scale pilot project that will be hopefully implemented by Imnus™ in the future. This thesis was presented in June 2014 through this booklet, a digital presentation and parts of a full scale prototype in the exhibition at the Department of Architecture at Chalmers University of Technology.

Master thesis time line



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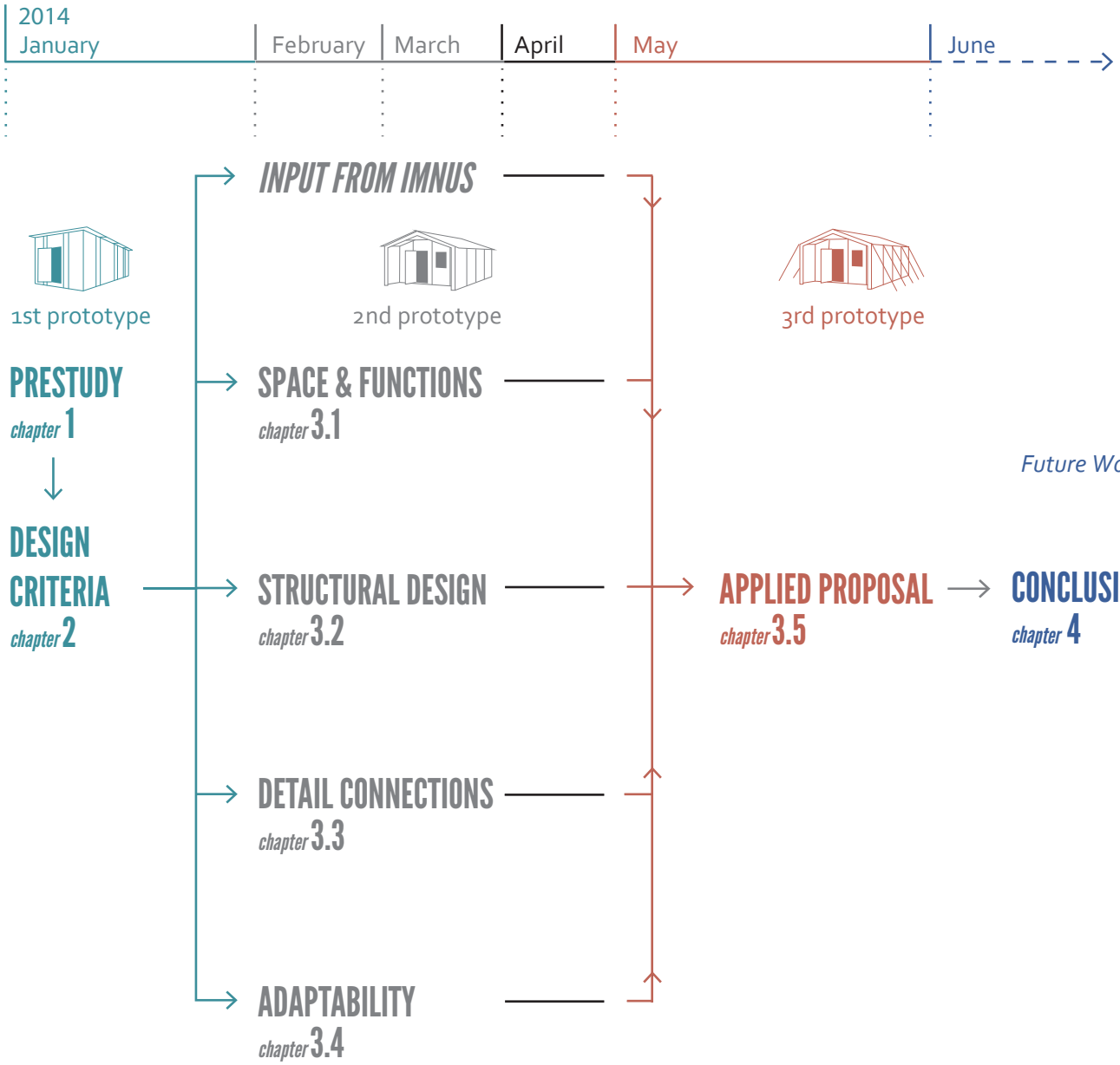


chapter 1.2
BACKGROUND

Definitions

Displaced persons

Persons who, for different reasons or circumstances, have been compelled to leave their homes. They may or may not reside in their country of origin, but are not legally regarded as refugees (Corsellis & Vitale 2005).

Refugee

A refugee is someone outside the country of his former habitual residence which, as a result of such events, is unable or unwilling to return to it. Reasons could be a well-founded fear of being persecuted for reasons of race, religion, nationality, group membership or political opinion. Owing to such fear a refugee can be unwilling to avail himself of the protection of the hosting country (UNHCR, 2011a).

Internally displaced persons (IDPs)

IDPs are groups of individuals who have been forced to leave their homes or places of habitual residence (in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights, or natural or man-made disasters) but who have not crossed an international border. Regardless of whether the reason for the evacuation is the same as for refugees, the IDPs remain under the protection of their government, even though it might be the very same government causing their situation. In contrast to refugees, IDPs are still citizens and retain their protection and rights under human rights and international humanitarian law. (UNHCR, 2012b).

Man-made conflict (complex emergency)

A humanitarian crisis which occurs in a country, region or society where there is a total or considerable breakdown of authority resulting from civil conflict or foreign aggression; which requires an international response which goes beyond the mandate or the capacity of any single agency (IASC, 1996).

Natural disaster (major emergency)

A natural caused situation threatening a large number of people or a large percentage of a population, and often requiring substantial multi-sectoral assistance (IGAD, 1999).

Temporary settlement

Settlement or camp resulting from a man-made conflict and natural disaster, from initial response to durable solutions (Corsellis & Vitale, 2005).

Post-disaster housing

Tent, shelter or house which provides a habitable covered living space and a secure living environment with privacy and dignity to those within it. Includes housing for the initial period after a man-made or natural disaster, an transitional stage and finally the achievement of a durable shelter solution (Corsellis & Vitale, 2005).

Involved organizations

United Nations (UN)

The United Nations is a large and widespread organization, founded after World War II to promote international cooperation. With a support of 192 countries the UN plays an essential role in humanitarian affairs through many of their subsidiary bodies, among them UN-Habitat, UNESCO and UNHCR (Kemenade, 2007).

United Nations High Commissioner for Refugees (UNHCR)

The Office of the United Nations High Commissioner for Refugees was established in 1950 by the United Nations General Assembly. The agency is mandated to lead and coordinate international action to protect refugees and resolve refugee problems worldwide. It strives to ensure that everyone can exercise the right to seek asylum and find safe refuge in another state, with the option to return home voluntarily, integrate locally or resettle in a third country (UNHCR, 2012b).

Int. Federation of Red Cross and Red Crescent Societies (IFRC)

The IFRC is the world's largest humanitarian network that reaches 150 million people in 188 countries through the work of over 13 million volunteers. By providing relief assistance in emergency situations of large magnitude such as natural disasters, IFRC is helping out with accommodation, food supply and healthcare in camps for IDPs.

International Organization for Migration (IOM)

The objective of IOM is to ensure the orderly migration of persons who are in need of international migration assistance. IOM works subject to the agreement of both (or all) the states concerned with the migration. IOM has worked closely with UNHCR, notably by assisting with voluntary repatriation.

Plan

Plan is an non-profit organisation which emphasizes community engagement and ownership as the means to address the needs of children around the world.
As one of the world's largest child-centred community development organisations, Plan works world-wide in 58,000 communities with 600,000 volunteers to improve the life quality for 56 million children.

Médicins Sans Frontières (Doctors without borders)

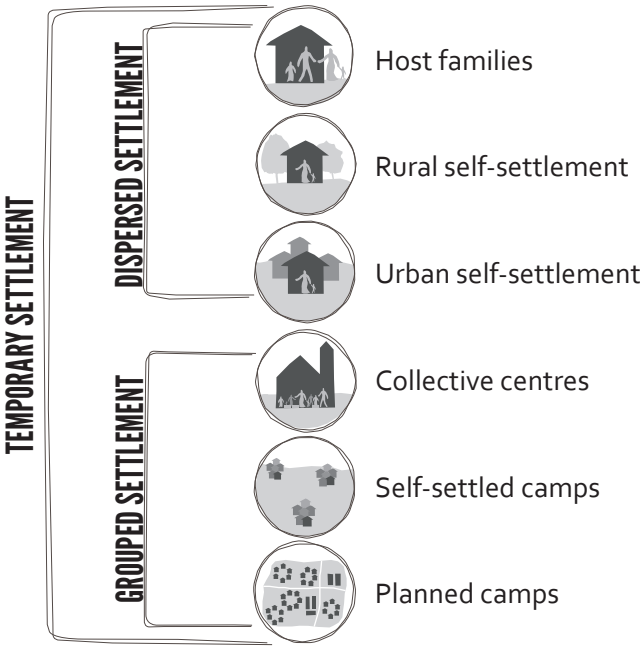
MSF is a French-founded now international and humanitarian-aid and non-governmental organization best known for its projects in war-torn regions and developing countries facing endemic diseases. Since 1971 MSF has set up hospitals and clinics in over 70 countries, but is also supporting camp accommodations.

Others

Other large organizations involved are Habitat for Humanity, Save the children, SOS Children's Village, Architects without borders, etc. Other large actors are governments hosting refugee camps.

Temporary settlements

There are several options of post-disaster housing response, most of them usually preferred to the application of camp structures. The alternatives open to displaced individuals for finding shelter following conflict and natural disaster have been categorized into six temporary settlement programme options, divided into dispersed and grouped settlements. The options can be viewed also as four self-settled solutions and two planned solutions (Corsellis & Vitale, 2005). For dispersed settlement the displaced population is sheltered within or nearby households of local families or their land. Usually the hosting people are extended family members or of the same ethnic background (Axelsson, 2012). Grouped settlements options require instead the aid community to provide centralized resources. Below you find a short definition on the different categories and on the following page advantages and disadvantages of grouped and dispersed settlements are listed.



HOST FAMILIES Placement of displaced people in existing homes, with relatives, friends, etc.

RURAL SELF-SETTLEMENT Displaced people settle in rural contexts owned collectively, rather than privately.

URBAN SELF-SETTLEMENT Settlement in an urban environment informally or occupying unclaimed property.

COLLECTIVE CENTRES Fitting people in pre-existing facilities as town halls, gyms, warehouses, etc.

SELF-SETTLED CAMPS Settlement in a camp with no assistance from government or aid organisation.

PLANNED CAMPS Purpose-built site with services provided by aid organizations and governments.

(Corsellis & Vitale, 2005)

Dispersed settlement

+ PROS

- Encouraging independence and self help
- Cooperation among families
- Better use of existing local contacts
- Infrastructure development for host country
- Smaller investments than for planned camps
- Less intensive demand of resources
- Fast solution to implement

– CONS

- Necessity of an non-occupied environment
- Time-consuming provision of infrastructure
- Risk of unwillingness by host to accept guests
- Competition with insufficient local resources
- Impact on the local environment
- Difficult to trace the affected population
- Harder to identify needs of affected people

Grouped settlement

+ PROS

- Provision of services and help from aid community
- Easier to achieve permanent housing solutions
- Contain the environment impact of the settlement
- Easier to identify needs of affected population
- Water and sanitation services are quickly available

– CONS

- Victims rely on external assistance
- Massive concentration of resource use
- Higher initial investment for emergency response
- Privacy, security and control are hard to reach
- Risk of contamination and spreading of diseases
- Risk of becoming potential military target
- Risk of resource conflict with host population
- Facilities are rarely enough to meet needs

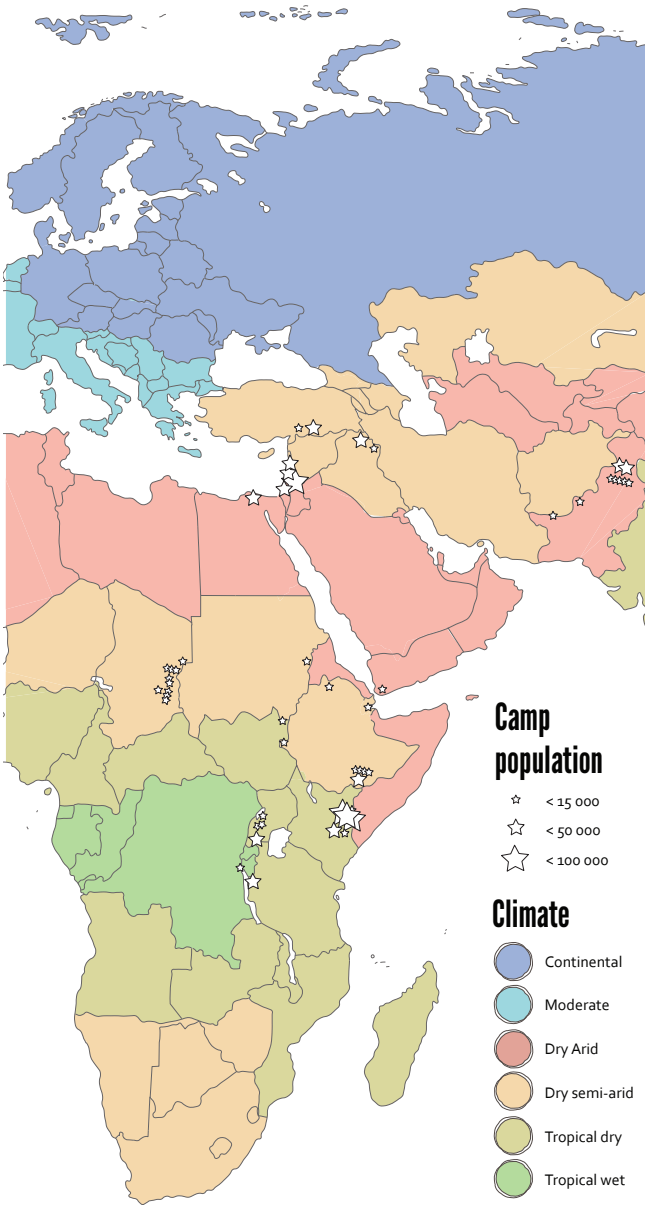
(Corsellis & Vitale, 2005)

Refugee Camps

In a post-disaster scenario communal infrastructures and services need to be re-established. Temporary settlements are complex logistical puzzles and aid organisations on site are engaged not only in solving accommodation but also basic needs such as food, water and sanitation. The host governments of such refugee camps require registration of all new arrivals to assure a secure control. The trend of isolating camp residents is called *warehousing of refugees* and is keeping order and security in camp but is at the same time inhibiting economic growth and is violating on human rights (Kemenade, 2007).

The sizes of camps vary depending on the nature of the crisis. For huge disasters or conflicts where hundreds of thousands of displaced people need shelter the aid organisations usually try to set up small camps of maximum 20,000 people rather than one big camp. Smaller camps are easier to manage and control, which is crucial regarding fire risk, security problems and the spreading of diseases. Camps are preferably located on open fields sloping for natural drainage. (CBC News, 2007).

One big problem is that camps sometimes outgrow themselves. The worst example is the three camps in Dadaab in Kenya. Originally designed in the 1990's for 90,000 refugees seeking protection from the Somalian Civil War, the last years has become overcrowded because of the East Africa drought (Edwards, 2011). Today the camps contain more than 340,000 registered people. UNHCR data on the Dadaab camps and some other refugee camps are illustrated more in detailed on the following pages (UNHCR, 2014).

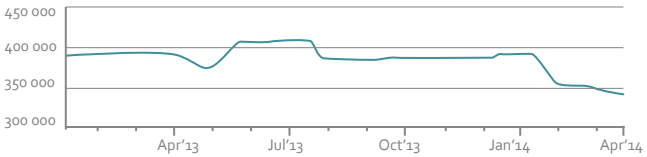


World map showing climate zones and the 50 largest refugee camps, excl. four camps in Mauritania, India, Nepal & Thailand (UNHCR, 2014).

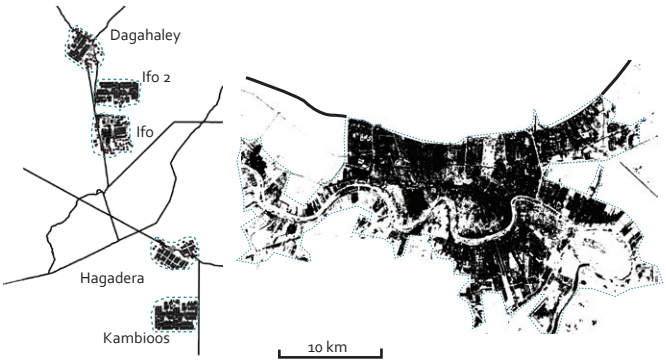
#1 Dadaab

Location:	Kenya
Settled:	1991
Country of refugee origin:	Somalia
Total refugee population:	343 694
Residents per household:	4,1

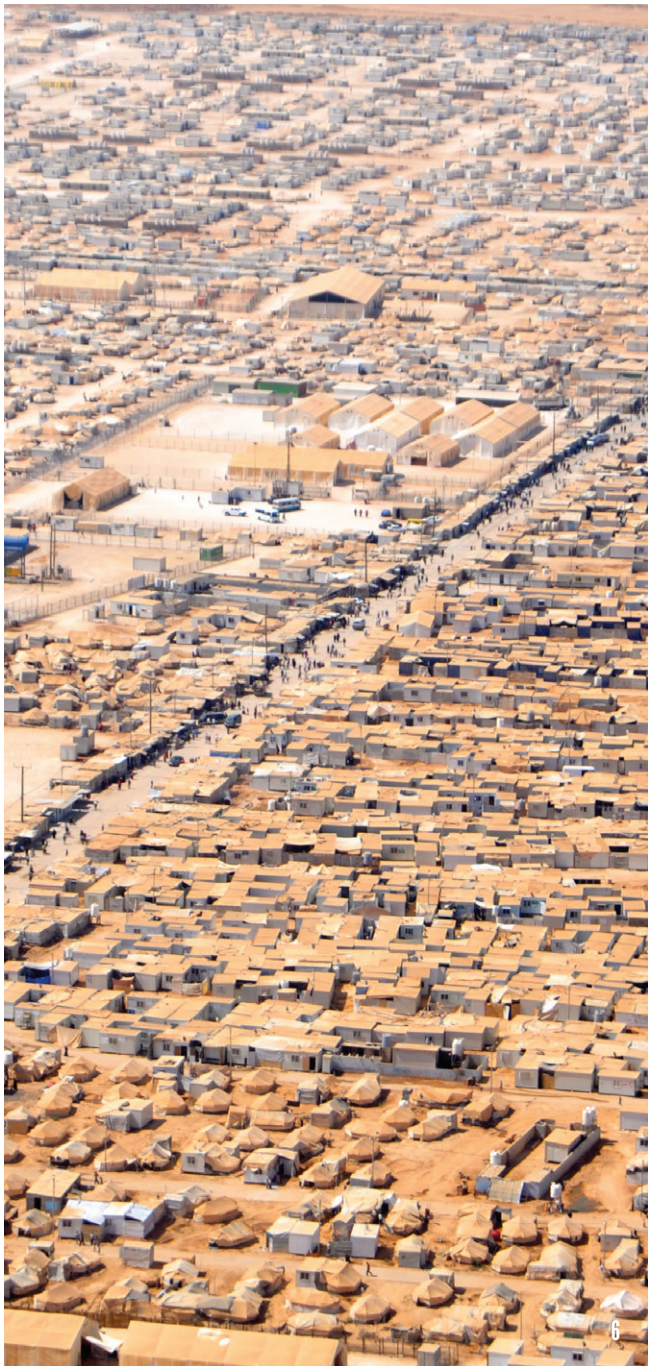
Climate:	Tropical dry
Temperature day:	28 - 36 °C
Temperature night:	23 - 26 °C
Precipitation:	<200 mm / year
Relative humidity:	70 - 85 %
Wind speed:	2 - 5 m/s



The population of the five refugee camps in Dadaab.



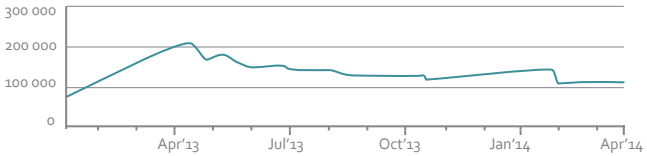
Dadaab camps is as populated as New Orleans, USA.



#4 Zaatari

Location:	Jordan
Settled:	2012
Country of refugee origin:	Syria
Total Refugee Population:	106 442
Residents per household:	4,7

Climate:	Arid
Temperature day:	12 - 32 °C
Temperature night:	4 - 21 °C
Precipitation:	<200 mm / year
Relative humidity:	30 - 70 %
Wind speed:	2 - 4 m/s



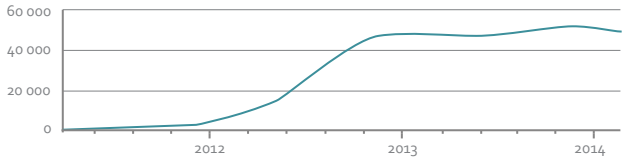
Population in Zataari camp last 2 years.

Zaatari camp, similar population size as Örebro, Sweden.

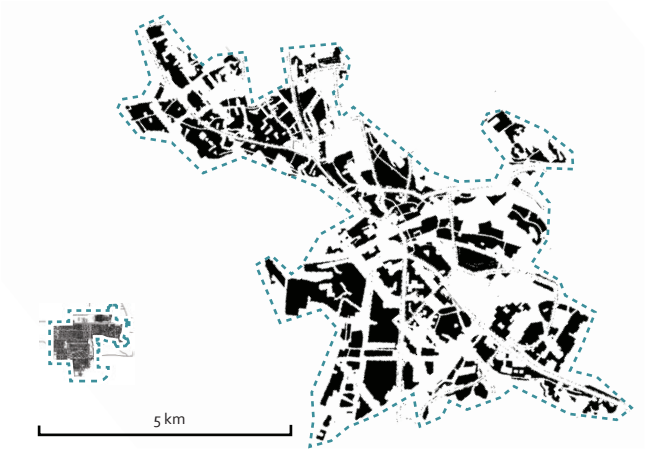
#12 Domiz

Location:	Iraq
Settled:	2012
Country of refugee origin:	Syria
Total refugee population:	55 830
Residents per household:	5,4

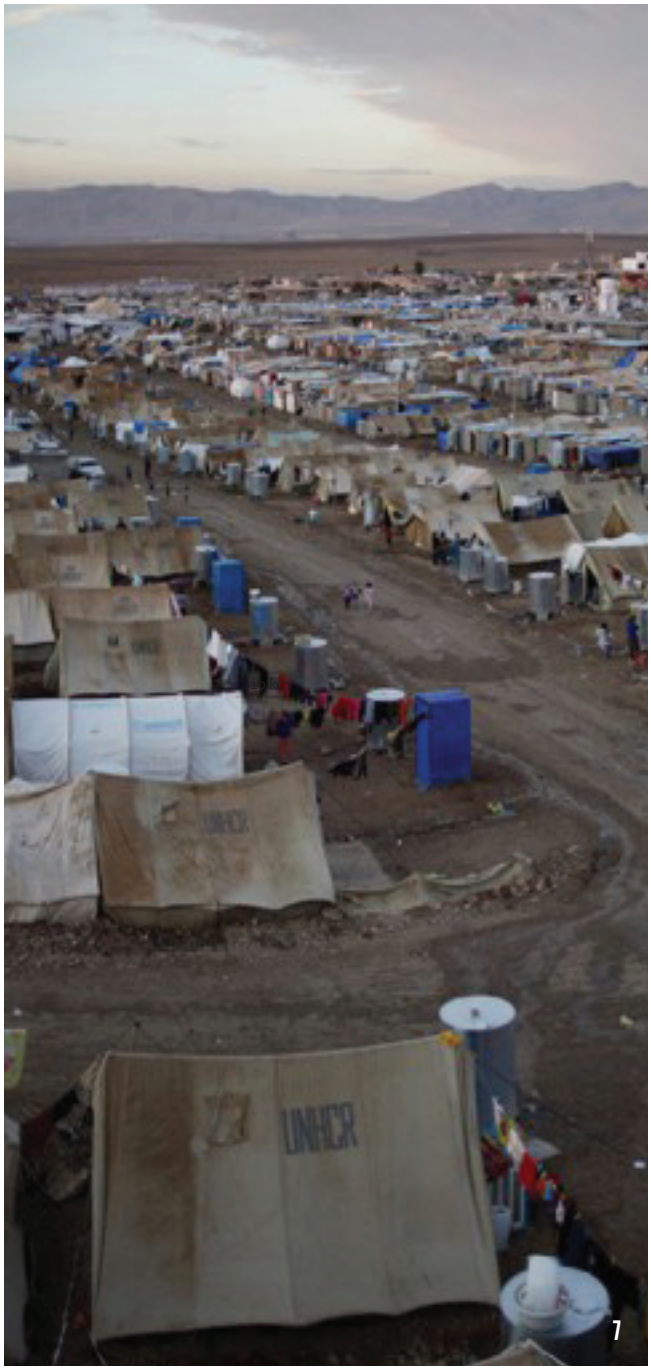
Climate:	Semi-Arid
Temperature day:	10 - 42 °C
Temperature night:	-2 - 24 °C
Precipitation:	600 mm / year
Relative humidity:	20 - 70 %
Wind speed:	2-5 m/s



The population of the Domiz camp outside Dohuk, Iraq.



Domiz has similar population size as Halmstad, Sweden.



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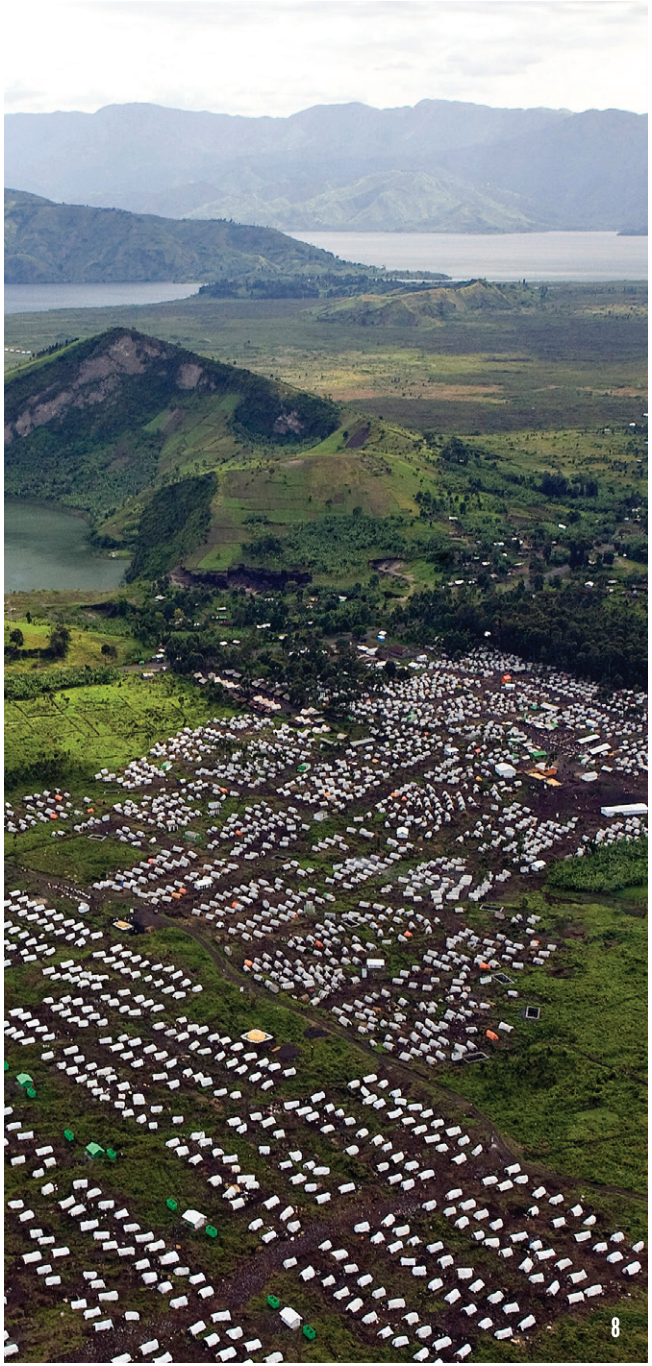
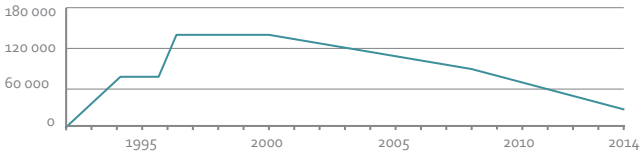
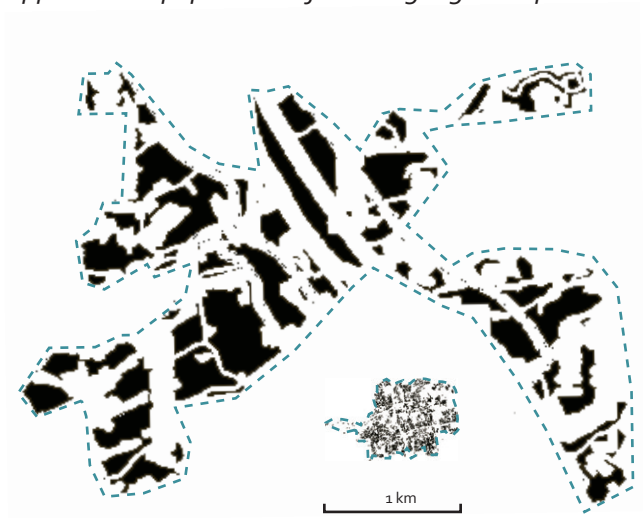


45 Mugunga

Location:	DR Congo
Settled:	1003
Country of refugee origin:	Dr Congo
Total IDP population:	17 000
Residents per household:	3,6
Climate:	Tropical Wet
Temperature day:	26 - 33 °C
Temperature night:	15 - 18 °C
Precipitation:	1 200 mm / year
Relative humidity:	60 - 90%
Wind speed:	1 - 3 m/s



Approximate population of the Mugunga camps.



Mugunga, much denser than similar populated Lerum.

Camp regulations

According to *minimum standards of shelters, settlements and non-food items* in the *Sphere handbook* (see chapter 2.3 for reference), an usable land area of 30 m² for each person should be devoted for households with necessary space for roads, footpaths and fire breaks. In total 45 m² per person is needed when including communal services as sanitation, educational facilities, administration, water and food storage, markets and healthcare.

Food warehouse and distribution areas are set up where camp inhabitants can line-up for rations once a week or month. In many camps there exist communal household areas for safe way cooking or distributing prepared meals. Other settlements have kitchen gardens, where the residents are given a small plot to grow their own food (The Sphere Project, 2005).

Administration and surveillance are usually set up to keep security, both in planned and self-settled camps. In refugee camps the host government usually use guards and sometimes the camps are fenced. New arrivals to a camp are usually registered and given residential documents, first shelter package or other relief items, and entitlements to get food rations.

Sanitation is important to solve to avoid spreading of diseases. Latrines should be located within a distance of 50 metres from sleeping accommodations. One latrine per family is optimal, since inhabitants in some cases tend not to use shared latrines. A water distribution point should be located within 100 metres, where at least 4 litres per person a day for drinking and 20 litres for hygiene is needed (CBC News, 2007).

A camp of 20,000 people should contain:


registration/entrance gate(s)


1000x latrines


80x water stations


5x small health centres


2x schools


1x food warehouse


1x market


1x feeding centre

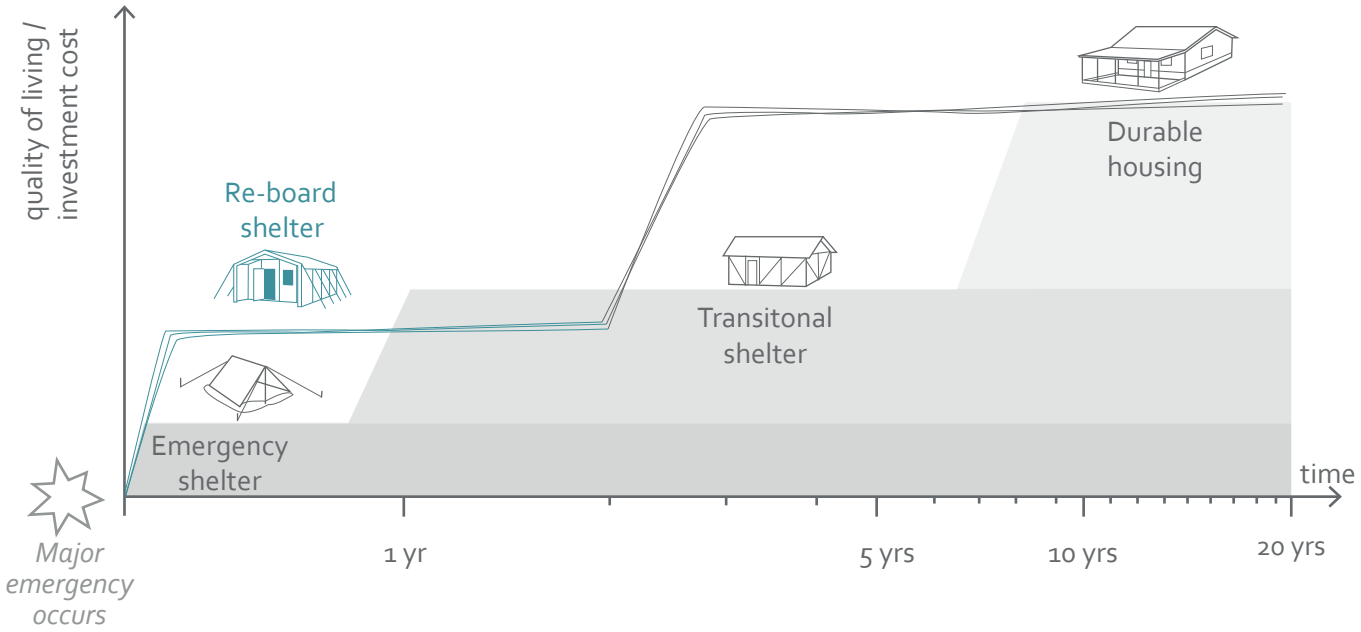

0,1x hospital

(CBC News, 2007)

Post-disaster housing

In temporary settlements the shelter is likely to be one of the most important determinants of general living conditions and is often one of the largest items of non-recurring expenditure. Shelter units must provide protection from weather, sleeping accommodation, space to live and store belongings, privacy and security. While the basic need for shelter is similar in most emergencies, considerations as the kind of housing needed, what materials and design are used, who constructs the housing and how long it must last will differ significantly in each situation (UNHCR, 2007).

A common way to look at the emergency response is the multi-phase approach, dividing the development into the three phases: emergency (initial), transitional and durable (reconstruction). There is current discussion on the large investment of money that is necessary to invest in the chain of upgrading of post-disaster housing solutions provided by humanitarian aid organizations. This cost sometimes is higher than the immediate construction of a permanent house. In some cases however, erecting emergency shelters is a required step to support the urgent necessity of dwellings following a disaster. This issue is acknowledged by setting the aim to develop a shelter design with the qualities of a transitional shelters but applied in the first phase of the emergency. The product would therefore result competitive for the reduced cost and the increased well-being, while facilitating the process of shifting back to a permanent housing solution.



Emergency shelters

Tarpaulins

Tarpaulins are one common solution in the initial emergency stage of the post-disaster response, due to the reduced weight and volume that allow to deliver them quickly. The term refers to a large sheet of strong and water-resistant material, made of woven high density polyethylene fibre. It is important that wooden support frames and stick skeletons for this type of shelter are provided immediately, in order to control the impact on the environment that would be generated from the cutting of trees (UNHCR, 2007). The durability of tarpaulins is usually low since the material get damaged by sun, wind and rain. Sometimes tarpaulins last as short as three months (Axelsson, 2012).

Tents

Tents are portable shelters, with a cover and a structure. It is possible to categorize the different tent designs into three main typologies: single-fly (one layer of fabric), double-fly (one layer of fabric and a fly-sheet) and winterized (one layer of fabric, an inside layer, a fly-sheet and a hole for the stove pipe). Tents have a longer lifespan than tarpaulins, but it is still short, varying between 6 months and 1 year. Due to the precarious nature of the materials, tents do not create any long-term value. Since tents have to be available for the delivery, they are stored and distributed in large quantities, therefore preventing the design to be adapted to different contexts and cultures (Axelsson, 2012).


9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LOCATION	Mogadishu, Somalia
ORGANISATION	Self-built
TYPE	Emergency shelter
MATERIAL	Branches, twigs, cloth, tarpaulin
SIZE	6-8 people, ~10 m²
WEIGHT	(-)
PRICE	USD $ 5-10 for tarpaulin
DURABILITY	< 6 months

LOCATION	Zataari, Jordan
ORGANISATION	UNHCR
TYPE	Ridge tent
MATERIAL	Cotton canvas, metal frame
SIZE	5 people, 16 m² + 6 m² vestibule
WEIGHT	100 kg
PRICE	USD $ 300-500
DURABILITY	6-12 months

Transitional shelters

Transitional shelters are intended to provide shelter between an initial stage and the time when durable housing is completed. They are implemented when local hazards and land tenancy issues have been solved, but also if the start of reconstruction is for some reasons delayed. The transitional phase can also work as an upgrade of emergency shelters, but there is a risk of this strategy since future intended extensions rarely are carried out (Axelsson, 2012).

Transitional shelters generally respect five characteristics: they can be upgraded into part of a permanent house, reused, relocated from a temporary site to a permanent location, resold and recycled for reconstruction. It is preferable that any transitional shelter solutions reflect local construction technologies, house designs and cultural preferences. However, the time required to develop solutions for the specific context can significantly delay the provision of more durable shelter assistance beyond emergency shelter. The shelter should be made from materials that can be upgraded or re-used in more permanent structures, or that can be relocated from temporary sites to permanent locations (IFRC, 2011). Problems connected to the persistence of transitional shelters settlements are the arising of slums, the occupation of an area that could be needed for a proper reconstruction and the waste of financial resources that could be employed for permanent solutions. In general the use of transitional shelters implies a three steps strategy: the implementation of an immediate shelter, the transitional shelter and finally the permanent dwelling.


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15


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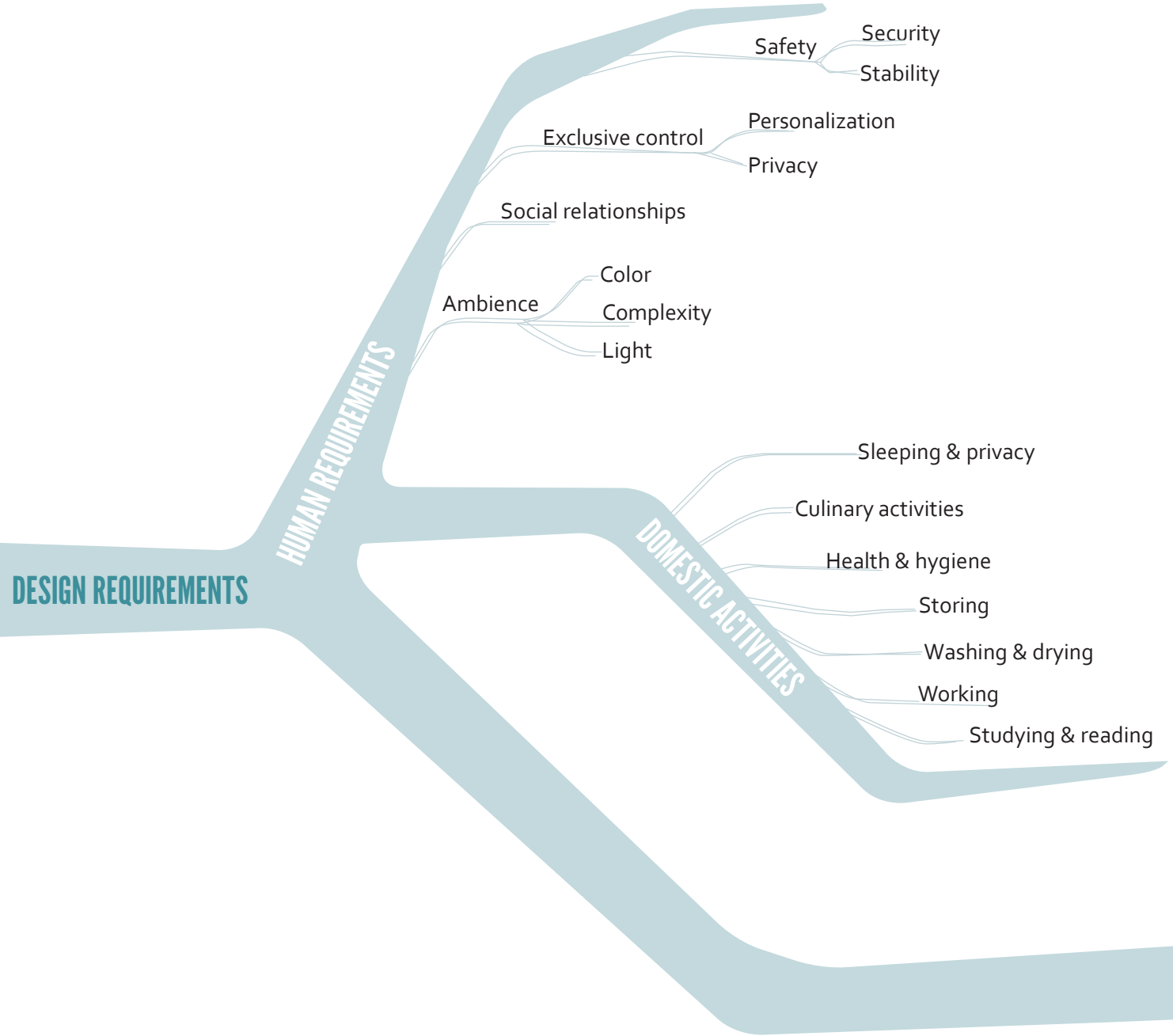
LOCATION	Port-au-Prince, Haiti
ORGANISATION	SOS Children's Village
TYPE	Foldable transitional shelter
MATERIAL	PP plastic, wooden beams
SIZE	6 people, 21 m²
WEIGHT	300 kg
PRICE	USD $ 1000-2000
DURABILITY	12-18 months

LOCATION	Aceh, Indonesia
ORGANISATION	IFRC
TYPE	Transitional shelter
MATERIAL	Steel frame & roofing, wood facade
SIZE	4-5 people, 25 m²
WEIGHT	~2000 kg
PRICE	USD $ 5,700
DURABILITY	>5 years

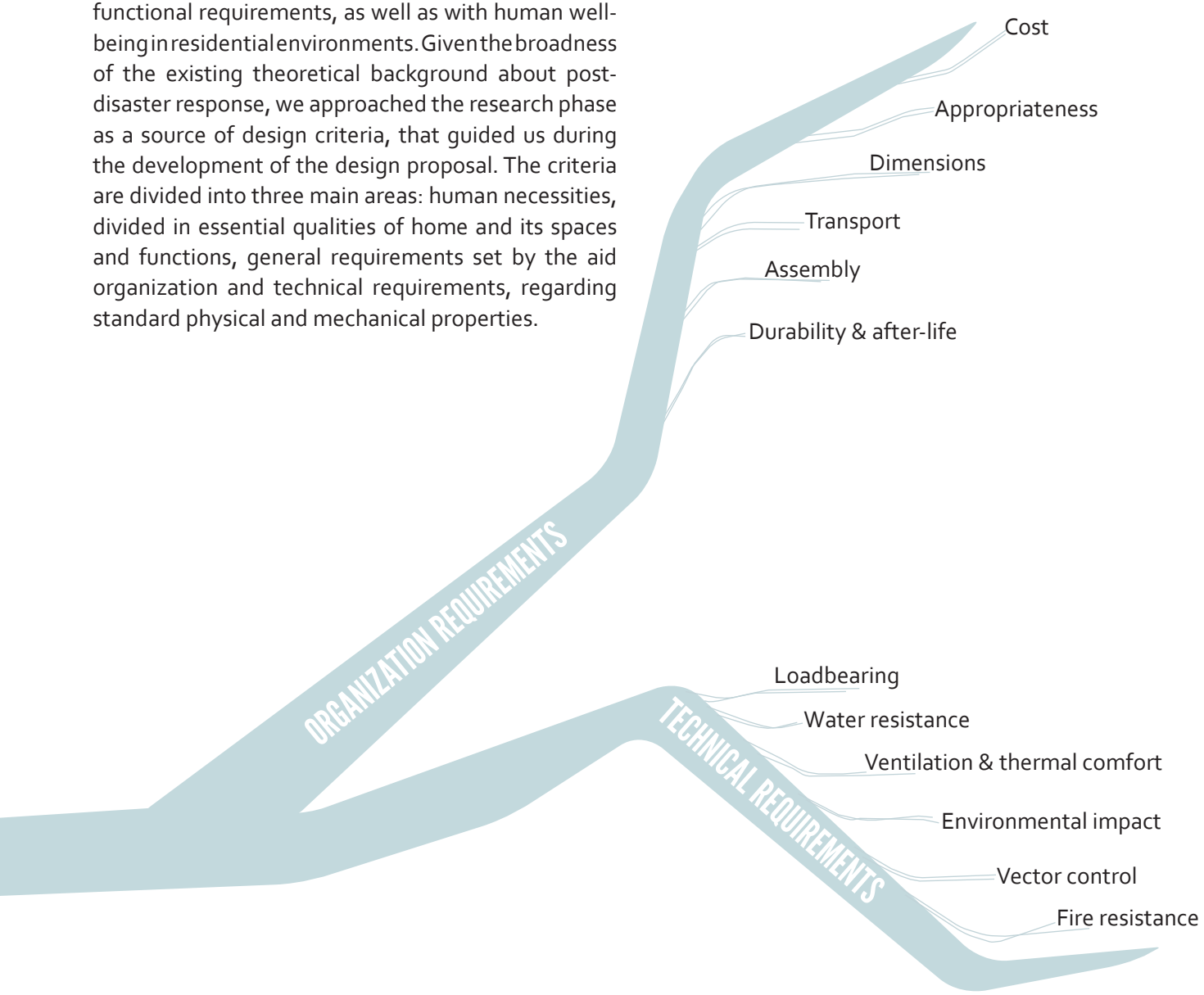
chapter 2

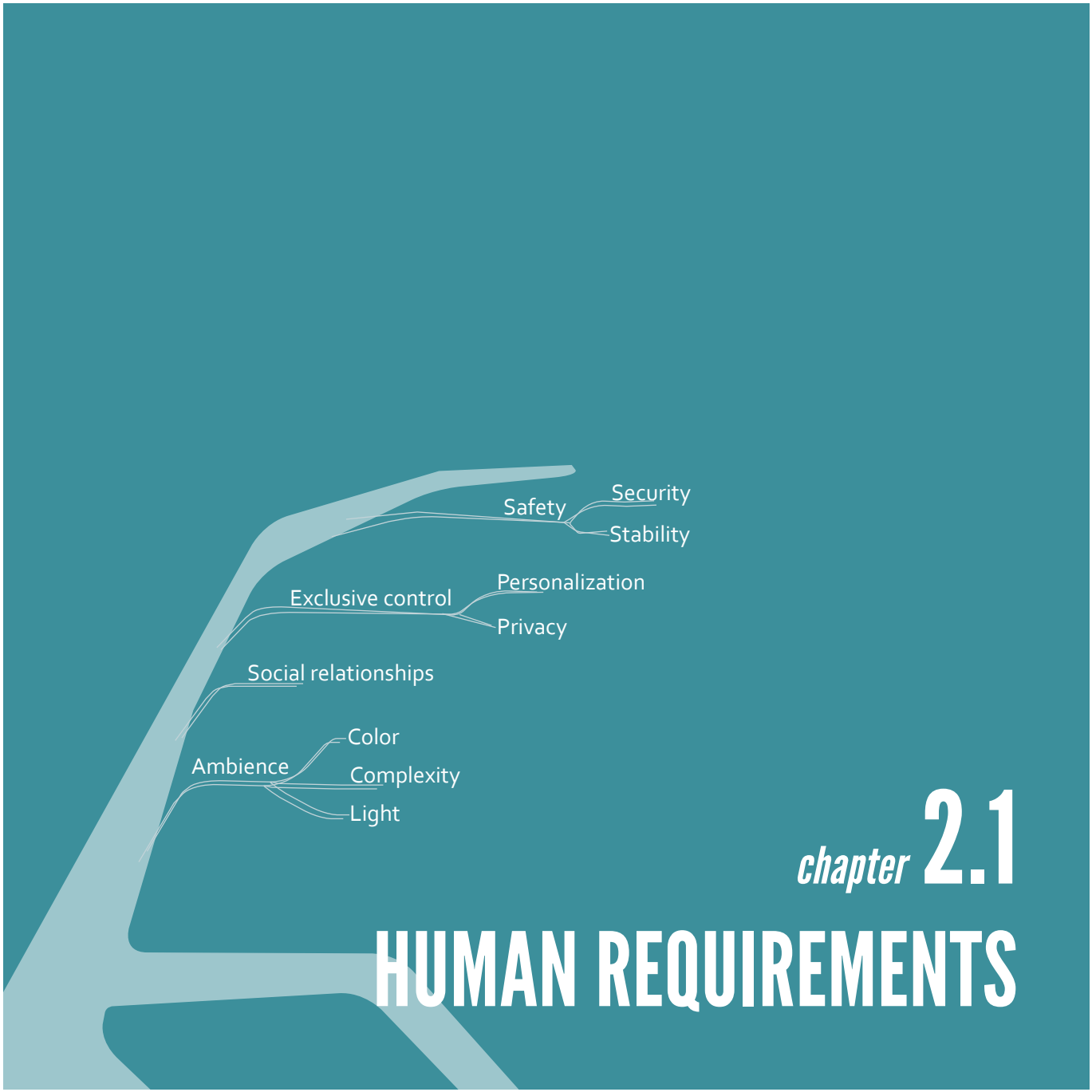
FROM THEORY TO CRITERIA


DESIGN REQUIREMENTS
HUMAN REQUIREMENTS
Safety
Security
Stability
Exclusive control
Personalization
Privacy
Social relationships
Ambience
Color
Complexity
Light
DOMESTIC ACTIVITIES
Sleeping & privacy
Culinary activities
Health & hygiene
Storing
Washing & drying
Working
Studying & reading

Design requirement overview

Developing a design proposal for emergency shelters demands to be acquainted with a broad range of functional requirements, as well as with human well-being in residential environments. Given the broadness of the existing theoretical background about post-disaster response, we approached the research phase as a source of design criteria, that guided us during the development of the design proposal. The criteria are divided into three main areas: human necessities, divided in essential qualities of home and its spaces and functions, general requirements set by the aid organization and technical requirements, regarding standard physical and mechanical properties.





chapter 2.1

HUMAN REQUIREMENTS

Essential domestic qualities

"Dwelling is not an activity that we perform alongside many other activities so that we work here and we dwell there. Instead, it is a way of existing in the world." (Manzo, 2003).

A proper design for post-disaster housing solutions cannot be based just on the practical fulfillment of the standard requirements set by aid organizations and governments, but it needs to be also supported by a reflection on the living conditions in domestic environments. The following research explores the essential qualities of domestic environments, aiming to reach a generalized result that could go beyond cultural and geographical differences.

The perception of home

The concept of home has been researched extensively within psychological and sociological literature. According to recent studies, it is not possible to elaborate an empirical definition of home disregarding its context and the dynamism of people's relationship to places (Manzo, 2003). For our research we focused on those qualities that positively affect place attachment, leaving aside the complex discussion on individual-place relationships in their larger socio-political perspective.

The reviews that examine home and its qualities tend to be based on a series of both objective and subjective assessments on the housing and neighbourhood quality. One explanation for this tension is the difference between concepts of home and house, the later more rooted in the concrete world (Moore, 2000).

Syrian family in a refugee camp in Bulgaria.

The notion of home implies the creation of a strong emotional relationship between the inhabitants and the physical space of the housing unit (Saegert, 1985), and it is intimately linked to concepts of identity and memory as much as territory and place (Black, 2002). Tognoli (1987) proposes that the most salient attributes of home are centrality, continuity, privacy, self-expression and personal identity, and social relationships.

In the experience of many displaced people and refugees, the impossibility of return and the longing for a far-off country produce a strong sense of belonging to a home rooted in a lost past (Black, 2002). Refugees yearn for their home territory, that grounds their identification, that activates their culture and gives substantive meaning to their lives. Without a home, people are left with no grounding and may just disintegrate into sickness, numbness, melancholia or even suicide (Markovitz, 1995).

The previous considerations emphasize the importance of considering emergency shelters not as mere structures that provide protection after a disaster, but as a new homes that could inspire a sense of belonging and security. As discussed, the perception of residential environments is subjected to constant reinterpretation, and cannot be considered regardless the level of fulfillment of the individual needs of the inhabitants. The following study introduces a brief reflection about human needs as source of motivation in life.

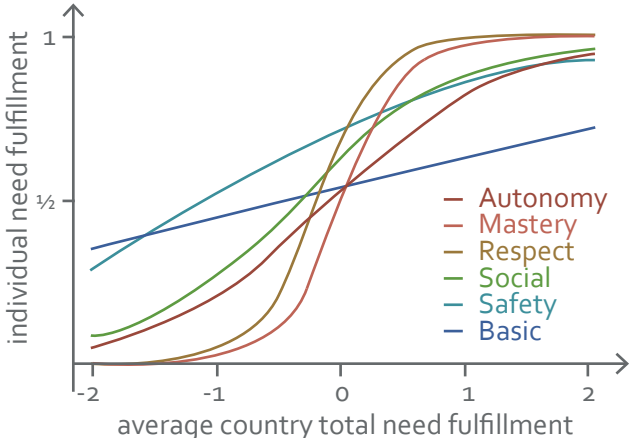
The hierarchy of human needs

The branch of psychology studying human needs goes back to Abraham Maslow, who in 1940 described a hierarchy of needs, often illustrated as a pyramid. The fundamental physiological levels of needs stand at the bottom of the pyramid, while the need for self-actualization at the top.

Maslow's hierarchy of human needs

Maslow claimed that when one level of needs begins to be fulfilled, it opens up for needs of the next level, but with a decreasing percentage of satisfaction as we go up the hierarchy of prepotency (Maslow, 1943).

Recently there have been studies on the association between human needs and happiness, or subjective well-being. One survey across a sample of 123 countries, made by researchers at University of Illinois, showed in fact that the need of fulfillment was consistently associated with subjective well-being across world regions. The evaluation of life of the interviewed was mostly associated with fulfilling basic physiological needs, positive feelings were mostly correlated with self-esteem while negative feelings were mostly associated with lack of basic, respect and autonomy needs.



Survey of country vs. individual need hierarchy.

The survey showed that Maslow's suggested hierarchy is partly correct. Needs tend to be achieved in a certain order even if it does not strongly influence their effects on peoples happiness. Citizens who live in wealthy countries have in general a high rate of fulfillment of basic and safety needs compared to

citizens in poorer countries. The study demonstrated also that the improvement of the individual life standard does not always ensure happiness, to obtain which an improvement in the societal level is also required (Tay & Diener, 2011).

From this research we can learn that "lower" needs (physiological, safety and security) are essential to fulfil in temporary settlements considering the precarious life standard in these contexts, but the "higher" needs (self-actualization, self-esteem, love & belonging) are as important for the residents to feel subjectively happy.

Newly arrived family in Zaatari refugee camp, Jordan.

The psychological recovery for victims of disaster

A careful shelter design addressed to the creation of a welcoming and familiar environment could facilitate the recovery process of the users through its inhabitation. In order to understand the psychological needs of victims of disaster, a range of articles related to cognitive and behavioral sciences have been reviewed. The outcome indicates a prevalence of posttraumatic stress disorder affecting refugees, together with depression, anxiety and psychological distress (Sundquist, 2004). Refugees with posttraumatic stress disorder often present with complicated symptoms, prolonged exposure to traumatic events, acculturation and social problems (Palic, 2011). Many refugees and asylum seekers in fact have experienced severe trauma, including protracted mental and physical torture, mass violence, witnessing the killings of family members and friends, sexual abuse, kidnapping, destruction of personal property, starvation and lack of water and shelter (Warfa, 2006). These traumatic events are established risk factors for long-term mental health problems, the risk being greater the worse the degree of the traumatic exposure (Craig, 2006). The uncontrollable loss of a home triggers a grief reaction, with victims experiencing feelings of loss, longing, depression, helplessness, and anger (Fried, 1963).

Even though a consensus about psychosocial treatments for refugees does not exist, this issue could be partially overcome by considering the residential environment as a place of regeneration, that could provide the conditions for renewing the diminished physical and psychological resources. It is proved that when individuals are in control of the space they live in, and have privacy needs met, feelings of comfort and freedom are possible. This freedom permits relaxation and the individual development of the self (Smith, 1994).

It follows a list of design criteria based on the essential domestic qualities emerged from the research.

Design criteria

Security

The feeling of safety and security is one of the fundamental aspects of the home environment.

The shelter should ensure protection for the inhabitants and their belongings. Door and windows should be lockable in order to protect from burglaries and aggressions.

Permanence

Permanence refers to the experience of continuity and stability that characterize the home environment. It recalls the sense of belonging and the connection with the place (Hayward, 1977).

Beyond the supply of residential needs, the shelter should provide long time benefits. For example it could be disassembled and the material could be recycled as furniture or insulation for a permanent housing solution.

Personalization

The home is a primary territory and so the owners expect relatively permanent, exclusive control and use of these environments (Altman, 1975). The freedom of the home permits an extensive and significant range of self-expression (Sebba & Churchman, 1986; Pennartz, 1986). Personal objects communicate information about their owner, and such a display communicates individual self identity and esteem (Lawrence, 1987a).

The inhabitants should see the shelter as their home, that they can manage however it suits best to their needs. This process starts with the possibility of self-assembly of the unit, thus creating a strong bond with the house from the beginning. The design of the shelter should allow customization and personalization of the spaces, by having interior movable partitions and furniture and adjustable openings.

Privacy

Privacy is a relevant aspect when considering refugee camps, that are generally dense and crowded environments. Control of space can be construed as control of social interactions within that space, and this implies a state of privacy, or control of access to the self (Altman, 1975).

Shelter walls should prevent people outside from being able to observe whether or not the shelter is occupied. It must be possible to cover door and windows, light the shelter at night without creating silhouettes and have sound insulation. The interior partitions will create a separation between the rooms.

Non privacy as a consequence of lack of permanence. Drage IDP camp in Darfur, Sudan.

Social relationships

Although home is characterized by the close relationships with family and other loved ones, the home also provides a significant social function (Smith, 1994). The quality of habitation depends essentially on the quality of the interpersonal relations, more specifically on the degree to which people try to approach each other (Pennartz, 1986).

The shelter should allow social interactions and feelings of ease and relaxation, preferably through a common room where the family can sit together. It will be important to divide the house in a private core and a more public area, where guests could be received. For this purpose a covered outdoor space could be also used for social activities, cooking etc.

Color

The perception and the meaning of colors is affected by physiological, environmental and cultural factors. Colors influence behaviors, creating negative or positive perception of surrounding environments (Nurlewati, 2012). Warm colors focus people outwards, while cool colors are calming (Hidayetoglu *et al.*, 2012). The shades of green and brown should be avoided in emergency settlements not to confuse them with military camps (UNHCR, 2011b).

The shelter can be adapted to different contexts by choosing the most adequate colors and patterns to print on the Re-board sheets. The original white color is good for refugee camps contexts and can be supplemented with colors that inspire calm and relaxation, such as green and blue.

Complexity

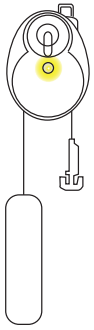
The complexity perceived in a scene is considered an important determinant of preference because it encourages exploration and offers immediate involvement with the environment. Both silhouette and surface features reliably influence visual preference through perceptions of complexity (Stamps, 1999a).

The possibility to customize the shelter by allowing flexibility in the arrangement of openings and exterior covered areas will add complexity to the scenario of application. Also windows, doors and structural parts such as beams and pillars could be emphasized by adding trims and frames. The presence of the sloping ceiling will break the regularity of the space.

Light

In a situation where electricity is not existing natural daylight becomes vital for indoor lighting. While the presence of openings can bring a feeling of safety, allowing to see who is passing by outside, it could vice versa result in a lack of privacy and exposure of the interiors if placed wrong.

The windows shall be large enough to avoid the feeling of entrapment. The windows should also be possible to close, specially in the sleeping area. The design can allow additional features on electrical light with for example photovoltaics or "GravityLight", turning a 3 second lift into gravitational potential energy which can give light for 25 min.



chapter 2.2

DOMESTIC ACTIVITIES

Spaces and functions

The research on the general qualities that contribute to the improvement of living conditions in residential environments is in the following chapter integrated with a study on the spaces necessary to carry out domestic activities.

The use of space in the home varies depending on many factors, such as physical features of the rooms, cultural habits, gender, household size, etc. In a post-disaster scenario, where daily life and gender roles are completely subverted, the domestic environments acquire a different meaning and have to subordinate to different functions and requirements. The small dimension of the shelters usually implies the impossibility to organize the space according to functional areas. However, by identifying the needs of an average shelter user it is possible to develop a design proposal that could support a proper functional zoning or a grouping of activities that require the same kind of space.

According to our research many shelters and tents have an insufficient standing height, that reduces significantly the living space. The standards state that activities such as sleeping, eating, cooking, washing, dressing, childcare, home-based enterprises should be enabled within the space of the shelter (Shelter Centre, 2012). A space for storage is also desirable to protect belongings and food. Given the lack of adequate indoor spaces, the daily life in camps is often performed outdoor, with activities such as cooking, farming, working, washing and drying clothes, socializing with neighbours and babysitting (Axelsson, 2012).

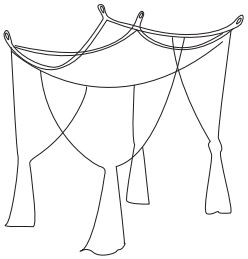
Family in Haiti lacking space of cloth storage.

Design criteria

Sleeping & Privacy

The sleeping area is the most private part of the shelter, where it should be possible to change clothes, pray, rest or find intimacy. Preferably the sleeping area could have another function during daytime.

Interior partitions are needed, for this Re-board panels or curtains could be used. The sleeping area of the family shall neither be too cramped nor wasting space. 2 x 3,5 m is a good benchmark, giving a family of five 70 cm each in width.



Mosquito nets are necessary in several climatic contexts.

Culinary activities

Cooking, eating and washing the dishes are some of the most regular domestic activities. The cooking area is regarded private in many cultures and is often placed indoor in order to protect it from rain, wind and sun (Nyström, 1994). This is though increasing the risk of inhalation and asphyxiation of smoke which is a common problem (Axelsson, 2012).

The adoption of a proper cooking stove in a shelter must be considered in the local context of cooking practices and kitchen design. However, the shelter should be designed to easily fit a stove, for example by providing a ready-made hole for a stove pipe or by having a functioning ventilation system. The stove could therefore be placed indoor or in a protected area outdoor. The main room can be employed as dining area and should be wide enough to allow a family to carry out activities and walk easily around a dining table.

Health & hygiene

As previously mentioned, one latrine per family in camp settlements would be preferable, even if the limited aid organization resources cannot often meet this need. It is important that the sewage grey water system is kept separated and protected, to decrease the risk of contamination especially high during flooding.

There is not strict necessity to include a toilet in the shelter design, since this function is generally fulfilled by common latrines. The shelter could anyway present the possibility to be integrated with an additional toilet unit.

Storage

Household possessions usually occupy a great share of the internal living space (Shelter Centre, 2012). Space for storage of personal belongings, such as bags of food, cooking equipment, furniture and clothes, is highly valuable in shelters to keep the small space of the house organized and clean. The presence of storage space, such as shelves, drawers or niches, provides also the opportunity to create a more personal environment, allowing appropriation and accumulation, as well as enabling the inhabitants to secure their belongings into the house.

By having a bigger house surface the space for storage would be reasonably increased. It could be possible to make use of the vertical surfaces as well, for example by providing the possibility to hang hooks from the structure frame, thus protecting the items from ants or other insects. Storage boxes under bed also can work as a food and clothes storage dry and free from vermin.

Refugee shelter in Sudan.

Washing & drying

Clothes are one of the few belonging that refugees manage to take with them into the camps. Keeping them clean includes functions as washing, drying, and in case of wealthy households even ironing. Washing and drying are activities which create a lot of humid air, and that are mostly performed outdoor in temporary settlements.

Washing and drying clothes are considered in some cultures private activities, preferably done inside or on a screened porch.

Working

Many shelter residents are afraid to leave their home during day because of the risk of thievery. Therefore some of them, like craftsmen or vendors, have to find an occupancy in working and sell things from home.

A shaded outdoor space as for example a porch could work as a semi-private connection towards your passing-by neighbors.

Studying & reading

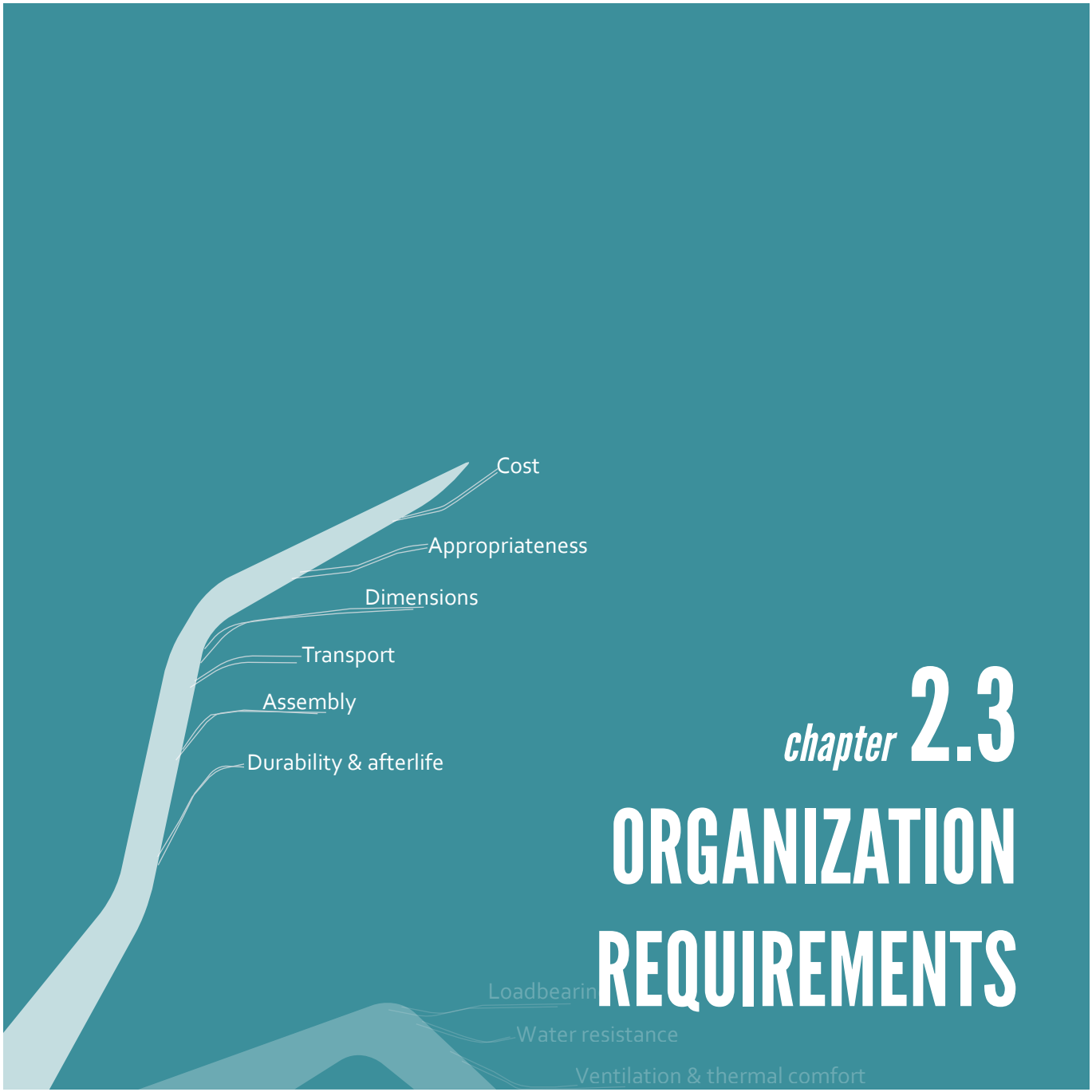
Even though the expectation is that all children should attend school, this is often of low priority in setting up a camp.

The indoor environment should provide adequate light and space for reading and studying, even in the private areas such as sleeping rooms.

Electrical appliances

Electricity can be seen as a rare luxury in temporary settlements. Only in few camps which have turned permanent this can be found and usually only is specific places as charging stations for cellphones. In some cases people have a strong wish to prioritize communication and outer awareness through cellphones, televisions or radios rather than domestic functionalities as ovens or refrigerators. The will to socially communicate can be linked to the higher needs in Maslow's hierarchy mentioned in chapter 2.1.

The shelter design could be adapted for additional features as electrical home appliances.



chapter 2.3

ORGANIZATION REQUIREMENTS

Standardised guidelines

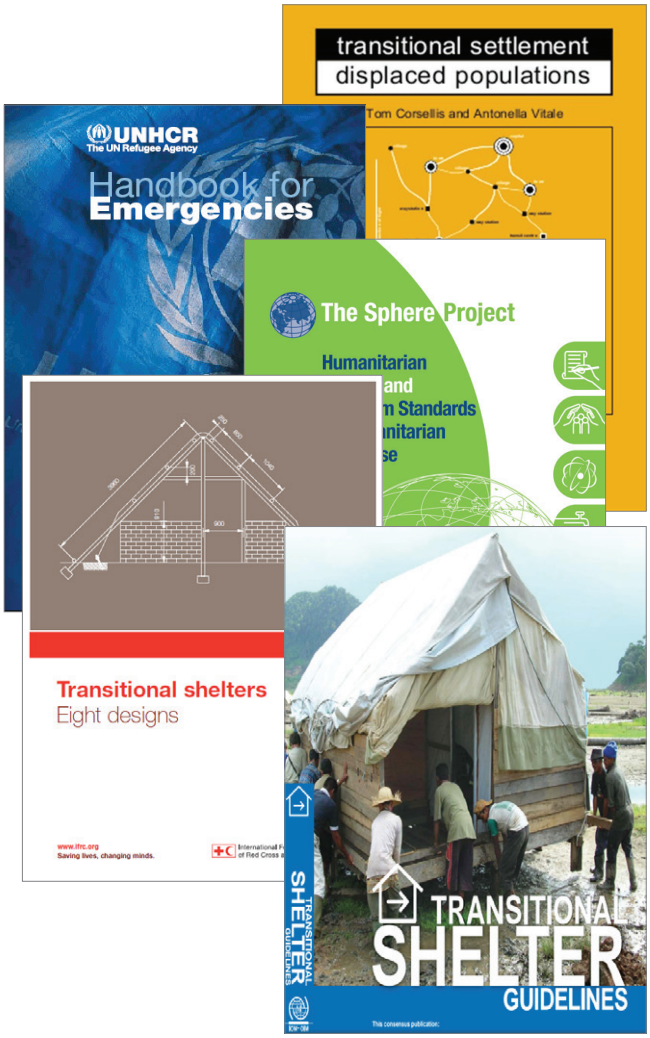
The aid organisations have set up some general requirements concluded in several instruction documents during the last ten years. Among the most recognized are *The Sphere Handbook* (Sphere Project, 2011), first published in 2000 communally by IFRC and several humanitarian NGOs. It includes a specific part on *Minimum standards for shelters, settlements and non-food items*.

UNHCR has in their *Handbook for Emergencies* (UNHCR 2007) produced a set of protocols covering emergency management and problem areas in refugee emergencies. Together with UN-Habitat and IFRC, they also each year publish a document on Shelter projects (IFRC et al., 2008; 2009; 2010; 2012).

IFRC have themselves published the document *Transitional shelters: Eight designs* (IFRC, 2011) with specific examples on different structural shelter typologies. We mainly referred to this document during the formulation of design criteria related to requirements of organizations, presented in this chapter.

Shelter Centre, a NGO registered in Switzerland, has similarly made up several protocols on transitional shelters with higher requirements than initial response shelters (Shelter Centre 2010 & 2012).

The humanitarian and campaigning agency *Oxfam* has developed the guidelines *Transitional settlement, displaced populations*, which is referenced extensively in this thesis under the name of the executive editors and lead authors (Corsellis & Vitale, 2005).



From the top:
Transitional settlement, displaced populations, 2005
UNHCR Handbook for Emergencies, 2007
The Sphere Handbook, 2011
IFRC Transitional shelters Eight designs, 2011
Shelter Centre Transitional shelter guidelines, 2012

Design criteria

Dimensions

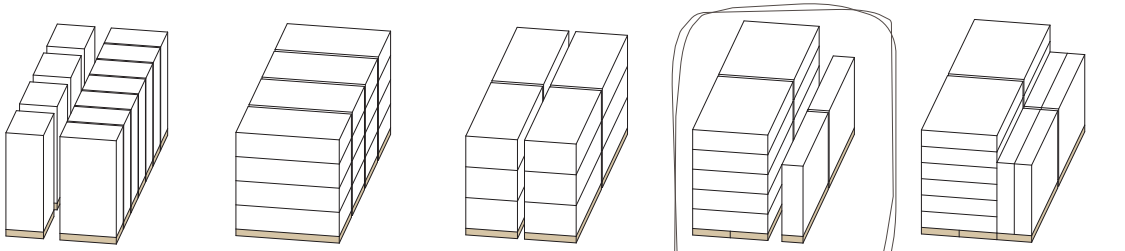
According to UNHCR (2007), a shelter should be a minimum of 3,5 m² covered living area per person in tropical, warm climates, excluding cooking facilities or kitchen. In cold climates or urban situations 4,5 to 5,5 m² are appropriate since people are likely to remain inside the shelter throughout the day. Usually covered living area also includes external living areas such as verandas. A shelter should fit a family of at least 5 people, hence a floor area of minimum 17,5 m². At least 60 % of the floor area should have a ceiling height of 1,8 m (Shelter Centre 2010).

The shelter will be designed to fit 5 people and will have a interior living area of 18 - 24 m² and a covered exterior part of 2 - 4 m². The shelter design should be based on modules, so that it would be possible to increase or decrease the interior area, depending on the size of the family or on the type of climate.

Transport

An emergency shelter packed for transport is recommended not to exceed 100 kg and 0,5 m³, and it should be possible to fit onto a 1200x800 mm EUR pallet at least four packed shelters. The height of the package cannot be more than 2100 mm to fit in shipping containers (Shelter Centre 2010). To be able to compete with existing shelter solutions it's necessary to consider demanding transport requirements, but if the higher durability of the shelter would be demonstrated, aid organisations could be convinced to invest more per unit and allow a larger package.

For this study a 20' container is considered. Having one package standing on each EUR pallet would limit the sheets to 1200x2100 mm, but results in more sheets to assemble and a low shelter ceiling. Therefore a solution of lying packages of 1600x2900x416 mm, is chosen. Considering 16 mm Re-board it equals to a maximum 132 m² of surface area, for a weight of 290 kg.



11 packages	16 packages	12 packages	12 packages	16 packages
1200x2200x800	1400x2200x560	1100x2900x720	1600x2900x416	1600x2900x368
50 sheets	35 sheets	45 sheets	26 sheets	23 sheets
2,1 m³	1,72 m³	2,3 m³	1,9 m³	1,7 m³

Cost

The financial assistance per displaced family varies for each disaster and the decision about the amount of the economical investment is a critical issue. Inexpensive materials are often preferred to avoid that components of the donated shelter could be sold or stolen. Also when aid organisations judge the costs of refugee camps, they compare the disposable income of the affected and the hosting population. A part of the cost is the matter of how fast the shelters can be produced and reach destination. For transport by airplane the airfreight can cost more than the actual tent. A long flight can reach as much as USD $1,000 for a 50 kg tent. For shipping by ocean containers this takes longer time but is instead of about USD $20. (Axelsson 2012).

Comparing with other competing solutions initial tents vary between $200-500 (See case studies) while longer lasting transitional solutions vary between $1000-8000. Re-board will have a production cost of approximately $7/m² which for 120 m² equals $840 in material cost but will lead to much higher cost including transport if sent by airfreight.

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CASE STUDY: refugee shelter IKEA , Ethiopia

A project developed 2012 by Kanter & Karlsson and Formens Hus which give the five residents a flat packed durable structure claimed to last at least 3 years. Additional features (not implied in the pilot project) are a solar cell driven lamp, plastic sheet flooring and a shade-net on the roof deflecting heat. The cost per unit is $8,000 but can reach $1,000 if mass-produced.


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Appropriateness

An appropriate shelter design reflects the human needs, vulnerability and capacities of the affected community and the resources available. As every context is different, so shelter designs must be adapted to each location, response and project. Preferable designs, layouts and orientations differ between countries, and even with people of different ethnicities in the same country (IFRC 2011). In general, the design brief should aim to encourage flexibility in design such as allowing occupants to add internal divisions for privacy.

The culture and circumstances of crowded camp settlements shall require as much of privacy as achievable but with possibilities to socially interact with neighbors if wanted. The shelter design shall also be able to address different cultures and climates and shall provide possibilities to adapt according to variation in human needs, cultural and social habits.

Durability & afterlife

Temporary shelters shall be designed to be upgradable, repairable and movable. The construction material should be reused or transformed into useful items for the durable housing solution. This requirement is fundamental for transitional shelters (IFRC 2011).

Stora Enso has set the aim that Re-board sheets should last outdoors for at least 2 years. The shelter shall be designed accordingly, especially if its cost is higher than that of tents. The shelter package shall contain a tool kit and instructions on how to maintain or repair house in case of damages. Solutions for the recyclability or reuse of Re-board shall be developed, as for example insulation material or rammed paper.

Assembly

For assembly it is important that the shelter can be raised by a few number of people with low technical experience. The time of assembly is also a important factor. Even if a shelter can be raised in a couple of hours, the amount of new-arrivals can be large and the labour assistance limited, and people need a place to sleep also the first night. Other important factors to consider are the weight and the volume of the box containing the shelter, to allow an easy transportation from the distribution site till the chosen location for the house.

The shelter package should contain clear and illustrative instructions on how to assemble. Two untrained people should be able to transport the packages containing the shelters components and assemble the house unit within 6 hours.

Syrians put up tents at the Zaatari refugee camp.

Self-assembly

Self-assembly is an important strategy that strengthen the sense pride and ownership of the future inhabitants, creating knowledge about house-maintenance and a greater involvement in the community. It helps also reducing the amount of paid labor needed for a house, and the necessity to recur to trained foreign staff for the construction works. This strategy is used by Habitat for Humanity, that refers to it as *sweat equity* as the hours of labor that the future homeowners dedicate to building their and their neighbors' homes, as well as the time they spend investing in their own self-improvement (Habitat for Humanity, 2014).

The possibility to self-construct the shelter is a great strength of the project elaborated in this master thesis, given the lightness of the paperboard material and the simple assembly process.

As emerged from the reviewed literature, alienation of self-labor is frequently a result of charity-based approaches to post-disaster recovery by both non-governmental and local organizations (Subasinghe, 2013). The common argument that supports the employment of especially trained staff is based on the consideration of post-disaster physical and mental exhaustion that affect refugees and the difficulty of organizing the works in field. We report below parts of interviews from Subasinghe (2013) that reveal the general sense of frustration of refugees over this marginalized treatment, that often generates the partial abandonment of temporary housing provided in camps in the presence of any other alternative living arrangement.

"We went from one disaster to another. We were transported like goods with no voices or emotions. I was not even consulted about where I preferred my hut to be located. They put me in a corner completely away from my people. I could have put together this roof better than they have done with help from my work buddies. It is worse than being invisible, when you are treated like something that is about to fall apart."
(Subasinghe, Interviewee #23, 2005)

"Can you really stay in a place where you feel you are inadequate, both in terms of knowledge and skills? I really hate these trips back and forth between my old house and the camp. My wife and kids are looking to me for bread so I do not have any option other than seeing the ugly faces of the camp-people every day. Actually, it is less painful to work for them as unskilled when I do not live on the same premises. Then you are like an outsider who goes there for paid work, even though the pay is much less that it supposed to be, at least in comparison with those highly-paid outsiders."
(Subasinghe, Interviewee #14, 2005)

"So many people care about us, but their overwhelming concern made us almost invisible. Rather than dealing us with as individual human beings, they see us as a one giant entity of disaster victims, so we do not have an identity. Whatever they do to us is considered goodwill and charity and that includes totally forgetting our own efforts in re-building this place. I could not deal with that any longer and left their so-called tsunami house. Only my oldest son goes there occasionally to get essential items that are needed for survival."
(Subasinghe, Interviewee #23, November 5, 2005).

chapter **2.4**

TECHNICAL REQUIREMENTS

Durable but inexpensive

The technical requirements on the shelter design are set by aid organizations but also by the limitations by the line of producer; in this case the main material is being produced by Stora Enso Re-board in Norrköping and the digital cutting is performed by Arkitektkopia in Gothenburg. For example pre-set options of fabrication set restraints in sheet sizes, tools for cutting, human handling and printing.

The most decisive requirement for financial purchase of shelters by aid organizations is the durability, since the investments is calculated per life span. As mentioned earlier many emergency shelters last shorter than expected. The durability of a shelter is substantially connected to the weather resistance and load-bearing properties, and since many shelters are placed in regions with yearly occurrence of extreme weather (typhoons, draught, monsoons, extreme cold or heat, etc.) the material quality of shelters is not dimensioned to endure this. The structure of shelters should therefore be calculated with a margin of safety, considering a structural capacity beyond the expected loads or actual loads. For some wearing out materials have to be tested for, one example is cheap tent canvas which are structurally weakened by the sun's UV light.

Since engineering calculations is outside the scope of this architectural thesis an approach of verification with relevant references is done. Technical product specifications on Re-board are found in the end of this subchapter and further descriptions of how to work with the material is discussed in the design development under detail connections, chapter 3.3.

Re-board, almost as strong as wooden boards but more lightweight.

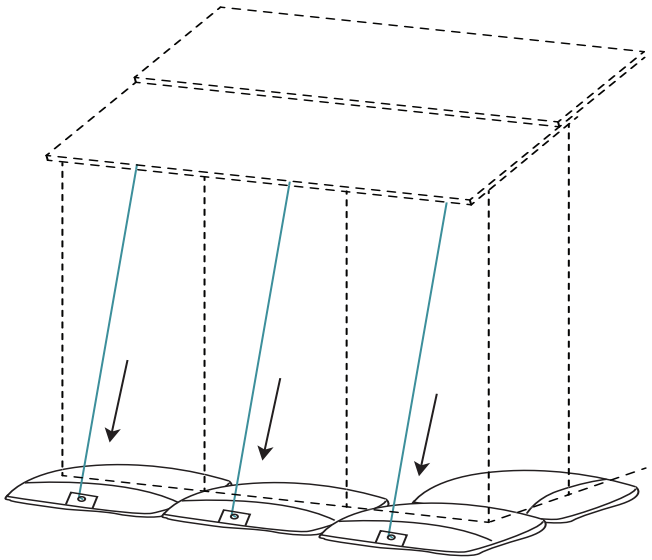
Design criteria

Loadbearing

A shelter with all doors and windows closed shall according to *Transitional shelter standards* (Shelter Centre, 2010) be able to withstand a minimum wind speed of 18 m/s in any direction. In order to avoid uplifts the building should be strongly anchored to the ground: this could be achieved simply by connecting the lightweight structure to a foundation. Earthquake loads are less affecting lightweight structures, but still windows and doors shall be placed more than 600 mm from corners, to promote good practice if families later move back to heavier construction. By having a symmetrical structure and a simple building layout the risk of damage in case of earthquake is reduced. The shelter shall withstand 300 N/m² of potential snow load without damage or changes reducing the functional capacity. In addition, the frame shall be able to support at least 6 hanging live loads of 30 kg. (Shelter Centre, 2010).

According to the structural load calculations and full scale tests done in the *PHIR project* by a research group at the Royal Institute of Technology in Sweden (Fransson 2006), the loadbearing demands can be fulfilled with appropriate dimensioned Re-board. In the calculations they also included human usage of people leaning against wall (0,25 kg/cm² with deflection <20 mm) and sitting on chair (6 kg/cm² with floor deflection <5 mm). Their results indicated that 16 mm Re-board for the walls sheets of 1200x2080 mm, and 22 mm Re-board for the flooring with a span of 600x675 mm were sufficient to meet the demands. To withstand uplift forces by wind guy-ropes may be needed to hold down the shelter (Fransson, 2005).

To be able to keep the loadbearing demands regarding self-weight, snow and wind loads and human live load, the shelter has to be produced with a stability equal or better than the PHIR project. Since that frame have additional reinforcing components in MDF, plywood and wooden floor joists, the way forward will be to design with a mindset if Re-board is used exclusively, dimensions of frame structure have to increase or spans have to decrease, compared to the PHIR house. Calculations will not be performed but the structure will be tested through the prototypes.



Guy ropes consolidated to sandbags give house stability.

Water resistance

Given the nature of the material, an adequate solution to protect the shelter from water and moisture should be considered as a priority in the design.

The most exposed part of the shelter is the roof, that shall preferably have an inclination of 20 to 30° to facilitate the drainage of rain water. A roof overhang would keep rain water off the walls and prevent the ingress of water at the junction. The overhang could vary between 15 and 30 cm, being limited due to wind loads. The flooring and wall basis in close contact with the ground has to be isolated from water. An elevated foundation or plinth can be used to raise the living area above the level of potential flood water. For this purpose sand bags can be a smart and cheap solution: the empty bag is lightweight and easy to fit in the shelter package, and it allows to fill it locally with available materials. For an additional protection a ground drainage is preferable.

A man digging his own drainage in Lokossa camp, Togo.

Ventilation & thermal comfort

As mentioned earlier the climate can vary heavily in emergency settlements around the world. Also people from different cultures will find different buildings comfortable, and be accustomed to different temperatures or humidities. In many settlements located in tropic areas overheating inside the shelter is a major problem and in some cases shading roof covers together with roof openings are used to create a proper ventilation (Axelsson, 2012).

Ventilation gaps shall be designed with possibilities of high air exchange rate to avoid overheating, preferably by using draft and stack effect. Too keep thermal comfort during night the envelope shall be designed as airtight as possible, with possibility to close ventilation gaps. An elevated flooring is a good way to keep away from the moist ground and if closed can create a pillow of warm air. For even colder climates place for installing fireplace & chimney shall be prepared.

Vector control

The term vector is used to define any organism or vermin that could carry diseases from one place to another. In case of a shelter two categories of animals should be considered: insects (fleas, mosquitoes, flies, etc.) and small animals (rats, birds, etc.).

The design of the shelter should prevent the insects to enter: it should be possible to hang up mosquito nets on the windows, at least in the sleeping area, and holes within the material should be avoided if facing outdoor and not filled.

Fire resistance

Fire is a common hazard in temporary settlements, even though the regulations are very strict in the indication of standards for fire breaks and other protective measures. When tents are made of textiles or plastics they can ignite easily if the material is not treated with some kind of flame retardant. Fires inside a building are generally started by people acting carelessly, while external fires can also be started naturally by lightning (Corsellis & Vitale, 2005).

Stora Enso claims the outdoor version also will be treated with a flame retardant with Euro-class C-s1-do. Settlement layout should be designed so distances between shelters are secure to prevent fire from spreading. In case of fire inside the shelter fast evacuation shall be possible through the door and the openable window.

Smoke generated under a fire drill in Azraq camp, Syria.

Environmental impact

"Climate change is not just a distant future threat. It is the main driver behind rising humanitarian needs and we are seeing its impact." (UNOCHA, 2014)

A study at Aalto University shows the environmental impact of eight transitional shelters built in different materials. It was shown that the greenhouse gas emissions for the steel frame shelters (630-1320 kg CO_2e/year) were more than 50 % of a timber framed shelters (390-440 kg CO_2e/year), calculated per estimated life span in years. The bamboo shelter which had the shortest life span was still outstanding in low impact of 60 kg CO_2e/year (Kuittinen 2013). A huge environmental problem in many settlements is the harvesting of local vegetation for self-built shelters. Since Re-board is produced from FSC certified forestry and utilizes water-based adhesives it has a low global and local environmental impact, even including transport. It has been calculated to have a carbon footprint of 2 kg CO_2e/m², based on CEPI and ISO14040 guidelines (Stora Enso, 2012). For a house of 120 m² lasting for 2 years that would result in total GHG emissions of 240 kg CO_2e/year. Hence between the timber and bamboo shelter in carbon footprint, which can be used as a unique selling point.

The environmental impact of the shelter won't restrain the design in usage of material more than the transport requirements. If other (non-cellulose) materials will be used, they will be examined with a environmentally low-impact perspective.

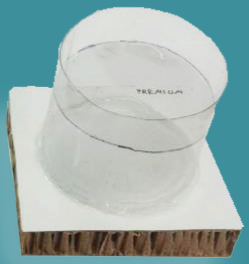
Material specifications

Re-board exists in the commercial versions *Basic*, *Premium* and *Outdoor.* In this project the Premium board was used for the first prototype and the Outdoor board for the second prototype. Re-board is produced in 5, 8, 10, 16 and up to 35 mm thickness. Here it follows a specification on the 16 mm version:

Maximum size:	3200 x 1600 mm 2400 x 1600 (Outdoor)
Density:	2,2 kg/m³ 2,1 kg/m³ (Outdoor)
Structure:	20 g/m² PE plastic 80 g/m² print paper 400 g/m² kraft liner 1200 g/m² fluted core *(vice versa on other side)*
Carbon footprint:	2 kg $CO_{2, eq.}$/m² (ISO 14040) *(+ fully recyclable as paper)*
In-plane compression:	50 % RH: 16 kN/m 70 % RH: 12 kN/m 90 % RH: 8 kN/m
Out-of-plane ":	50 % RH: 826 kN/m 70 % RH: 676 kN/m 90 % RH: 351 kN/m
Flame retardant:	Euro-class C-s1,do
Certification:	FSC-STD-40-004

During the design process Stora Enso Re-board developed the Outdoor version with a thinner but more moisture resistant surface liner. To realize the improvements in waterproofing capacity we conducted a water pillar test. The difference in the outcome was significant, since water started to permeate through the Premium board liner immediately, while the Outdoor board resisted water for a long time.

Outdoor



Premium

chapter 3

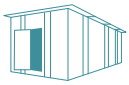
DESIGN DEVELOPMENT

Design process overview

2014
January

February

1st prototype



PRESTUDY
chapter 1

DESIGN CRITERIA
chapter 2

INPUT FROM IMNUS

Transport limitations!

Rationalization due to cost!

SPACE & FUNCTIONS
chapter 3.1

Grouping daily activities

Plan evolution

15 plans 20-24 m²

9 plans 20-22 m²

STRUCTURAL DESIGN
chapter 3.2

Modelling & sketching

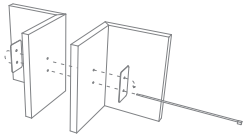
Foundation & flooring

Roof structure

DETAIL CONNECTIONS
chapter 3.3

Working with re-board

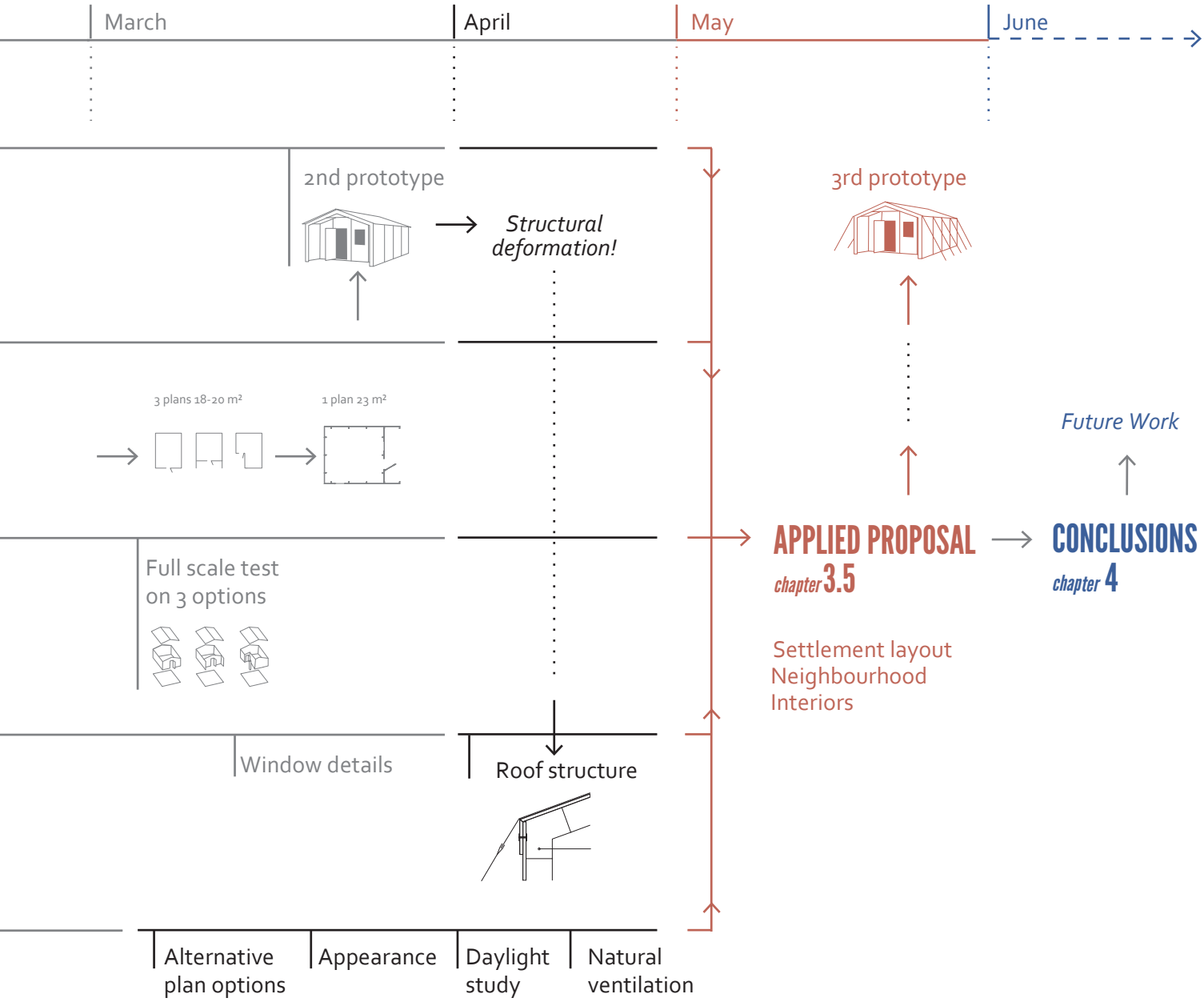
Wall connections

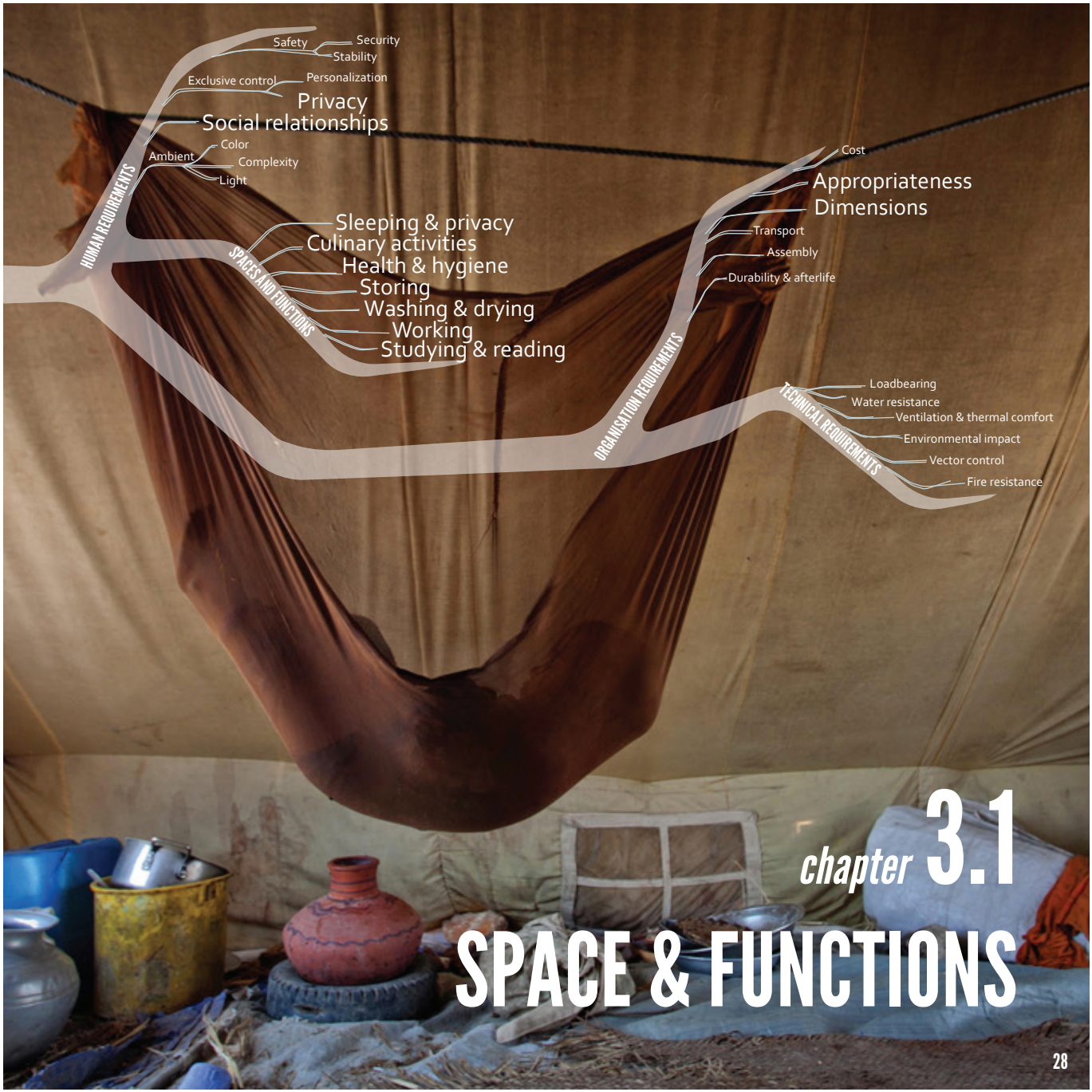


ADAPTABILITY
chapter 3.4

Furnishing

Context adaptability


March
April
May
June
2nd prototype
Structural deformation!
3rd prototype
3 plans 18-20 m²
1 plan 23 m²
Future Work
Full scale test on 3 options
APPLIED PROPOSAL
chapter 3.5
CONCLUSIONS
chapter 4
Settlement layout
Neighbourhood
Interiors
Window details
Roof structure
Alternative plan options
Appearance
Daylight study
Natural ventilation



chapter 3.1

SPACE & FUNCTIONS

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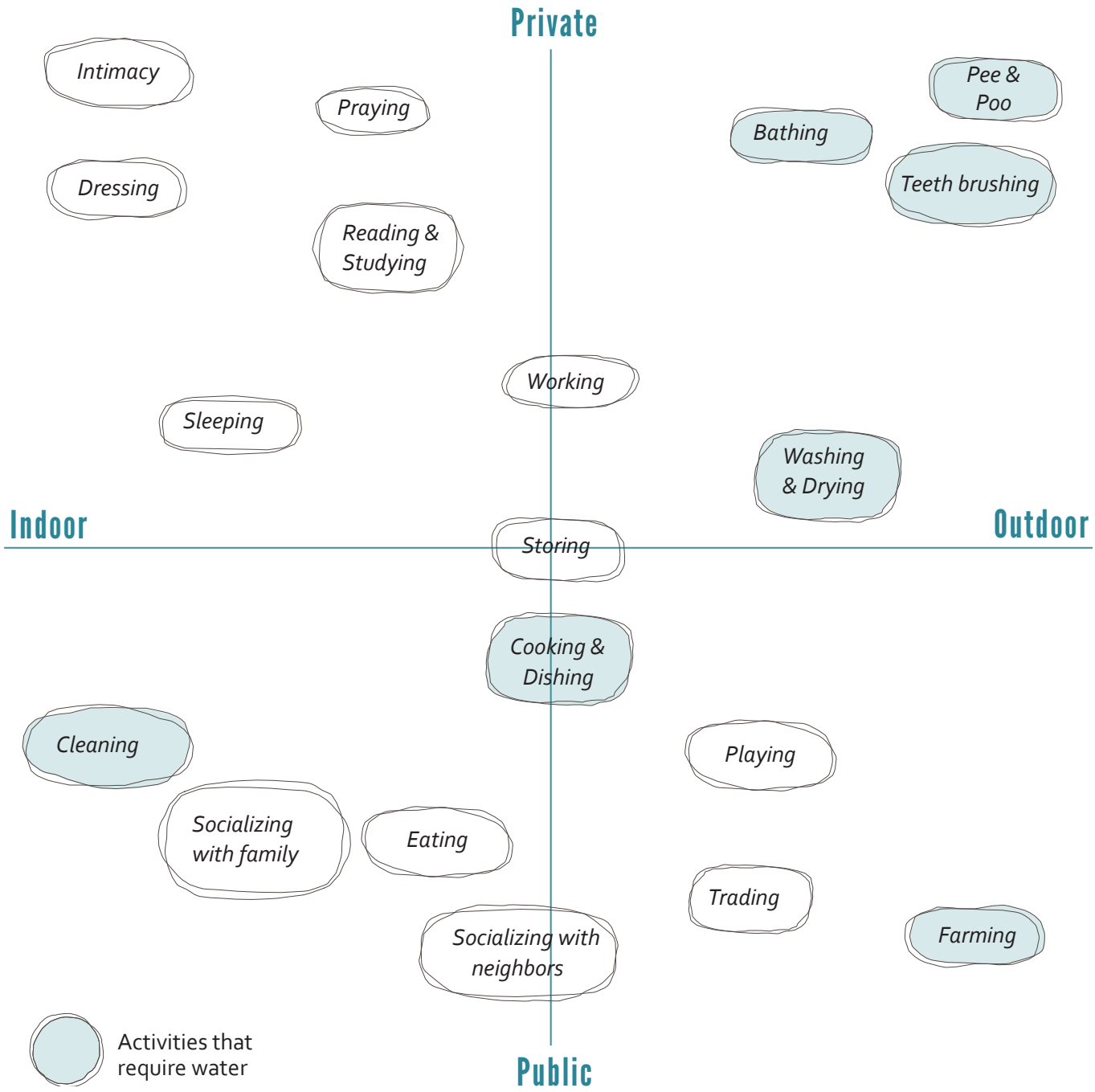
Grouping daily activities

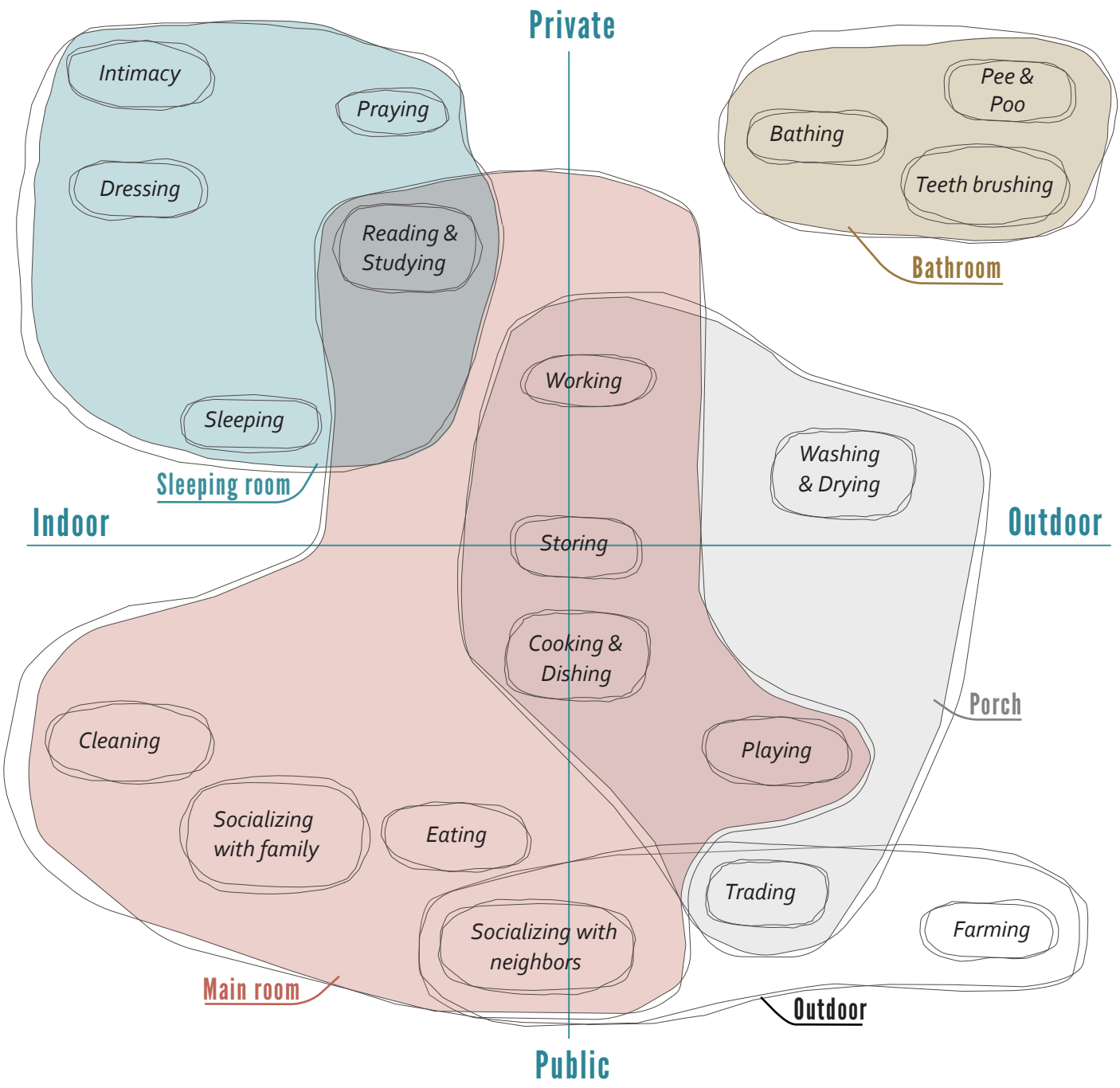
Seen to the left is the design requirement overview with the criteria relevant to this subchapter. This will be repeated every subchapter to show the link between criteria and design development.

Designing an emergency shelter requires culturally specific considerations to be identified and reflected, so that the shelter can support daily activities and answer to the necessities of inhabitation of the final users. In order to achieve an appropriate design when shelters are constructed locally, the affected community is in general involved and consulted during the process. This passage is missing in the case of prefabricated shelters, where the design solutions cannot be but the result of general assumptions.

In order to obtain a welcoming and functional residential environment we considered the basic activities and functions that are carried out globally in the home, such as sleeping, cooking and eating, praying, washing and cleaning, studying and reading, child care and social activities. We ordered these activities in a diagram depending on their level of privacy and if they are possible to carry out indoor or outdoor. The results describe a pattern of activities that require the same kind of space (e.g. sleeping, praying, intimacy and dressing) that guided us in the elaboration of the most adequate floor plan solutions.

Syrian refugees cook in Bekaa Valley, Lebanon.


Private
Intimacy
Praying
Pee & Poo
Bathing
Dressing
Teeth brushing
Reading & Studying
Working
Sleeping
Washing & Drying
Indoor
Outdoor
Storing
Cooking & Dishing
Cleaning
Playing
Socializing with family
Eating
Trading
Socializing with neighbors
Farming
Activities that require water
Public

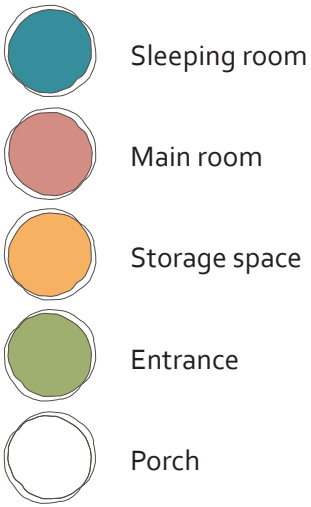

Private
Intimacy
Praying
Dressing
Reading & Studying
Sleeping
Sleeping room
Pee & Poo
Bathing
Teeth brushing
Bathroom
Working
Washing & Drying
Indoor
Outdoor
Storing
Cooking & Dishing
Porch
Cleaning
Playing
Socializing with family
Eating
Trading
Farming
Socializing with neighbors
Main room
Outdoor
Public

Plan evolution

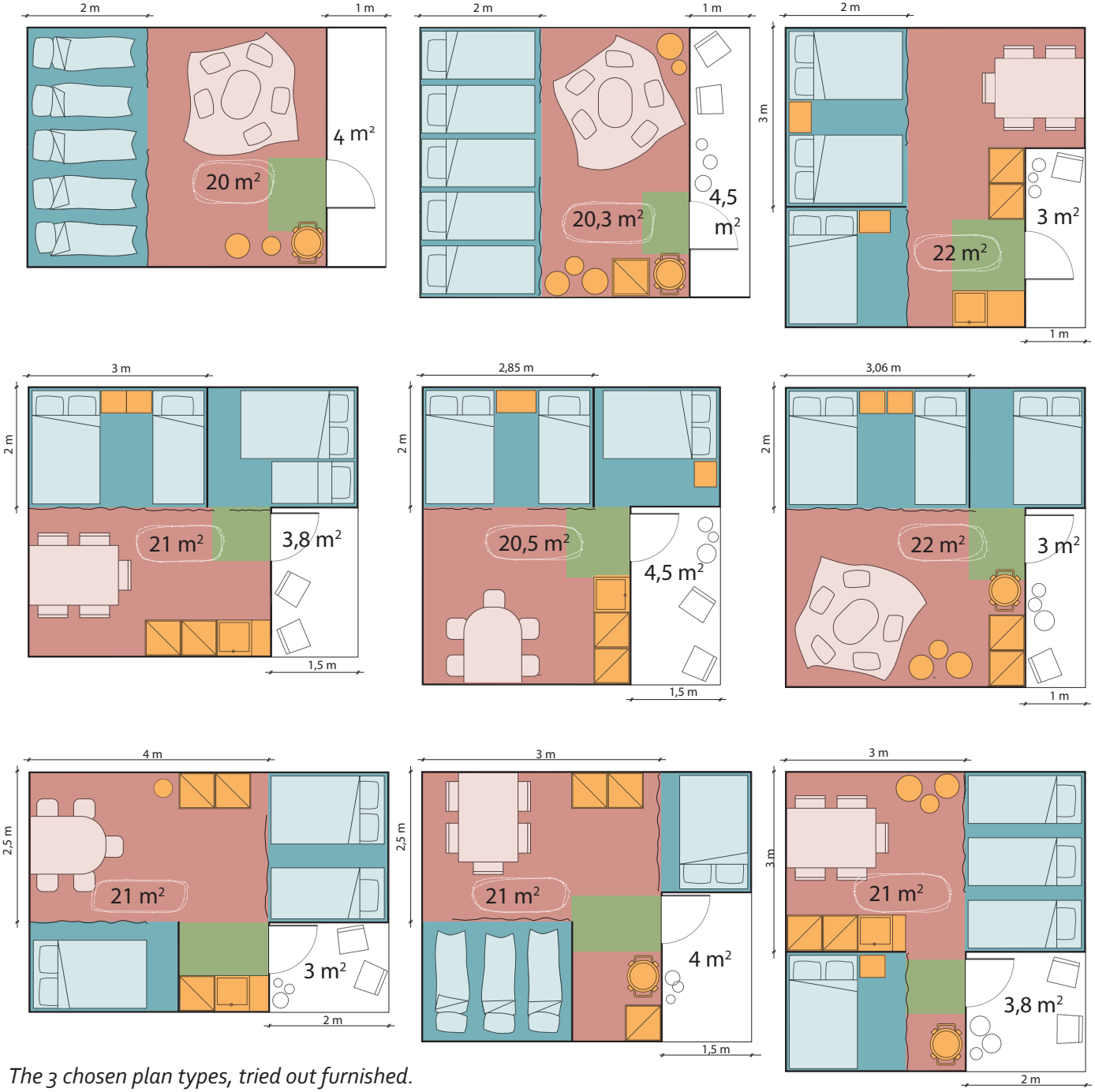
The design criteria set limitations regarding shelter size and volume of the materials needed for the construction. Therefore a little variation is allowed in the elaboration of floor plan suggestions. Hand drawn sketches were rationalized into five types of plan layout with varying degrees of privacy. These are here shown with three different proportions between length and width. The grey grid shows the square meters, so plans vary from 20-23 m² indoors and 2-5 m² outdoors.

Out of the five types, three were chosen to continue with (row 1, 2, 4 in illustration). Both type "Private-separate" and "Enclosing" require a large entrance and distribution space, which limits the main area. On the other hand this space could be used to store belongings. From this study the importance of optimizing the already limited indoor space and adopting a proper functional zoning emerged: by having adjacent bedrooms for example it would be easier to create a separation between sleeping and living areas.

To investigate the three chosen layout types we tried furnishing the floor plans. This was done with the understanding that inhabitants have often few or none belongings with them, and donated non-food items are basic. Still, by adding sleeping mattresses, dining table, space for storage and kitchen utilities, the potential living scenarios become more conceivable. Some plans belongings to the "private at side" option resulted in such a cramped space that the area proportions were adjusted. In the following pages we present the floor plan development and evaluation.



6 x 4 m
5,5 x 4,5 m
5 x 5 m
Private in back
Private at side
Private separately
Private in corners
Enclosing



The 3 chosen plan types, tried out furnished.

+ Wide living area and porch
Possibility to create unique space
Adaptability to other arrangements
Absence of partition walls

- Open view on the interiors from the entrance
Storage in the living area
Single sleeping area

+ Wide living area and porch
Possibility to create unique space
Adaptability to other arrangements
Absence of partition walls

- Open view on the interiors from the entrance
Storage in the living area
Single sleeping area

+ Separation living-sleeping area
Partition between bedrooms
Entrance and storage space
Covered view on the interiors from the entrance

- Inflexibility in the floor plan
Unexploited space needed for movements
Small living area and porch

+ Separation living-sleeping area
Partition between bedrooms
Entrance space
Partial view on the interiors from the entrance
Wide living area and porch
Space for storage in the bedrooms

- Inflexibility in the floor plan

+ Separation living-sleeping area
Partition between bedrooms
Entrance space
Partial view on the interiors from the entrance
Wide living area and porch
Space for storage in the bedrooms

- Inflexibility in the floor plan

+ Separation living-sleeping area
Partition between bedrooms
Entrance space
Partial view on the interiors from the entrance
Wide living area
Space for storage in the bedrooms

- Small porch

+ Separation living-sleeping area
Separate bedrooms
Entrance and storage space
Covered view on the interiors from the entrance

- Inflexibility in the floor plan
Small porch

+ Separation living-sleeping area
Separate bedrooms
Entrance and storage space
Covered view on interiors from entrance
Wide porch

- Inflexibility in the floor plan
Unexploited space needed for movements
Small living area

+ Separation living-sleeping area
Separate bedrooms
Entrance and storage space
Covered view on interiors from entrance
Wide living area and porch

- Inflexibility in the floor plan
Unexploited space needed for movements

Solutions with the most efficient use of space, developed in 3D in chapter 3.2.

chapter 3.2

STRUCTURAL DESIGN

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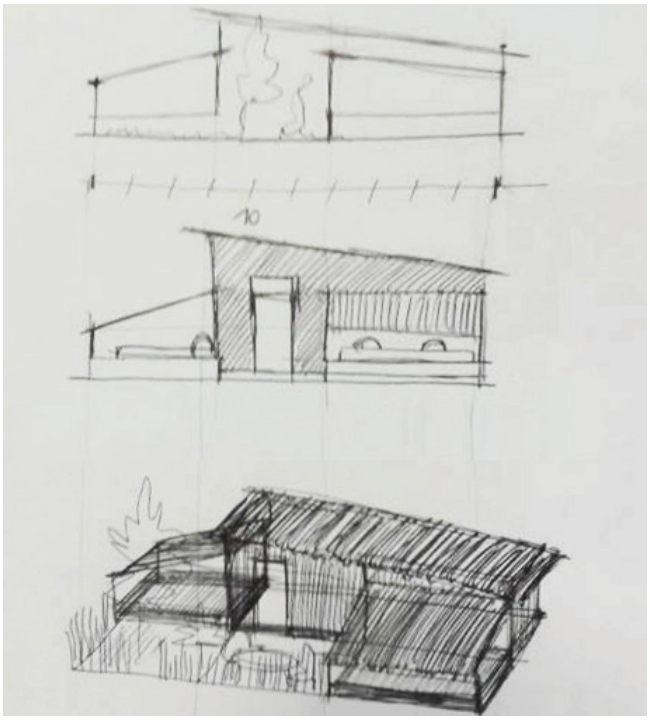
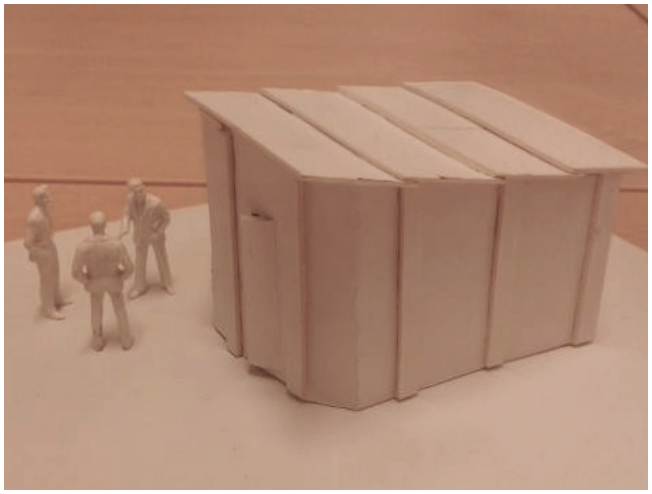
Modelling & sketching

Considering the design criteria on human and technical requirements we initially performed physical modelling parallel with the plan sketching. The user perception of the three dimensional space is vital for such a compact living. Nonetheless the height of the ceiling is restrained by other factors, for example the transport package dimensions and ease to reach when assembling the roof.

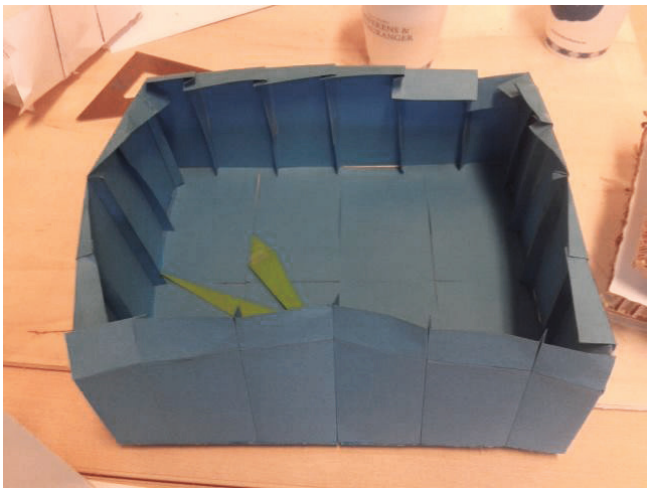
The early design development was significantly influenced by the experience from the first prototype (see following spread), already erected in the start-up stage at the same time as the design criteria were developed. The lessons learnt brought to the elaboration of an appropriate structural system for Re-board. This is described further in chapter 3.3 while this subchapter will explain the 3-dimensional development of the plans in the previous chapter.



Sketching of possible customization using modules.



Starting of with the experience from the 1st prototype.



Early modelling, imaging the Re-board sheets folded.

1st prototype

Size	3 x 5 m = 15 m²
Assembly	6 hours by 4 persons
Material	93 m² Re-board used, 10 m² waste
	~300 plastic screws
	15 m L- & 5 m H-profiles

Goal

Testing the possibility to build a full scale shelter in Re-board, to cut and fold the material and to assemble the unit in a short amount of time and with limited tools.

Assembly

The system of using screws for connecting sheets was very time-consuming, especially with hand screwdrivers and without pre-drilling. This indicated the need to substitute screws with another construction system (interlocking, folding or pre-drilled) in order to speed up the assembly process. It went smooth to carry sheets by two persons, but the shelter package was too bulky. Wind loads on raised walls were an issue when assembling, and the structure was unstable until the positioning of roof and floor beams. The shelter components should be marked to facilitate the assembly.

Moisture resistance

The sensibility of the material to water appeared as a clear limitation, with the most vulnerable spots being folded corners, holes and open edges. The liner here tended to be more subjected also to scratches. As solution we propose that Re-board edges should be covered, taped or waxed for the following prototype.

Loadbearing

The span between the floor beams appeared to be insufficient, it should be shortened or intersecting and supporting elements should be added. To avoid uplifts a system of consolidation of the building to the ground is necessary. Attaching wall sheets directly to a foundation would make a more stable structure.

Cost

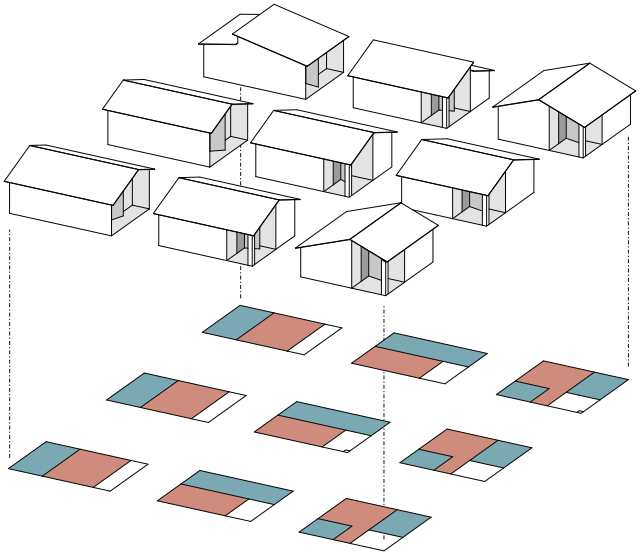
The material is expensive and cutbacks should be considered. For the prototype the floor is 30 % of the material and the exterior wall pillars 15%. A lower ceiling height is also suggested to reduce material and simplify assembling. Further additions as partition walls, windows, etc. could be integrated for the next prototype but Re-board should be kept as main construction material.

Assembly of 1st shelter prototype in January 2014.

Roof structure

As a result of the construction of the first prototype we realised the difficulty in erecting a roof placed too high. After considering single pitched, double shed and hipped roofs, the gable roof was chosen because of its structural advantages and for keeping an average ceiling height reachable when assembling and sufficient when standing. This typology is also part of traditional architecture in several cultures.

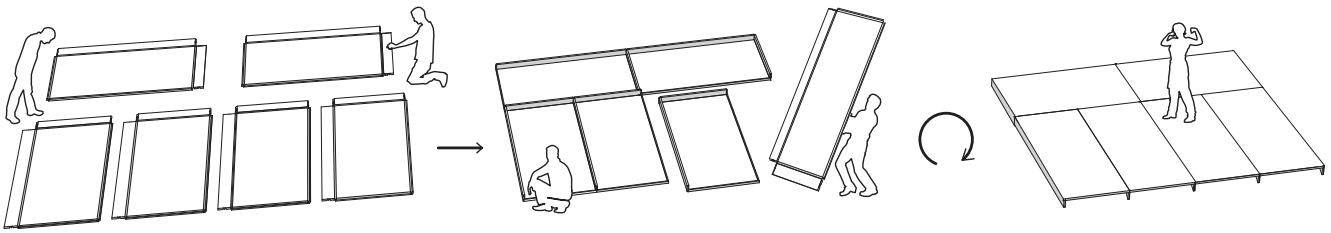
The limitations given by criteria such as shelter dimension and transportation packages brought to a necessary reduction of the sheet sizes. The following adaptations were handled by parametric design using the Grasshopper plug-in to Rhinoceros, allowing small updates to the design throughout the design process.



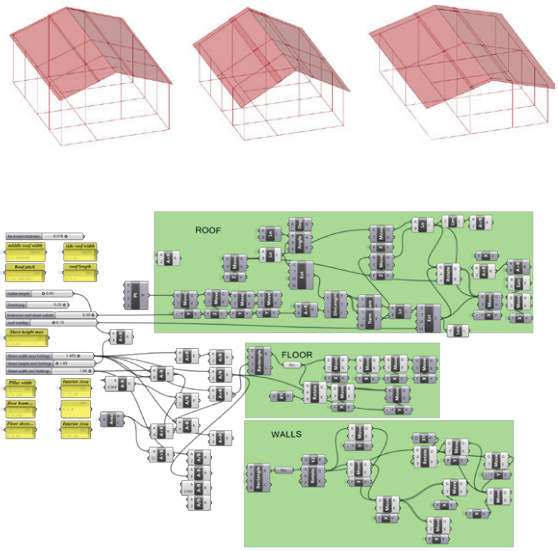
The plans from chapter 3.1 tested with three roof types.

Foundation & flooring

The presence of a flooring or a foundation enhances the quality of a residential environment, as well as protecting from flooding and insects and insulating from the ground. However, a flooring is not necessarily needed for the structure, and in emergency shelters is often excluded. A flooring technique of joining Re-board sheets (see below and chapter 3.3) was tested, but because of issues of deflection due to large spans, difficulty in assembly and restrictions in material availability, it was chosen not to be further develop this solution. Instead it was considered a solution with protective tarpaulin on the ground, to be folded outwards and taped around the walls.

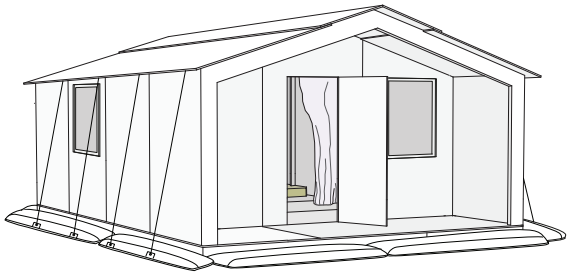


The assembly technique of the flooring is not optimal since the all sheets need to be assembled upside-down.



Parametric design of chosen gable roof.

As set as design criteria, sandbags could protect from flooding and consolidate the lightweight structure. Standard woven polypropelene sandbags filled with soil on site are inexpensive, costing around USD $ 0,30 each, excluding transportation costs.

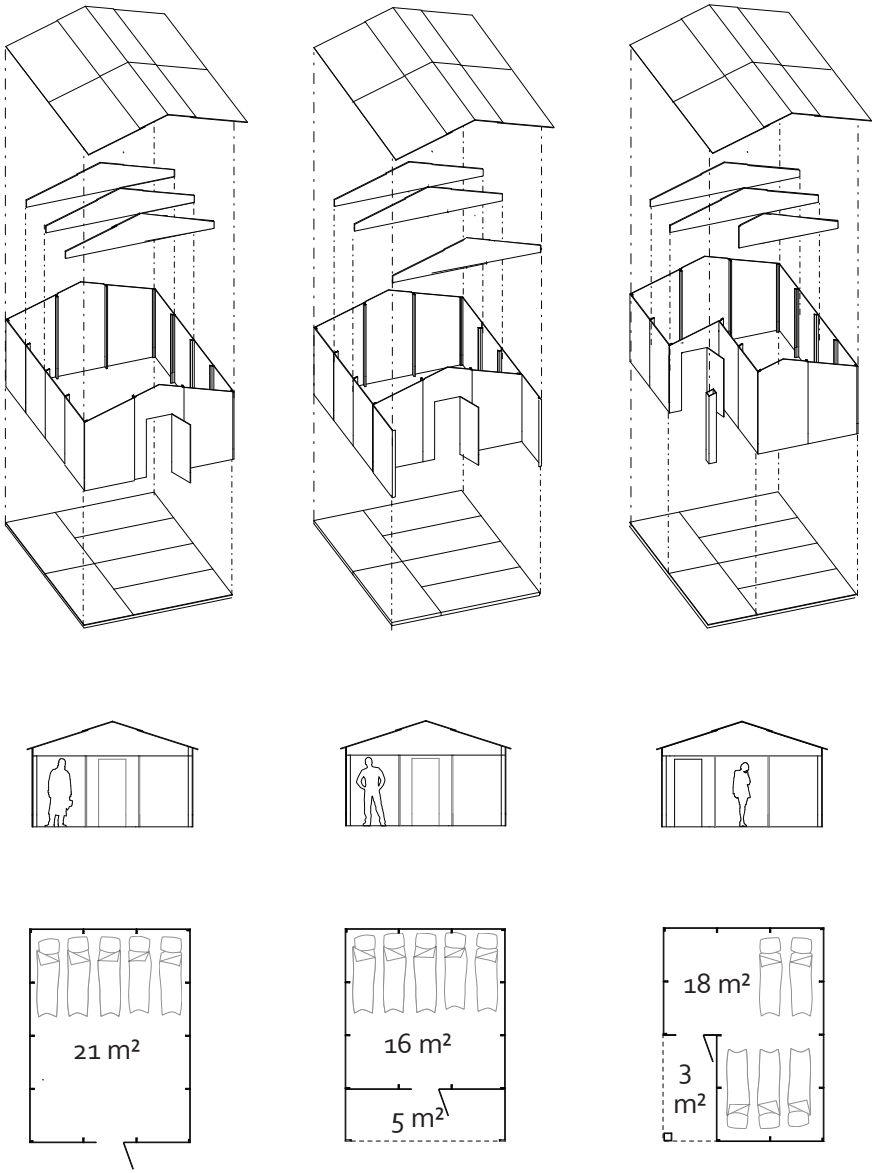


Roughly 10 sandbags would close in the shelter.

CASE STUDY: Shigeru Ban paper house, Japan

After the earthquake in Kobe 1995 the well known Japanese architect designed a transitional emergency shelter using a structure of paper tubes adding a tarpaulin as roofing. To protect the plywood flooring from flooding, a foundation made of beer crates filled with sandbags was used. To adapt to colder climate, the paper tubes can be filled with shredded paper. The unit cost was less than $2,000.

Full scale test on three options



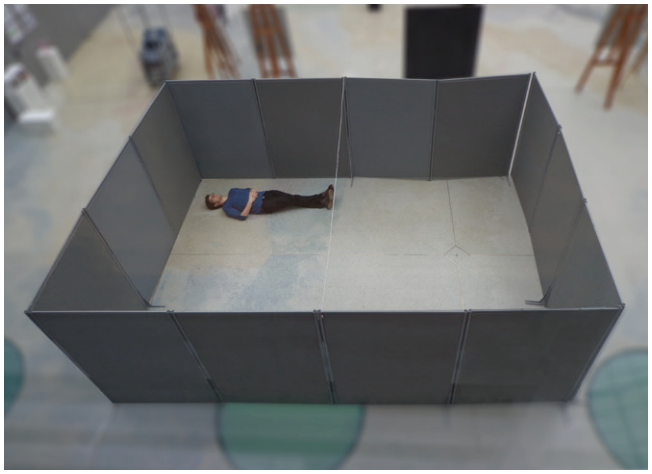
Structural alternatives considering a smaller shelter area.

By implementing the choice of the gable roof in the chosen plans (end of last chapter), we realized that a smaller area and a more elongated house body was needed to structurally work, considering the restriction in sheet size. Three revised layouts were drawn (see figure to the left) and recreated by setting up a workshop with screens, in order to get a perception of the volume.

The first option without the porch (20,3 m²) was experienced as a quite large space, that would be easy to separate with curtains.

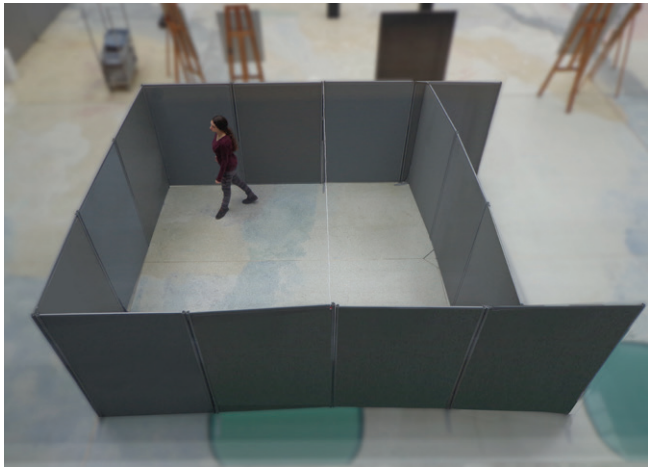
By folding a corner inwards, we obtain the alternative with porch on the side. Even though the interior space (16,9 m²) is clearly divided in two areas, it is perceived as narrow considering the amount of space needed for sleeping area for a family of five.

The solution with the porch on the front is selected to continue with due to its flexibility and the importance of providing a covered outdoor space. Instead, the 4th full-scale option shows the possibility to add an external latrine unit in the porch.

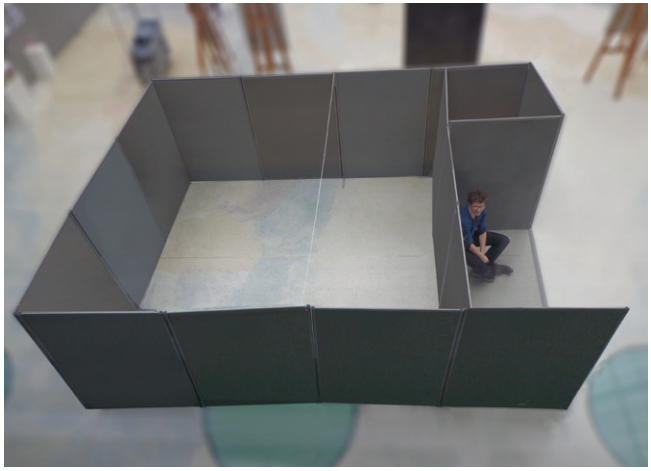


20,3 m² interior

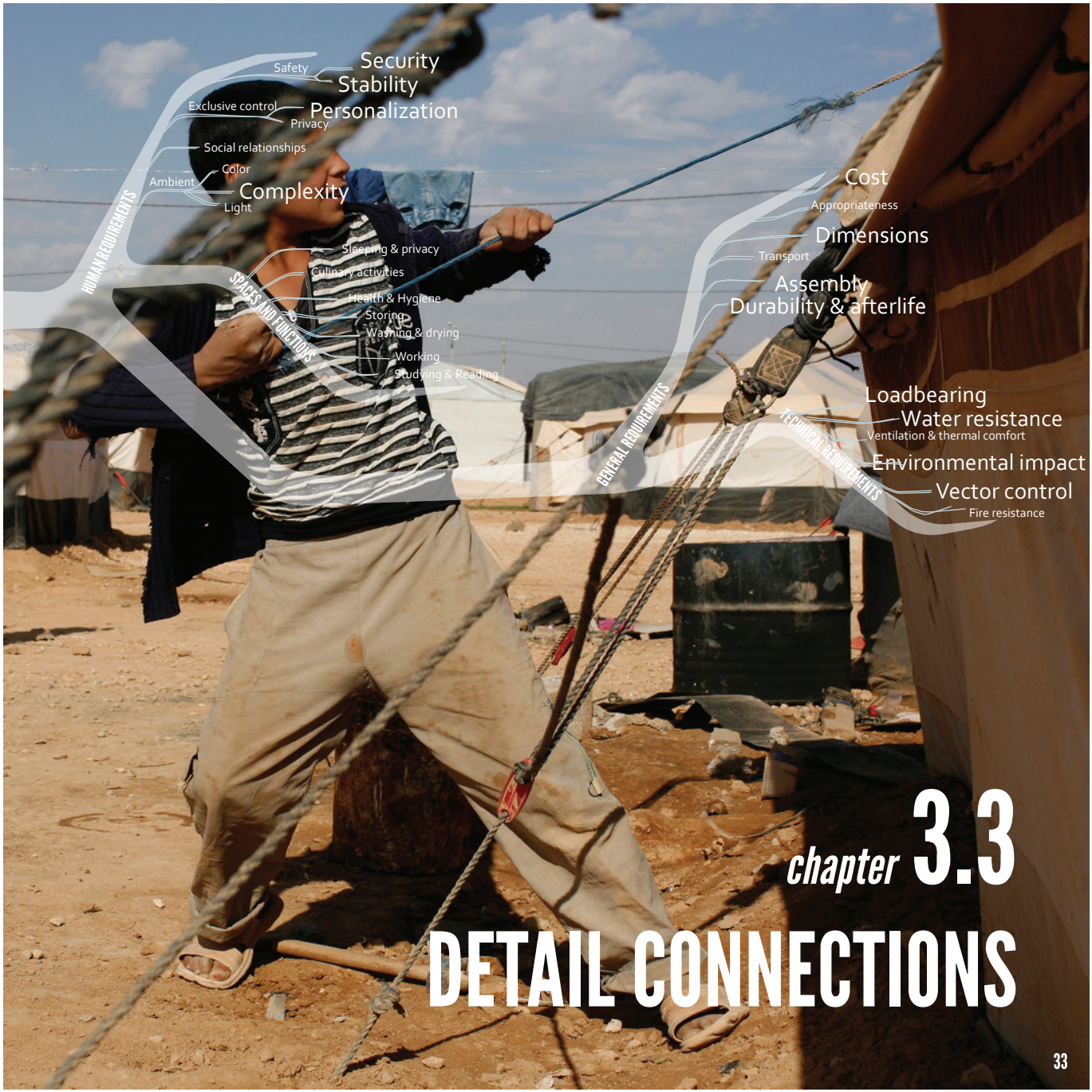
16,9 m² interior + 3,4 m² porch



15,2 m² interior + 5,1 m² porch



15,2 m² interior + 3,4 m² porch + 1,7 m² latrine



chapter **3.3**

DETAIL CONNECTIONS

33

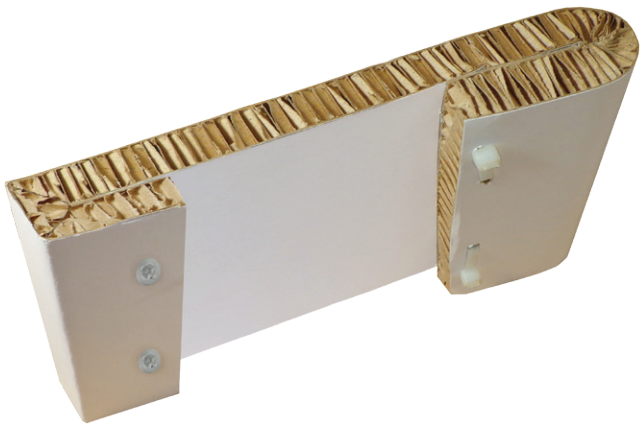
Working with Re-board

During the structural design development process, material workshops with Re-board were arranged to develop a series of connection techniques that could be fast and easy to understand when assembling, without using electrical building tools. A small kit with for example a manual screwdriver could be included in the shelter package but since the intended users themselves should be able to erect their home, the assembly should be easily performed without any previous building experience. The material of connections and fasteners cannot be too economically valuable, primarily due to the risk of thievery in camps but also to prevent the residents themselves to take down and sell the pieces. These are generally later replaced with locally sourced wood, causing local deforestation problems.

In the 1st prototype plastic screws were used to connect the wall sheets to each other and to keep the pillars folded (see detail on the following page), but due to the time-demanding assembly other solutions were looked into. As reference a previous master thesis named *A Prefabricated Cardboard Emergency Shelter* (Riesenfeld, 2005), done at the department of Architecture at Chalmers, was of major influence in the development of connection details. This previous project, that anyway had not been tested in full scale, gave us the idea to connect the sheets by folding them inwards, and to substitute screws with plastic cable ties, that don't require tools for assembly and have a much more reduced cost.

Two 45 ° cuts make the Re-board foldable 90°, a "v-cut".

Plastic screws or cable ties can connect sheets.

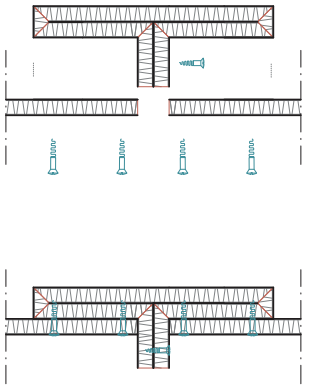


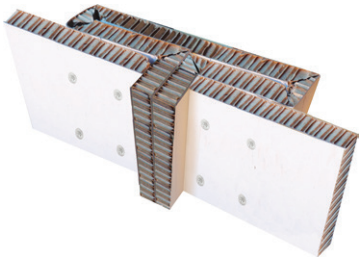
Two v-cuts folded (screwed) and a "bullet nose" (tied).

Wall connections

1ST PROTOTYPE

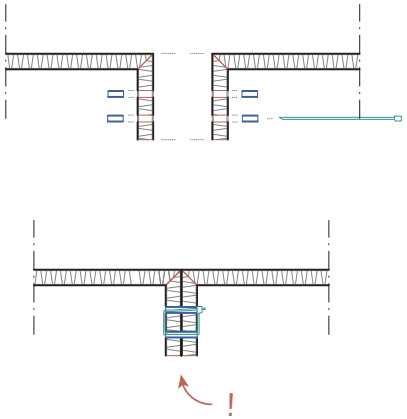
For the first prototype plastic screws were used for connections. The assembly was very hard and time demanding. The individual pillars demanded a large amount of material compared with the stability they provided. *In need of development.*

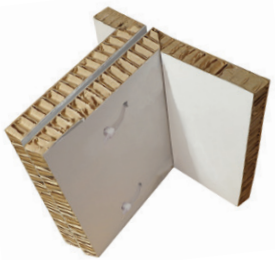




OPEN-EDGE FOLDING

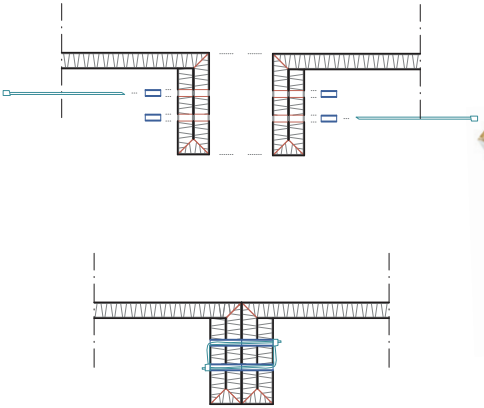
By including the pillar in the sheets less material is used and by folding them inwards the edges are protected from rain. The solution with cable ties tightening the walls together is chosen as a faster assembly method. Interior moisture released from people and daily activities is still a problem. *Used in the 2nd prototype.*

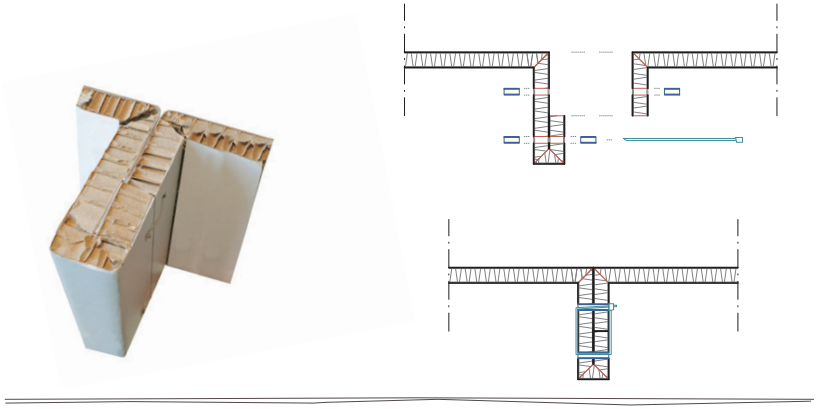




DOUBLE CLOSED-EDGE

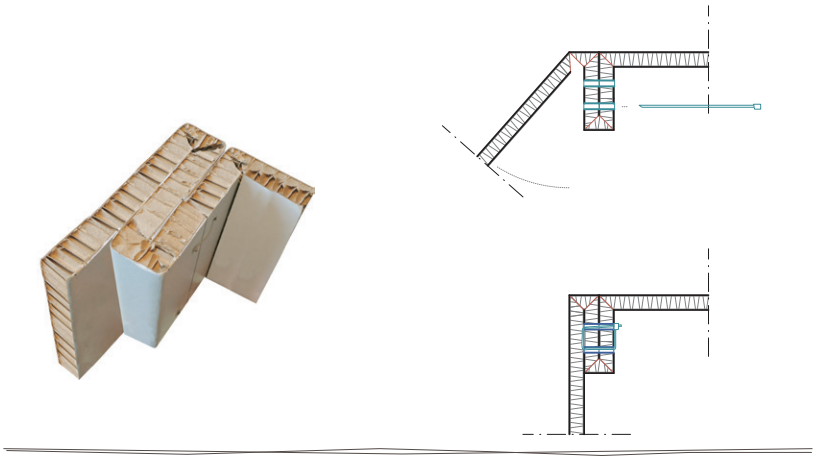
This detail of folding the walls double and connect them with cable ties make the edges hidden but is complicated to assemble. The pre-drilled holes with covering plastic pipes inserted also become twice as many and this solution is therefore too time demanding in production. *Too complicated.*





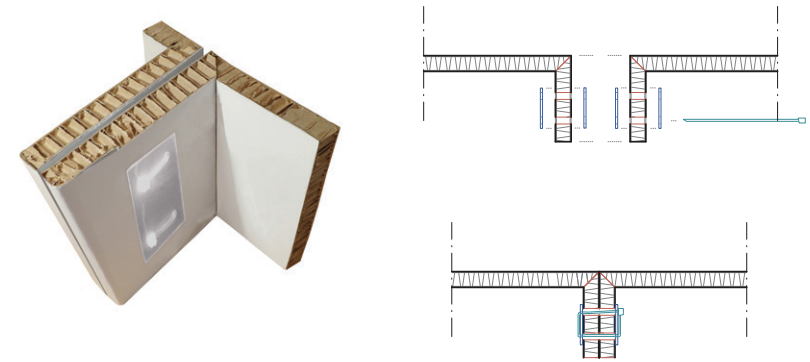
SINGLE CLOSED-EDGE

If one pillar side is folded towards the other, an easier and less material dense detail solution is created which still protects the sensitive edges from moisture. *Good solution but extra cutting expenses due to increased number of foldings.*



CORNER

The single closed-edge solution could be applied for corners as well, but this solution would generate a variation of length between wall and roof sheets, which would complicate the assembly and and adaptability in adding modules. *Complicated, high number of cuts needed, v-cut corners are easier.*



SEALED OPEN-EDGE FOLDING & PLATES

Since the open-edge folding is not moisture proof and the folding too complex, an added sealant on the edges is preferred. This could be a tight profile, tape, wax or a change in fabrication to have the liner folded around the edges. The covering plastic pipes are changed to exterior plastic plates to better distribute the tension of tightening the cable ties. *Final solution in applied proposal.*

Window details

MOSQUITO NET

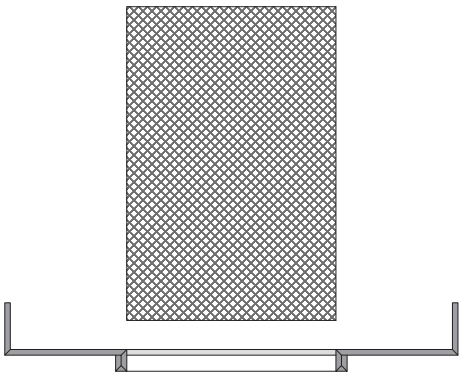
In this first version a lateral frame is created by folding the material outwards. A mosquito net is inserted in between the foldings. *External foldings create 2-sided cutting and risk of water infiltration.*

ADDITIONAL SHUTTER

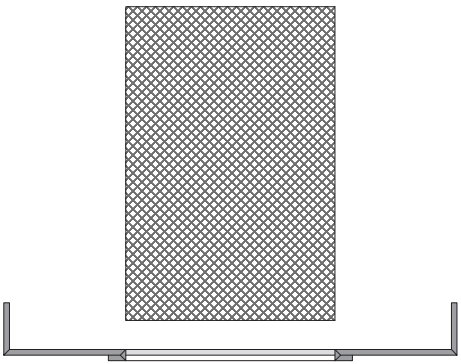
By folding the frame inwards it simplifies the fabrication and could serve as a support for a window shutter. In the first example headers are added at the top and the bottom, while in the second the frame is obtained from the same window hole, leaving uncovered the v-cut on the corners. *Costly solution for material and digital fabrication.*

CUT-OUT SHUTTER

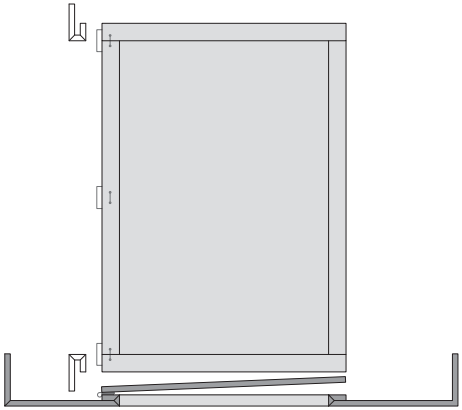
With a double v-cut and taped edges it is possible to use the cut-out material as a folded window shutter, thus avoid making use of an external piece. *Fragile connection in the v-cut and exposed core.*



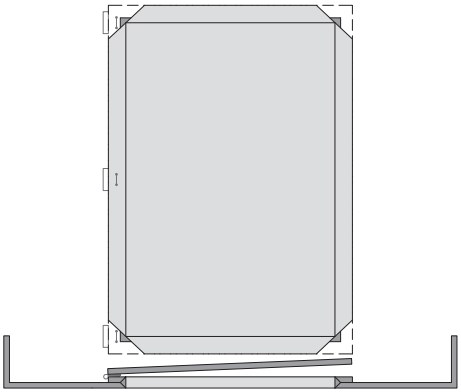
a) closed folding
6 v-cuts + 4 straight cuts



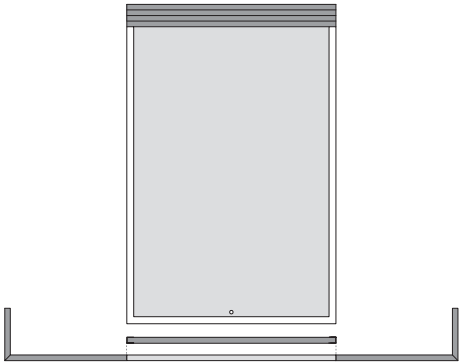
b) open folding
4 v-cuts + 4 straight cuts



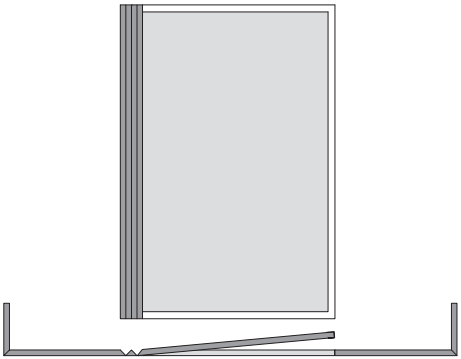
a) folding + header + sill
8 v-cuts + 32 straight-cuts



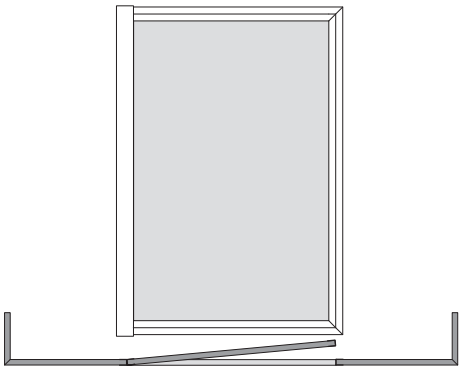
b) cut-in foldings
8 v-cuts + 12 straight-cuts



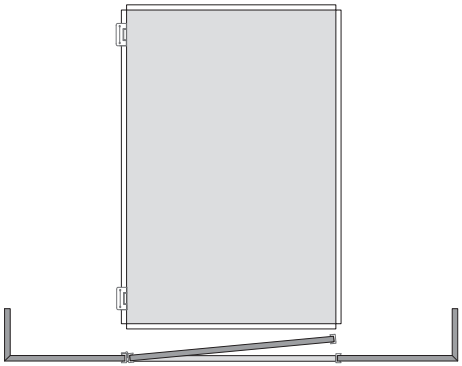
a) top-hung folding
2 v-cuts + 3 straight-cuts



b) side-hung folding
2 v-cuts + 3 straight-cuts



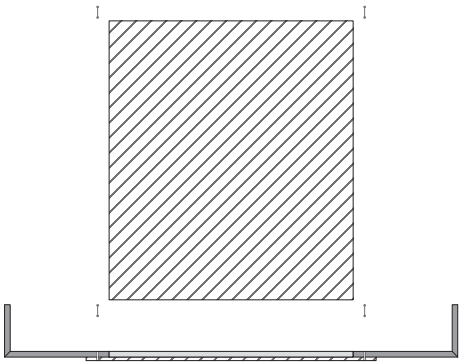
a) taped hinges
4 straight-cuts



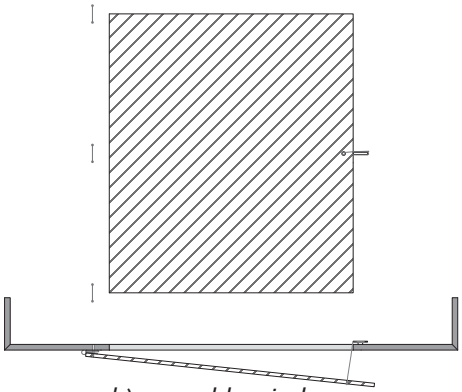
b) metal hinges
4 straight-cuts

SHUTTER HINGE

The connection between wall and shutter is strengthen by adding a hinge. In the first version the edges are taped, while in the second a u-profile ensures a better resistance. *Hard to find prefabricated profiles and expensive to custom make new.*



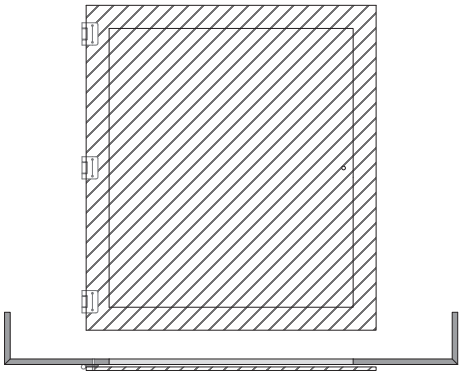
a) fixed window
4 straight-cuts



b) openable window
4 straight-cuts

2ND PROTOTYPE

A plastic sheet of 4 mm provides a better light inlet, while allowing the window shutter to be openable outwards without the material being damaged from the weather. The first version is fix, while the second has metal hinges and is closable with a string. The edges are taped. *Good resistance of material and hinges. Openable window is preferable.*



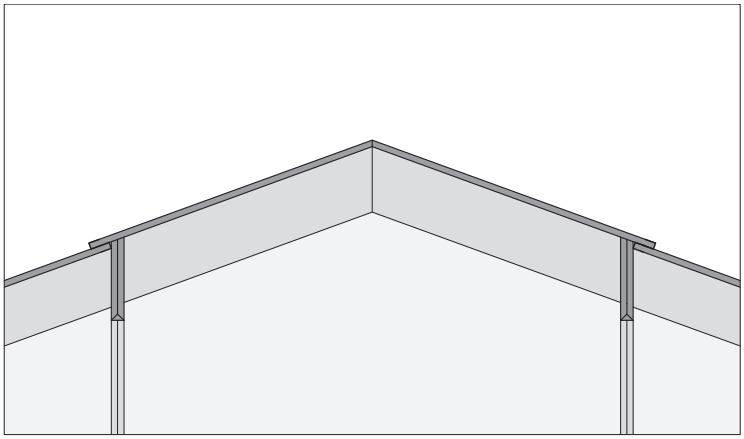
APPLIED PROPOSAL

For the final design the principle of the second prototype was chosen again with no further developments. Represented in the illustration is the appearance of the window from outside.

Roof structure

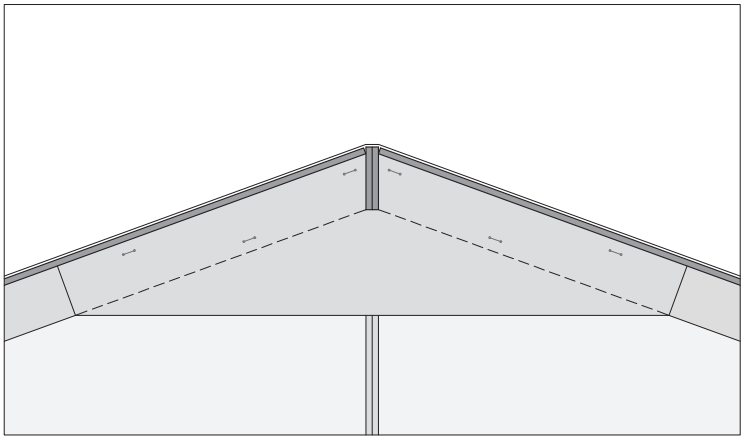
OVERLAPPING ROOF PANELS

To solve the water protection issue overlapping boards were chosen initially, thus avoiding the use of added profiles or tarpaulins. The roof was formed by six boards longitudinally arranged, the middle ones folded along the ridge. *The longitudinal arrangement of the boards limits the size of the house and does not allow to have integrated beams in the roof panels.*



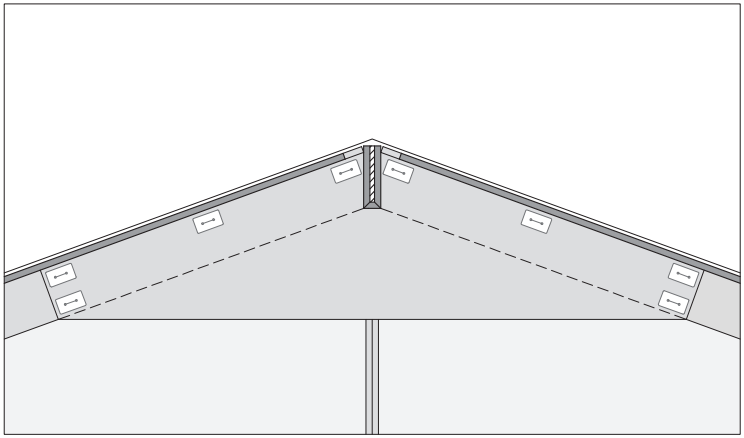
2ND PROTOTYPE

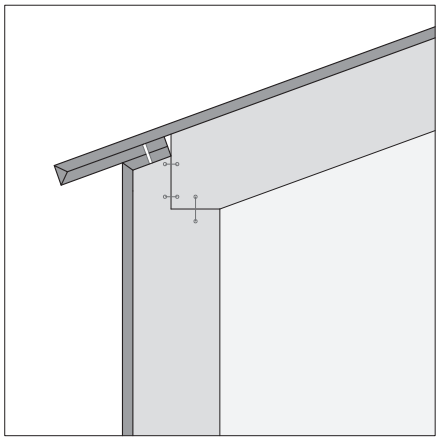
Shifting to a transversal arrangement of the roof panels helped to increase the size of the house and to obtain integrated roof beams, cut within the same panel and then folded out. The roof consists of eight boards; taped and folded inwards to become beams. The two-layer ridge beam covered by a plastic sheet rests upon a Re-board triangle which connects the two sides of the roof. *The roof structure and especially the ridge beam was under-dimensioned and needs to be more moisture safe.*



APPLIED PROPOSAL

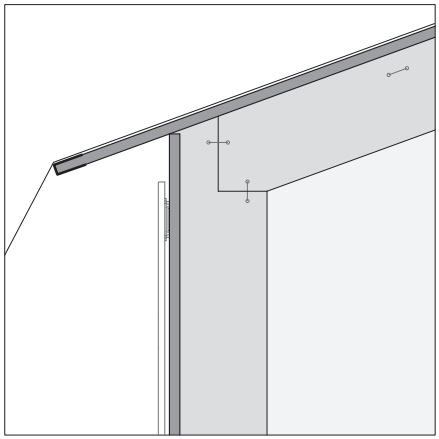
The roof structure is strengthened by adding a tertiary beam system, and by strengthening the ridge beam with a wooden core. The triangles are connected with the beams in the upper side, and by using plastic plates it helps distributing the tension in the connection on a larger area. To moisture proof the whole roof a tarpaulin is added, allowing skylights next to the ridge beam solving the problem of too dark interiors (see chapter 3.4).





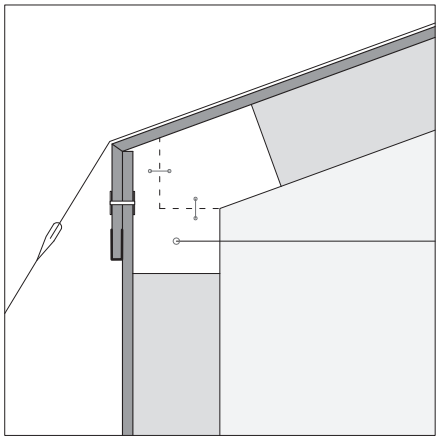
FOLDED OVERHANG

In the first version of the design the roof panel was folded inwards in the lower extremity. The fold allows to connect the roof with the wall panel without perforating the board, and to protect the open edges further by directing them inwards. *The solution requires many v-cuts and is a bit complex to assemble.*



2ND PROTOTYPE

Due to the necessity to contain the production cost, in the second prototype (see next pages) the connection between roof and wall sheets is simplified and realized only through the pillars and beams, which are connected in two points. The overhang measures 17 cm and the edge is taped. *Due to water absorption, the overhang bends and deforms, especially under the guy ropes.*



APPLIED PROPOSAL

After the evaluation of the second prototype some changes to increase structural capacity and durability were done. The roof sheets were folded in around the walls, so that the overhang is constituted just by the tarpaulin. The meeting between wall pillars and roof beams is reinforced adding a thin wooden board on each side, that helps in distributing the loads over a larger surface. The boards also are adapted to attach a tension wire connecting to the opposite wall and preventing the structure to deform.

2nd prototype

Size	4,2 x (4,4 + 1,2) m = 18 + 5 m²
Assembly	5 hours by 3 persons
Material	26 sheets 2400 x 1600
	81 m² Re-board used, 19 m² waste
	~ 1200 plastic cable ties
	40 m guy ropes + tent pegs
	5 x 5 m floor tarpaulin
	2 plexiplastic window sheets
	5 metal hinges
Weight	180 kg Re-board + 20 kg rest

Goal

Testing the digital fabrication and cutting of Re-board. Simplifying the assembly process and shortening the construction time. Testing the structural properties of the shelter and reflecting on the qualities of its space, which is 8 m² larger than that of the first prototype.

Assembly

Using cable tie connections was a much smoother than assembling with plastic screws. The walls were erected in less than one hour but it is necessary to simplify and speed up the construction of the roof, which had to be assembled on the ground.

Adaptability

Possible to adapt to geographical and cultural contexts by moving the front wall to have a porch or to have larger indoor area. Also possible to move front window to the back and freely place side window. The possibility to print directly on the material could be explored in the third prototype.

User perception

The positive value of self-assembly was clear even to us while assembling the house. When fully assembled the indoor space felt quite sterile, and to visualize a realistic scenario the shelter's single room was furnished with three beds, curtains for the windows and as internal partitions and a dining table. The floor plan area was sufficient to separate living and sleeping area, though there were some problems in partition with curtains due to the presence of the roof truss triangles. The covered outdoor space felt big and appeared valuable for cooking, storing belongings, washing clothes or socializing with neighbors. The windows felt large and low-placed, and if not screened with curtains this could expose too much the interiors and cause lack of privacy. One cost limited option could be to include curtain rod or bungee chords in the shelter package.

Assembly of 2nd shelter prototype in March 2014.

Durability

Re-board Outdoor appeared much weaker than the Premium version used in the first prototype, mainly because of the reduced thickness of the liner. Surfaces and v-cuts were more vulnerable to damages during the assembly, entailing a higher sensibility to moist and water infiltration. Rain influenced the waterproof capacity of the material already after some days, and the expected durability of at least one month was therefore not reached.

Moisture resistance

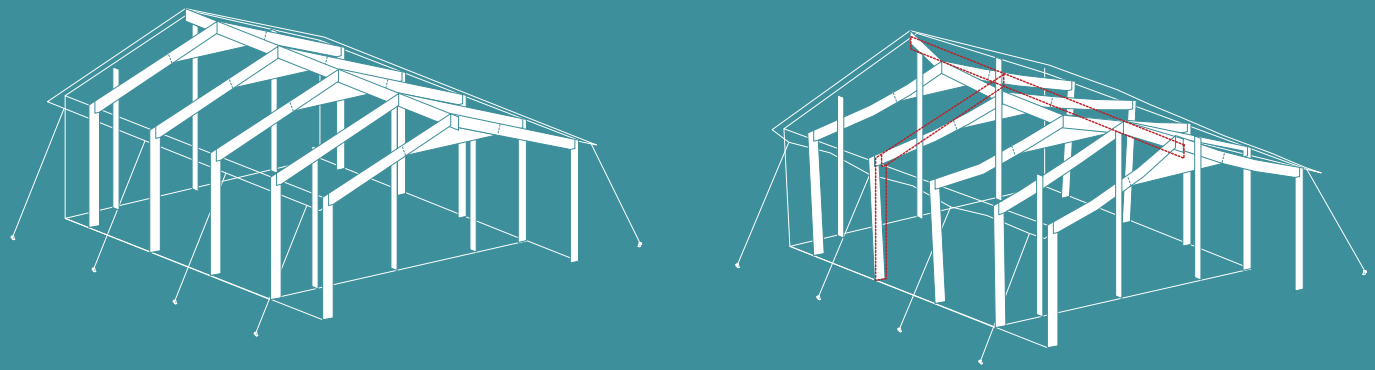
The decreased strength of the roof boards was accordingly caused by moisture infiltration and absorption of the board edges, enough to damage the entire board. An early problem was one of the taped roof seams and the overlapping rooftop detail. A roof tarpaulin was immediately added to protect the ridge of the roof, even though it was hard to stretch and set in place. The tarpaulin however prevented the water trapped underneath to evaporate. The moisture also caused deformation of the boards, especially the overhang under the pressure of the guy ropes.

Loadbearing

Because of moisture absorption the structure lost its loadbearing capacity, which resulted in the walls pushing outwards and the roof sacking. It is difficult to predict how much of the structural deformation was caused by the lack of strength in the material, the moisture infiltration or under-dimensioning of the roof structure. For future development it is recommended to troubleshoot the failure by first improving the moisture proofing and strength of the Re-board.

Cost

Comparing the two erected prototypes, the amount of Re-board used is roughly the same, even though the area of the second prototype is 50 % larger (see comparison to the right). The material is used more efficiently mainly because of the integrated pillars and the lower ceiling height. Though the waste almost doubled because of the more complex cut pieces, which thus increased the production cost. Besides the cost of the digital fabrication the second prototype is more expensive mainly for additional elements as tarpaulins, guy ropes, tent pegs and plastic sheet windows.



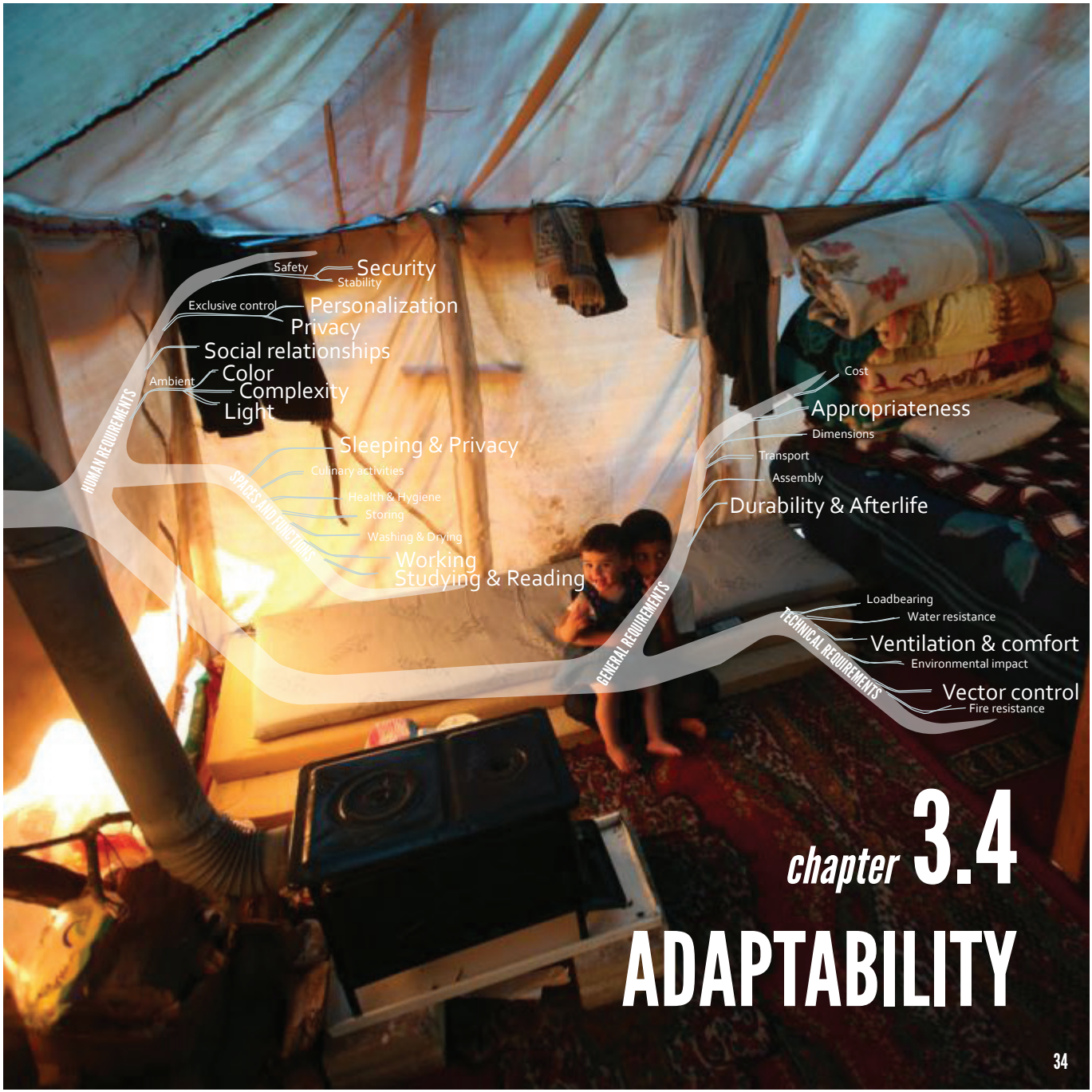
Structural deformation of the roof due to water leakage weakening the Re-board material.

1st prototype

PACKAGE	1600 x 3200 x 320
WEIGHT	200 kg
AREA	15 m²
TIME	6 hours by 4 persons
MATERIAL	93 m² Premium
WASTE	10 m²
ASSEMBLY	400 plastic screws
COST	USD $ 1200

2nd prototype

	1600 x 2400 x 420
	180 kg
	23 m² (+50 %)
	5 hours by 3 persons
	81 m² Outdoor
	19 m²
	1100 plastic cable ties
	USD $ 1700



chapter **3.4**

ADAPTABILITY

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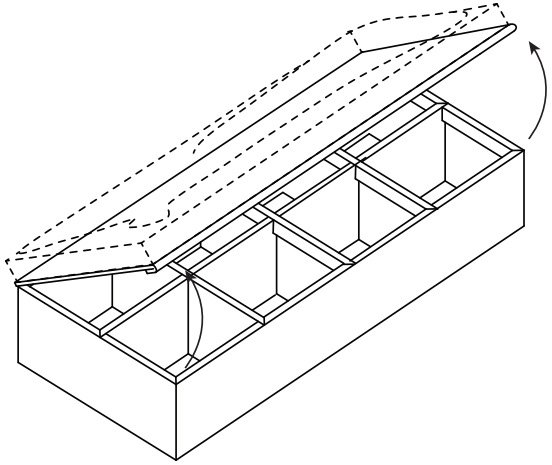
Furnishing

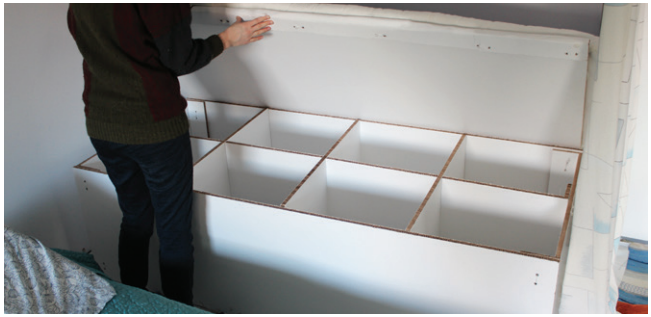
In the second prototype some experimentation of furnishing was performed by digitally cutting a bed in Re-board. The structure was adapted to contain eight boxes for storages, and at the same time work as a thermal pockets elevating the person sleeping off the cold ground. For the windows and interior partitions textile curtains were hanged up. We encountered problems with the partitions following the ridge, since the structural triangles were obstructing the sliding. The alternative of having Re-board as partitions walls could be considered: this could work at the same time as structural support decreasing the long span of the ridge beam.



The box storage keeps away vermin, but is ventilated.

Prepared mountings for curtains for more privacy.

The user can sleep elevated from the cold ground.

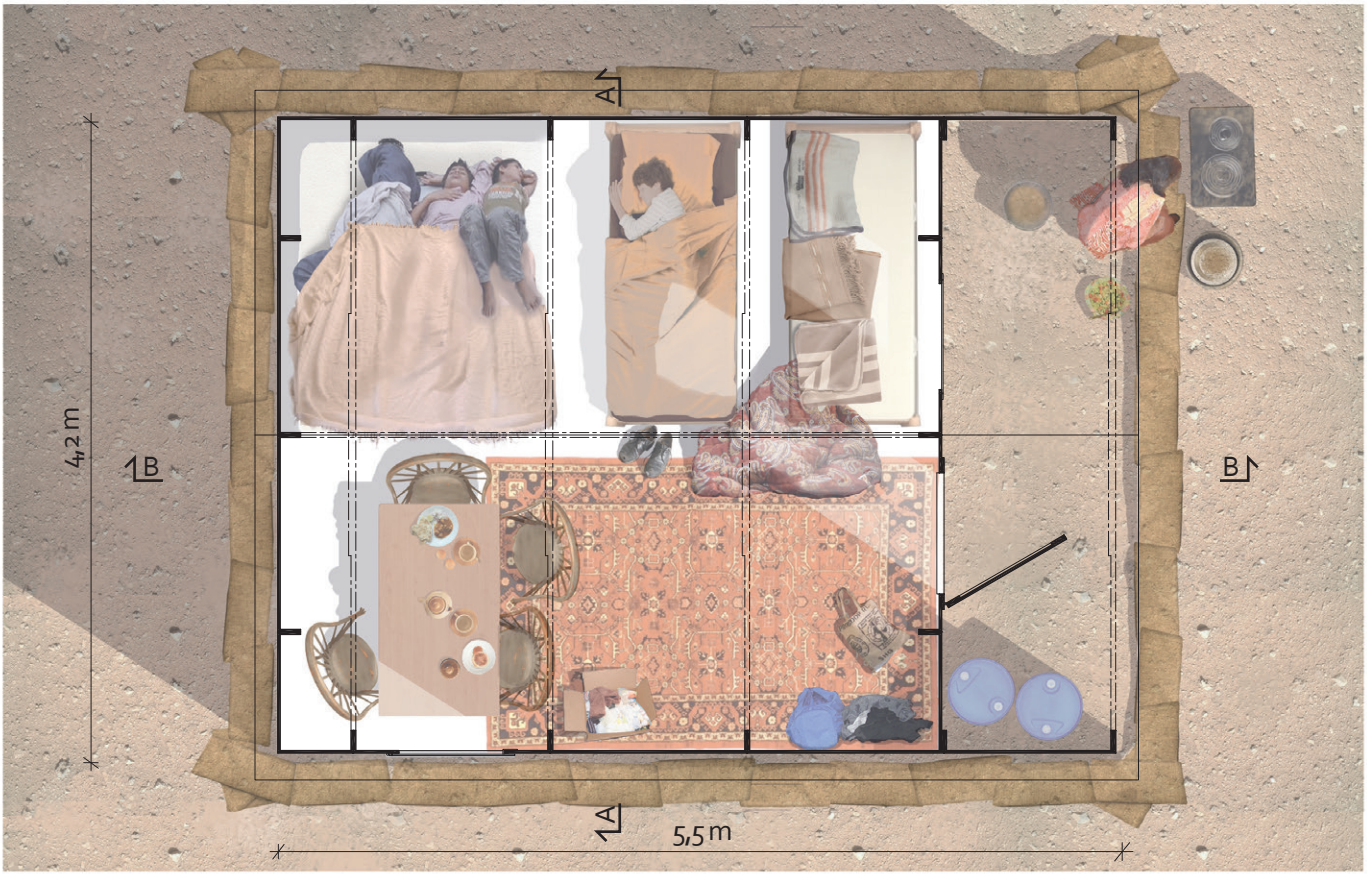


The bed box with 2 x 0,8 x 0,5 m of storage.

Context adaptation

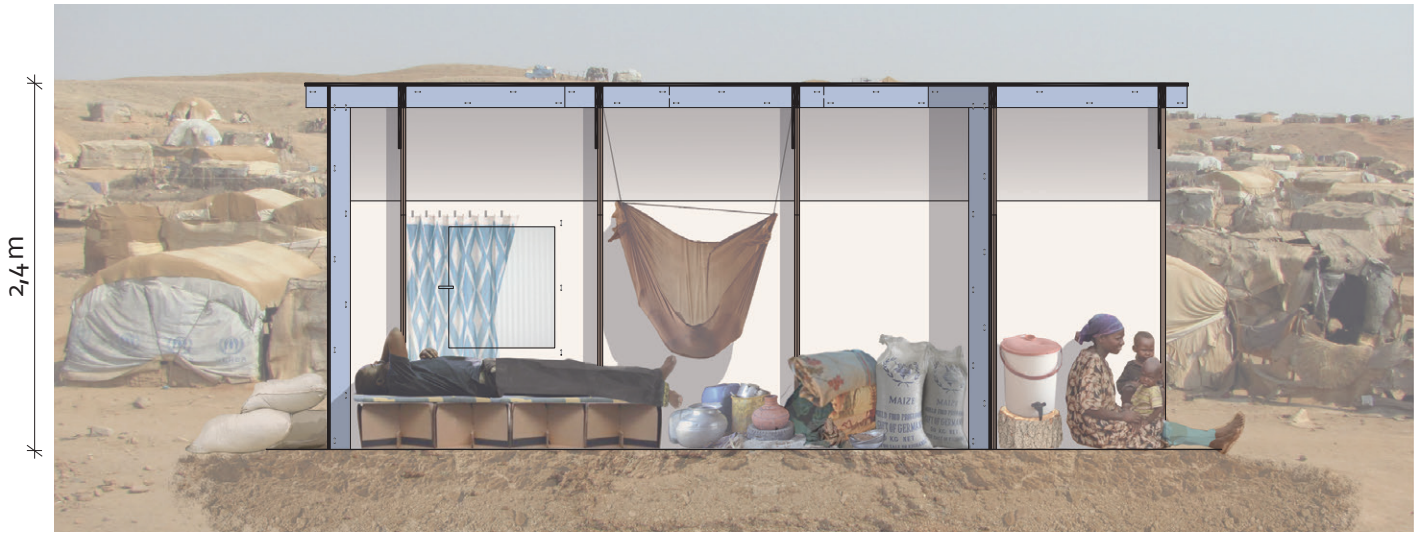
To illustrate the adaptability potential of the project, the shelter's drawings are presented considering different contexts. Later in this chapter alternative plan options demonstrate the possibility to address different scenarios of inhabitations and interior arrangements, depending on the user's preferences.

Perspective. Nakivale, Uganda. A thicker roof tarpaulin for extra roof cover is recommended for tropic wet climate.



Plan 1:50. Tamil Nadu, India. For a tropic wet climate sand bags can be used to avoid floodings.

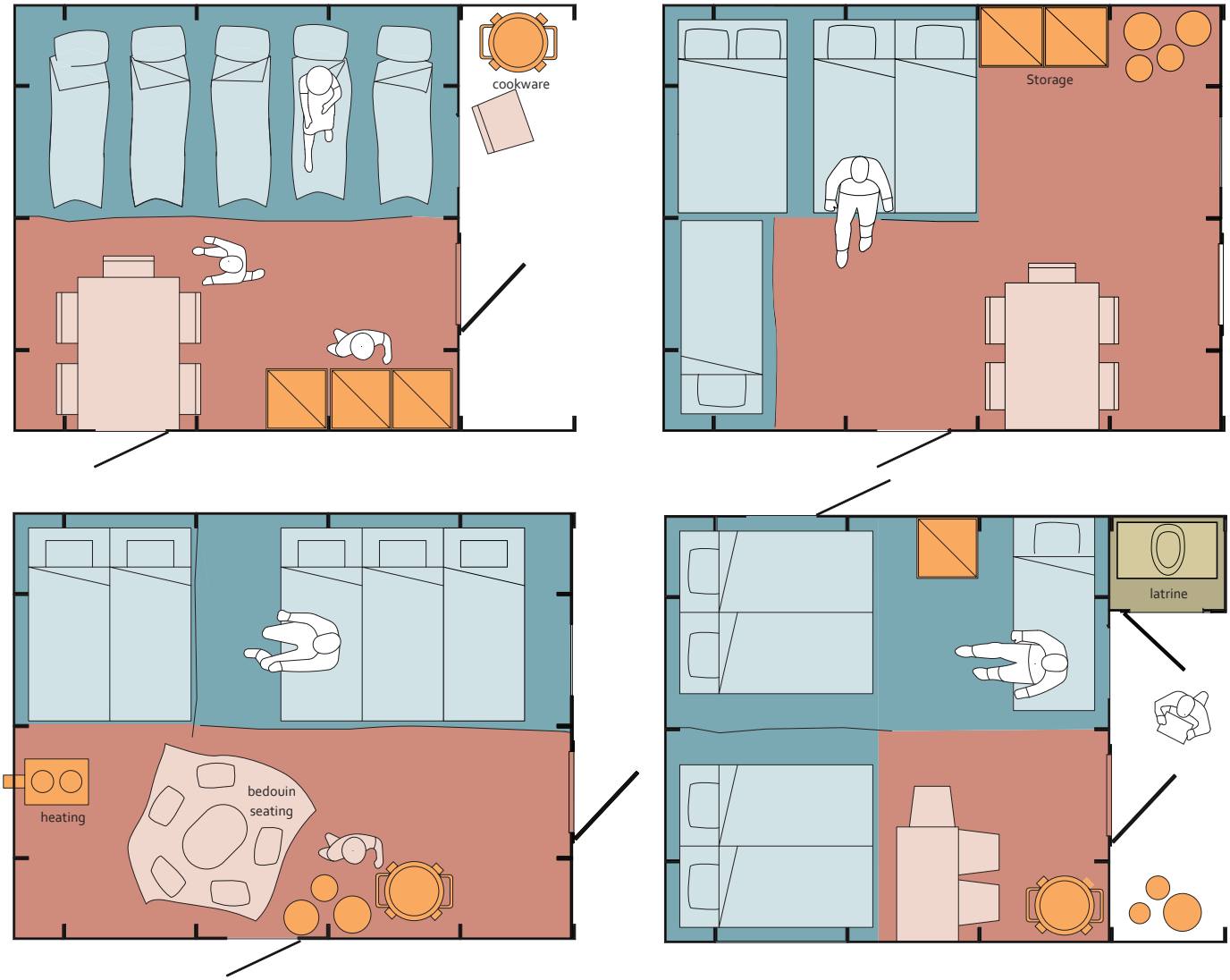
Section A-A 1:50. Beqaa camp, Lebanon. Locally built foundation and heating stove is recommended in cold climates.



Section B-B 1:50. Dollo Ado camp, Ethiopia. It would be possible to hang up curtains or light weights to the structure.

Alternative plan options

The following plans present a study on alternative interior arrangements that would be possible to reach basing on the design of the second prototype. We noticed the importance of maintaining the porch, that could be used to perform activities that require the use of water, for cooking or for social relationships.



The shelter's windows and front wall can be relocated depending on surrounding context and climate.

Appearance

We see a strenght in the possibility of adapting the appearance of the shelter to different cultural contexts and concepts of aesthetics. By printing on the material it would be possible to customize each shelter with patterns, instructions or aid organization logos. This would also create diversity in the camp, allowing each family to feel a stronger belonging to their house. However both color dying in production and printed patterns applied afterwards are expensive. In addition, camp regulations often require light colored shelters on the exterior not to be confused with military camps.

White exteriors are in many camps a mandatory.

Dark colored frames to enhance feeling of stability.

Varying colored houses to personalize neighborhood.

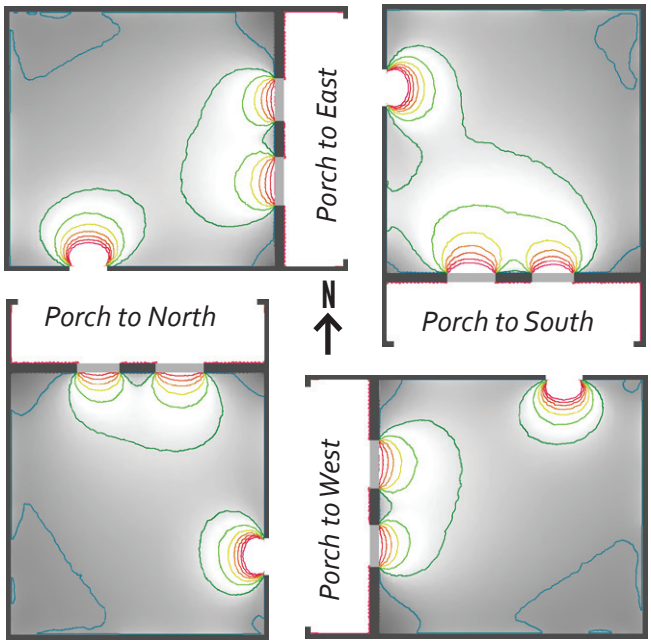
Varying colors to simplify and speed up assembly time.

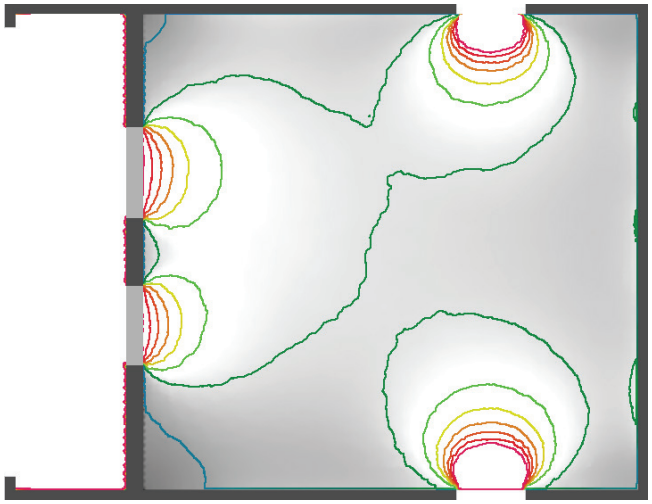
Patterns adapted to cultural context.

Daylight study

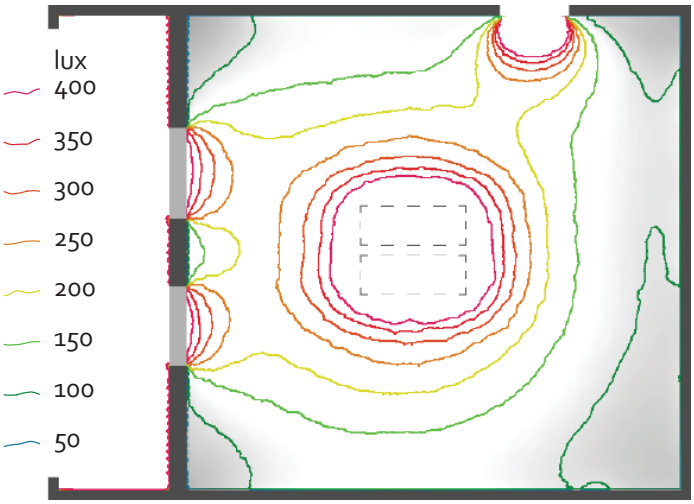
A simulation of daylight was performed in *Velux*. The proposed plan from chapter 3.2 was simplified, excluding interior pillars and beams but keeping the porch by imitating a large window in the front. The illuminance of daylight results in the sum of direct light and reflected light from internal surfaces. A recommended interior value of illuminance is around 300 lux, with a minimum of at least 100 lux. The location was set to South East Syria, in a sunny day in July. The small simulations to the right are showing the difference in daylight rotating the shelter. Since the simulations show low values of illuminance, two new simulations were done, one with an added window and the other with an added skylight. The option of having a skylight provides adequate illuminance to around 60 % of the interior space, which still is low so additional skylight(s) are recommended.

AL BUKAMAL, SYRIA, 12 PM JULY 21





Porch to West with added window to South.

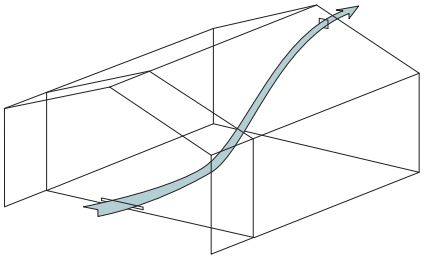


Porch to West with skylight.

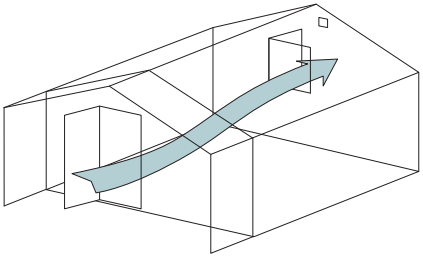
Natural ventilation

As earlier mentioned both overheating and freezing are big problems in shelter settlements depending on location and climate. While the hot climates demand a high air exchange rate, the cool climates demand a slower air flow to let the air get heated up by the body heat of the inhabitants, but still require enough air exchange to let pollutants out and bring in fresh air. In colder climates additional heating stoves and air tight envelope is required.

To allow a continuous steady air exchange for fresh air the stack effect creates a draft from a gap under the door to an added exhaust device in the top back wall. For hot climate the gable window can be placed in the back and if the room is overheated the door and window(s) can be opened to create a larger air draft, as seen in the figure down to the right.



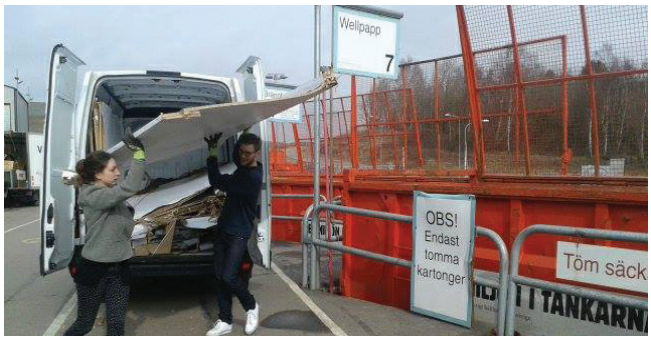
Concept of natural ventilation due to stack effect.



In case of overheating door and window can be opened.

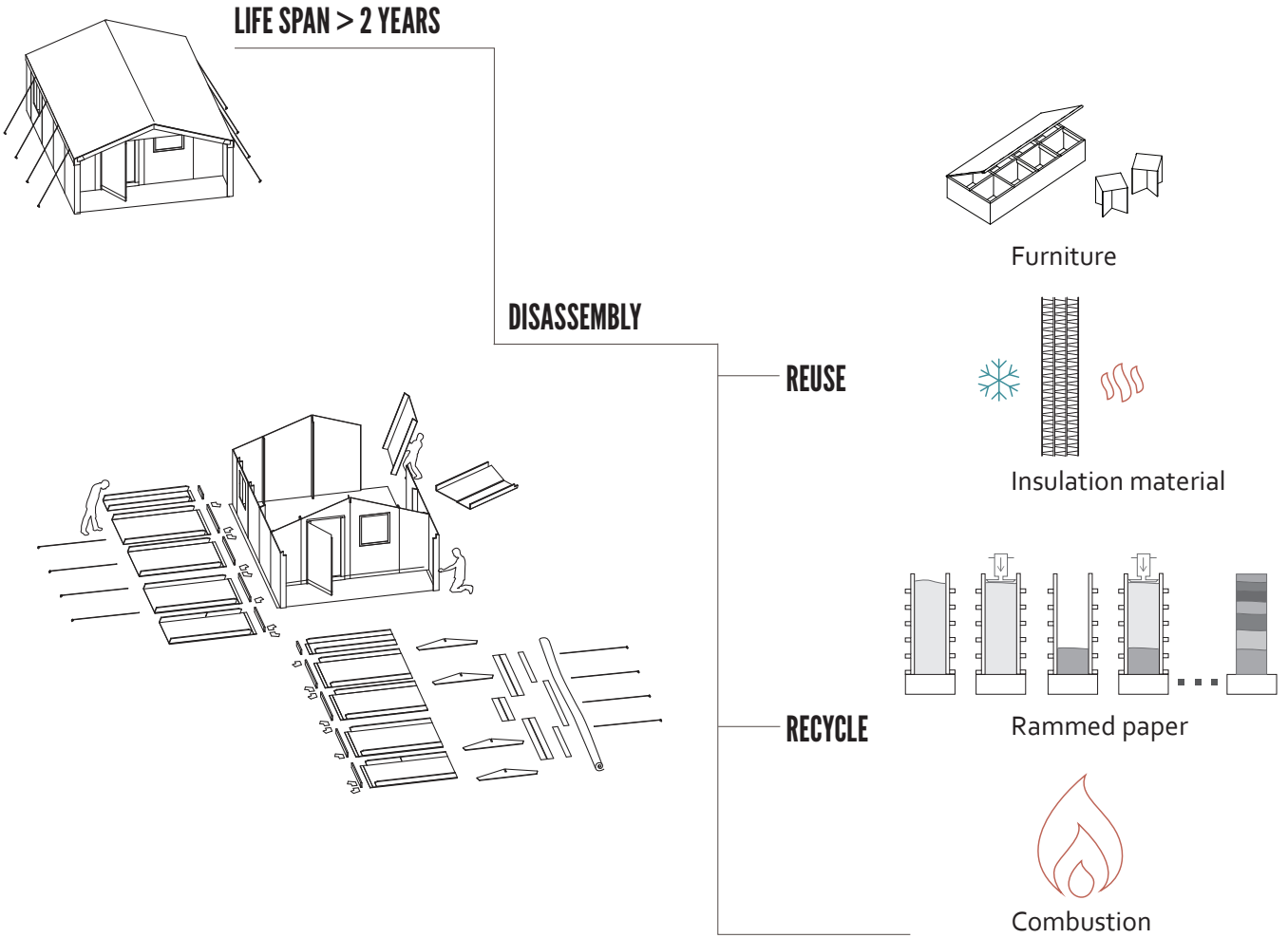
Recycling & afterlife

The afterlife of housing units is a large problem in refugee camps. Usually when shelters are damaged or reach the end of their lifespan prematurely, they are thrown away in landfills or get combusted. Some tents containing non-degradable plastics degrade slowly and releases phthalates, chlorides and formaldehydes into the air and ground water. As previously mentioned, a unique selling point of Re-board is its full recyclability, since both the thin liner of polyethylene plastic and the water-based adhesives can be recycled together with the core as paper. Not all refugee camps or hosting populations have access to waste treatment and recycling facilities.



Disposal of Re-board in bin for corrugated paper.

Rammed paper by Ásgeir Sigurjónsson.



To promote reuse of the material, as a link of going from transitional shelters to reconstruction, after the Re-board shelter has served its purpose it can be disassembled and the sheets can be used as for example additional insulation or turned into furniture. Otherwise, if the material is moisture damaged it could be possible to transform it into paper pulp. For an in-depth study of this process we refer to a master thesis at Chalmers on Rammed Paper (Sigurjónsson, 2013), showing the possibilities of reusing paper for structural purposes by applying the same method as rammed earth. By compacting paper pulp in a mold and letting it dry, the paper waste can come to new life as building blocks, pots, etc.

chapter 3.5

APPLIED PROPOSAL

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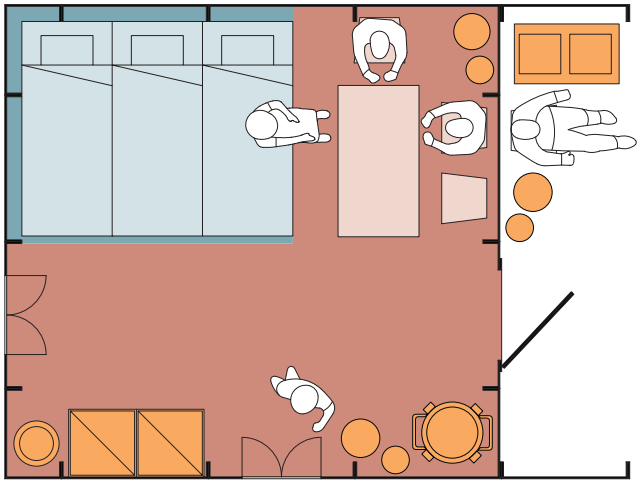
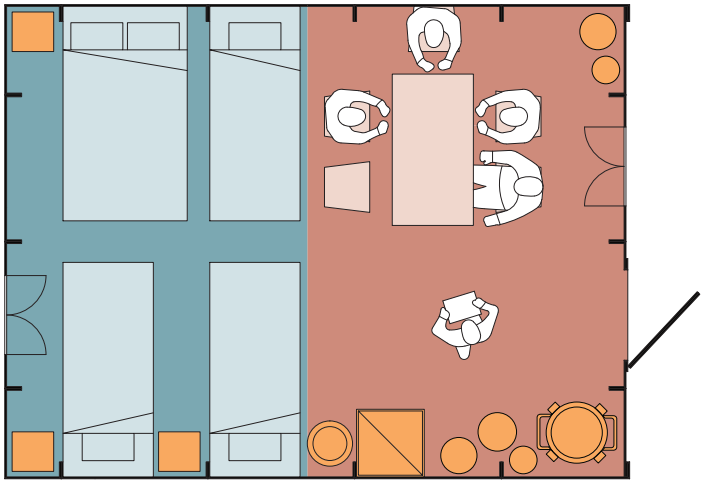
Meeting a Palestinian family

As a following step in the project we decided to adapt the shelter design for a specific context. We based this choice on the consideration of the climate zone in which most of the refugees in the world are hosted, and also basing on the interview with a Palestinian family who lived one year in a refugee camp on the border between Syria and Iraq. The contact was established through the Swedish Immigration Board. From the interview we got information regarding details of the life in camps, such as the constant feeling of insecurity, the lack of privacy and proper shelter facilities (no space to divide living and sleeping area, latrine indoor, etc.), difficulty of getting water since the station was far away and required to line for more than one hour every time. The wife worked at a pharmacy while the husband was helping UNHCR in transporting new-coming refugees.

"The biggest problem was security. One time the strong wind tore down our tent and we couldn't afford a new one so we had to repair it ourselves. Sometimes in the camp there were fires which spread rapidly because the tents stood too crowded. And someone of us always had to stay at home since the risk of thieves breaking in was big. At night you could see through the illuminated canvas, so everyone knew who was home. "

When confronted with our design proposal, the family reviewed it positively mainly for its solid appearance and for the large floor plan. The husband also liked the suggestion of a porch where he could have sold goods. For the islamic culture home is regarded as sacred and private, so the windows were preferred to be closable or placed higher. The family was asked to arrange the daily activities in functional areas (the results were similar to ours, pag.59) and to furnish the floor plan as preferred, with and without the porch.





Plans 1:50. Different furnishing proposals done by the family.

Settlement layout

To contextualize the design for the applied proposal Domiz camp in Northern Iraq (studied in chapter 1.2) was chosen. This location seemed suitable also for the arid climate, preferable for the moisture sensivity of the material. In Domiz, as a result of nationwide armed conflict, refugees continue to stream from Syria at a rate far surpassing expectations. The camp settlement is illustrated, highlighting the three main layout typologies. These are then elaborated with the insert of different layouts of Re-board shelters. Due its modularity and flexibility the shelter could be placed differently or combined in order to create a bigger residential space.

Domiz refugee camp.

3 typologies of settlement layout in the Farashin quarter.

Sleeping room

Food distribution

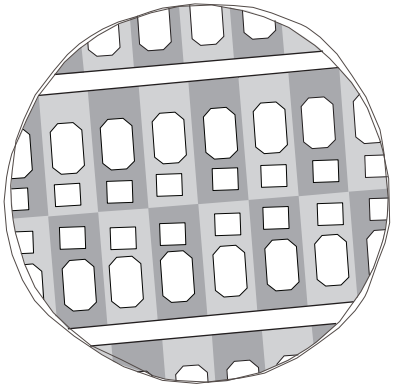
Community service

School

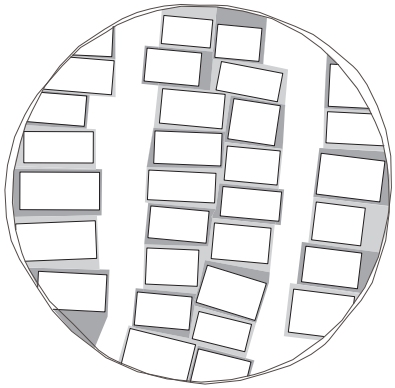
Arrival registration

Office

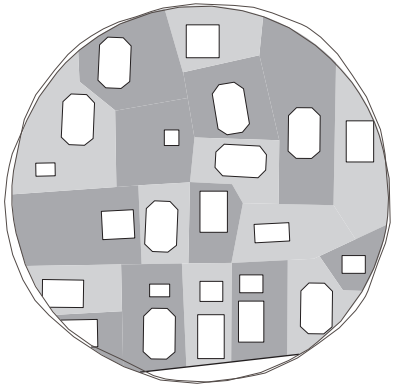
Typologies in Farashin quarter, Domiz



1. Planned line settlement
Private outdoor and
indoor space



2. Irregular line settlement
Public space and
private indoor space



3. Unorganized settlement
Semi-public space and
private indoor space

Implementation of Re-board shelters in the different typologies.

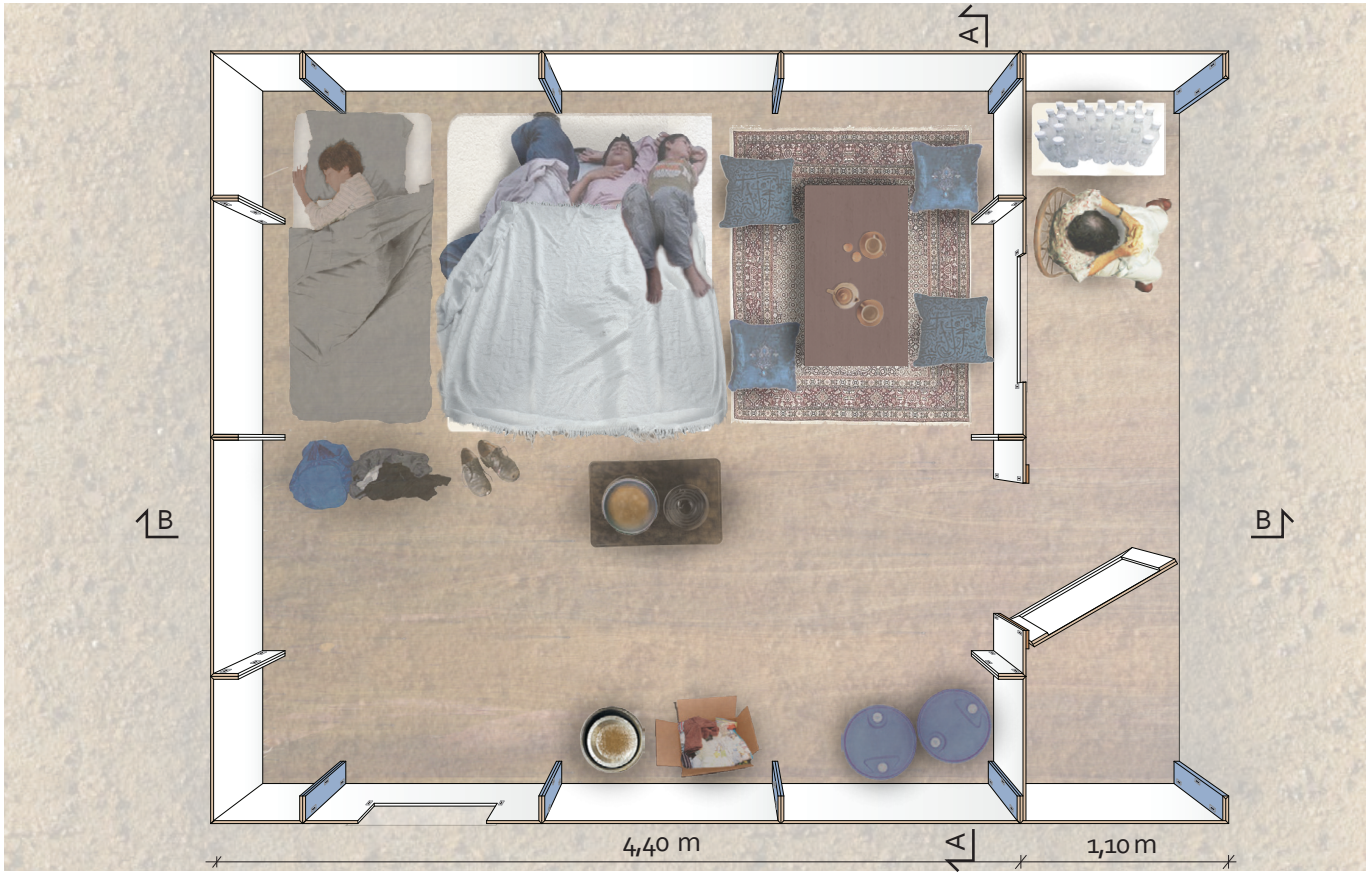
Planned settlement. The implementation of the 1st typology shown in aerial view.

Unorganized settlement. The implementation of the 3rd typology shown in aerial view.

Irregular line settlement. The 2nd typology shown from road.

Interiors

The following detailed drawings present a shelter designed to host five people, referring especially to the interviewed Palestinian family. The design of the applied proposal is meant as an improvement of the one implemented in the second prototype, and except for structural reinforcement it presents similar features. We decided not to have a Re-board flooring, as the optimal integration would be to build a foundation locally. This will also keep away dust, water leaks and vermins. The Palestinian family for example built a floor with wooden bars, which provided thermal comfort at night since they sleep on thin mattresses. A stove centrally placed in the shelter works as heating source and for cooking. To provide an effective water resistance, in this version a tarpaulin covers the whole roof. In order to withstand the strong winds in Northern Iraq, guy ropes are secured to the ground with anchors.



Plan 1:40

Cross section A-A 1:40

Longitudinal section B-B 1:40

chapter 4

CONCLUSIONS

chapter 4.1
DISCUSSION

Resume of design results

In this chapter the conclusions are subdivided between the evaluation of the applied proposal in itself and in comparison with another similar paperboard shelter project, the recommendations for product development and the discussion of the results in relation with the initial research questions.

The process evolved as an integration of academic research and fulfillment of the design improvements needed for the product development. During the iterative design process we brought forward different aspects and tried to find solutions for those that appeared to be the main issues: cost and transport limitations and provision of effective water resistance. The design results were implemented in three prototypes realized in January, March and June 2014.

The 1st prototype experience was useful for understanding the properties of the material and the construction techniques, even though we realized the necessity to shift to a faster and easier assembly process. In the 2nd prototype we studied a structural system with sheets folded inwards to create pillars and beams, and connections based on cable ties. The strategies adopted for protecting the edges from moisture absorption seemed to be still insufficient, which led to the necessity to use a protective tarpaulin on the whole roof for the 3rd prototype. Here we developed a structural reinforcement and a more detailed solution for connections and assembly techniques, such as using plastic plates to protect the holes and assemble the roof board by board. We also experimented with digital drilling and printing of patterns on the material.

3rd prototype

The third prototype follows the design of the applied proposal in the chosen context of Domiz, Iraq. It was digitally cut and partially erected for the final exhibition at Chalmers in the end of May 2014 and entirely built in June 2014. Given the time limitations, the evaluation of the prototype is restricted to the construction process. The response to the elements is being tested.

AREA	4,2 x (4,4 + 1,2) m = 18 + 5 m²
MATERIAL	26 sheets 2400 x 1600 86 m² Re-board + 2 m² plywood 1400 cable ties + 500 plastic plates 20 m guy ropes + tent pegs 50 m² tarpaulin floor & roof window + hinges (same as 2nd)
WASTE	14 m²
ASSEMBLY	4 hours by 3 persons
COST	USD $ 2000
PACKAGE	3 x (1600 x 3200 x 450)
WEIGHT	190 kg Re-board + 30 kg rest

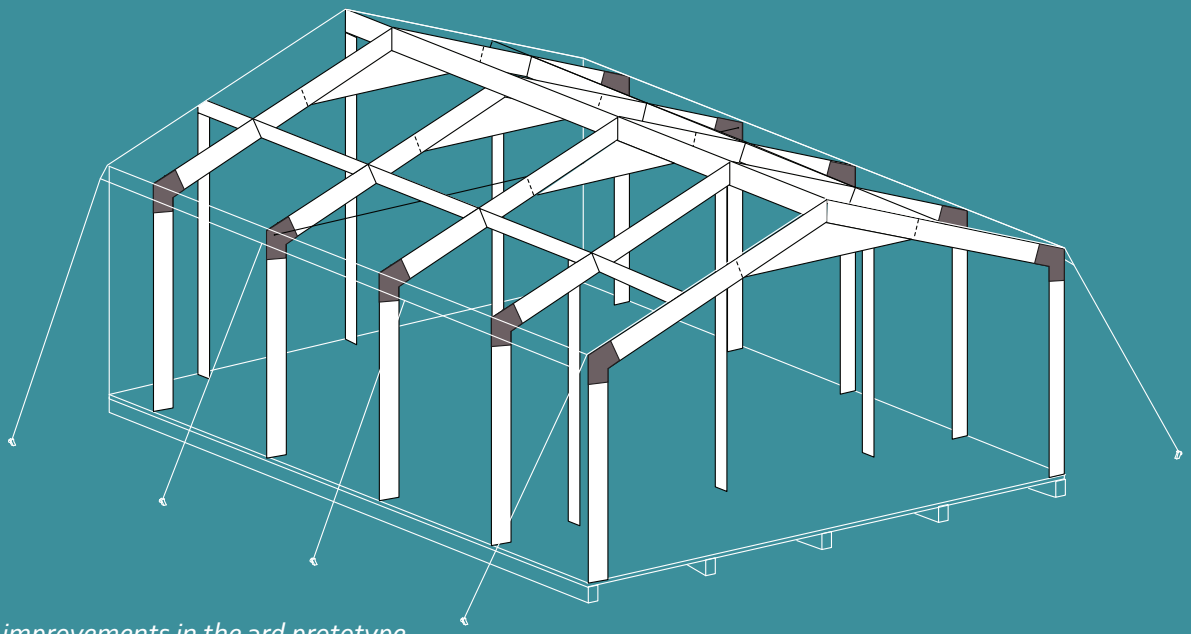
Goal

Testing the improved structural system and the waterproof capacity of tarpaulin as a cover of the entire roof. Testing the digital drilling and printing.

Fabrication

The 3rd prototype was built in Re-board Premium as the strength of the liner of the Outdoor version still was under development after the evaluations from the 2nd prototype. Besides the through-cut and the v-cut, already experimented during the fabrication of the 2nd prototype, we had the possibility to try out digitally drilling the 6mm holes. The process went smooth, and with the pre-drilled holes the assembly resulted much faster and precise even if not all of them were perfectly perforated. In order to protect the holes, plastic plates were used to substitute the pipes. The plates were laser cut in the workshop at Chalmers. This solution allowed to prepare all the components in a very short time, but with a higher material cost. The 3 mm plywood plates that strengthen the connection between the pillar and the beam were also cut digitally at Chalmers.

Wooden plates and plastic plates.



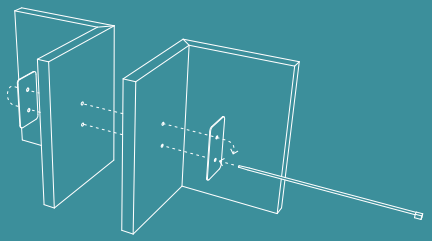
Structural improvements in the 3rd prototype

Transport

Considering the previous experience, in order to have a clear understanding of the weight and the volume of all the components needed to build the house, we packed the boards and the other material needed in 3 packages. The weight for each package was around 73 kg, allowing an easier transportation for 2 people.

Assembly

The process of assembly went faster thanks to the pre-drilled holes and the construction of the roof proceeding by single boards. In fact by using a tarpaulin that covers the entire roof it is possible to skip the taping of the creases and the assembly on the ground. This solution reduces the number of people needed previously to lift the complete roof parts. Even though there would have been the possibility to insert tension wires in the wooden plates to ensure resistance to wind loads while assembling the walls, due to the higher rigidity of the Premium boards this appeared as unnecessary.



Plastic plates were used to strengthen the connection.

The 3rd prototype partially assembled at the final exhibition at Chalmers in May 2014.

To solve the weak connection between metal hinges and Re-board, as it is for door and windows, an extra wooden layer is inserted around the door in order to distribute the tension concentrating in the holes. Printed instructions or numbers directly on the boards could facilitate the assembly further.

Door and window in detail.

User performance

The presence of pre-drilled plywood plates in every pillar provides an easy support for hanging cables, curtains or other items. The necessity of increasing the amount of natural daylight received in the interiors combines with the need of preserving the privacy. In this way the skylight works very well to let sunlight in without revealing the interiors.

Adaptability

The possibility to switch the position of windows and door around the perimetral walls allows to adapt the arrangement of the shelter depending on the characteristics of the surrounding environment. By printing on the material opens up to the customization of the appearance depending on the local preferences and aesthetic. As a demonstration, we chose to decorate with an Arabic geometrical pattern the front beams and pillars.

Thermal comfort & ventilation

The ventilation is improved by facilitating the stack effect: the air circulates from a small gap below the door to the vent positioned high up in the back wall.

Structural performance

Considering the structural problems of the previous prototype, in this version we improved the structural capacity by adding a tertiary beam system, formed by double Re-board beams as an additional connection between the roof panels, and reinforcing the ridge beam with the addition of a plywood core. The walls could be kept together by adding tension wires, connected to the top of the pillars through wooden plates. By folding the roof panels and connecting them to the walls stabilizes the whole structure and directs the vertical tension of the roof downwards, preventing the walls to bend.

Waterproofing

Due to the extreme sensitivity of the board edges to water infiltrations, we decided to cover the whole roof with a tarpaulin and eliminate the rooftop detail. Extended beyond the walls, it creates an overhang of 20 cm, that substitutes the problematic overhang made out of Re-board. This solution makes it easier to stretch the tarpaulin and to pass ropes through the extremities. All the open edges are sealed with tape, which is the cheapest solution in prospect of a more appropriate material development, but is in aspect of lacking durability less recommended than a prefabricated sealed edge.

The 3rd prototype fully assembled in June 2014.

Comparing our results

During the last phase of master thesis work, in April 2014, an experimental project called *Origami Paper Houses* was released and caught our attention for being a post-disaster shelter built in paperboard. The project, developed by the architects from *Architecture Global Aid*, a group based in Spain and Japan, aims to lower the cost of emergency shelters and to be easily transported and assembled The project was exhibited in April 2014 at the Association of the Architects in Jaén, Spain. The comparison with this project is a good opportunity for us to acknowledge the strengths and the weaknesses of our proposal.

As we have concluded from the reading of the main aid organizations requirements, the minimum covered living area per person is 3,5 m^2 in a warm weather environment. We considered this dimension as one of the fundamental requirements to fulfil, obtaining a total area of 25 m^2 and a 4,6 m^2 per capita. Instead, the Origami Paper House has a total area of 1,5 m^2 and it claims to host up to 3 adults, which makes a surface of 0,5 m^2 per capita.

The main issue that the project leaves unsolved is the water protection of the material. The open edges are exposed both indoor and outdoor. This is also due to the choice of an interlocking construction system, that speeds up the assembly process but implies additional waterproofing strategies to be feasible.
The door and the window shutters are simply cut through the material, and foldable along the lateral v-cut. We initially considered this less complex connection, but we finally excluded it because of its fragility: the shutter is in fact hanging from nothing more than the liner, which will be likely damaged in a short time. The door is formed by two full-height openable panels, that work as the main source of daylight but that cannot be locked or kept closed. When considering a paper material security is a challenging aspect to address, and in the Origami Paper House the extremely easy permeability proves no attempt to ensure the protection of personal belongings. The contained dimension of the house allows the walls to be loadbearing without using additional pillars. However, the house should be able to withstand heavy wind, and due to the light weight of paperboard it would require a strong consolidation to the ground, which is here missing.

In conclusion we believe that the project could be more suitable for collective shelters, where the displaced population is hosted in pre-existing facilities, rather than for planned or self-settled camps. In this sense the house would mainly serve as partition system in a bigger crowded space, not addressing issues such as loadbearing capacity or water protection.

Origami Paper Houses, by Architecture Global Aid.

Research questions

Enabling dignified living conditions

Planning for emergency housing requires a strict fulfillment of the requirements set by international authorities and organizations, and to adapt the design to the limitations dictated by transportation and logistic. Through this research we have noticed the real need of development in this field in order to develop a shelter design that is more user oriented, but we have also understood that even though a good shelter design would provide better living conditions, housing is just one of the many factors that contribute to the well-being and rehabilitation of affected population.

By adapting the design to the limitations dictated by transportation and logistic, and considering the necessity of developing a low-cost design proposal, the danger is to neglect the user perspective and the actual utilization of the shelter. Aware of this aspect, besides watching movies and documentaries, we initially planned to set up interviews with immigrant families with direct experience in refugee camps. This would have enriched our perspective and balanced the sterile and impersonal notions we can extrapolate from the official documents. Unfortunately it was harder than expected to get in contact with refugees or with local organization that act in this field. The few families that are hosted in Sweden are in fact scattered around the country, and as reasonable considering the protection of privacy, it is hard to get in contact with a specific family. Helped by the Swedish Immigration Board, we finally got in contact with a Palestinian family who lived for one year in a refugee camp on the border between Syria and Iraq. The warm welcome and the way they openly told us about their experience made the meeting very successful and enriching, from the human point of view and for the formulation of a more adapted design proposal.

We recognize the impossibility of getting contacts during the time span of our thesis as a limitation of our proposal, that could have otherwise been stronger. However, throughout the process we have been able to increase our awarness and knowledge about a design development that balances effectively production cost and good quality of the environment.

Appropriatness to cultural and social contexts

The shelter is not assigned as ready made but actively built by the inhabitants thanks to an assembly process that eliminates the need of specialized staff and particular tools. The participation of future occupants in the construction consolidates their bond with the house, promoting self-reliance. The features of the house are not pre-set but can vary depending on the preferences of the inhabitants. This flexibility is partially achieved in the design proposal with the possibility of changing the position of walls and windows and to create the preferred settlement (combining two or more houses, placing them side by side, sharing the porch, etc.) given the modularity of the house.

Prioritizing of human needs

The human needs that we considered as the most important in the creation of a state of well-being in the house are safety and privacy. The experience of continuity and stability that characterizes the home

environment is ensured by the achievement of a safe and solid house. Thanks to the ropes that consolidate the house to the ground and the increased structural capacity, the life span of the house is expected to be up to a year, lasting six months more than an average tent. The durability could be extended through material development and waterproofing strategies, therefore providing the possibility to prolong the hosting time until shifting to a transitional or permanent housing solution. Safety in camps does not mean just protection from natural hazards and diseases, but also the protection from burglaries and robberies. In the design proposal the door is lockable from inside and outside.

Privacy is a fundamental issue in a densely populated environment as a refugee camp. We addressed this issue by having interiors that are wide enough to allow the separation between sleeping and living area and by providing a protected outdoor space, that could be used for social interactions or for activities that require the use of water or fire. In fact we decided not to compromise on the dimension of the house, even if reduced dimensions would have brought less structural problems, obtaining a final floor space of 4,6 m^2 per capita, 1,1 m^2 bigger than the standard for UNHCR tents.

Developing a design solution that could successfully address a diversity of cultural and social contexts is partially achievable considering the strict economic limitations. Our solution is based on a modular construction system that allows a certain flexibility in the disposition of the walls. In a warm climate for example, the presence of a porch is valuable, as it orienting windows in order to maximize natural ventilation.

Stable and safe shelter in paperboard

Paper is definitely an unusual material to use for the construction of emergency shelters, due to its general fragility and sensibility to water. However, as a result of the thesis we state that it was possible to achieve the construction of a stable and safe shelter with a paper material. Re-board in fact demonstrated to be easy to manufacture, easy to store and transport, assemblable with almost no tools and resistant to weather. Other benefits that distinguish this from other emergency shelters are the opacity of the material, that prevents silhouettes to be visible on the walls even when the shelter is illuminated and its full recyclability.

Working with such a untested material as Re-board for building construction meant that our process was therefore slowed down by the necessity to get to know the material properties and to elaborate the most appropriate connections and structural details. Therefore, the collaboration with Imnus™ and Stora Enso also resulted in material development process, as we had several meetings where we discussed failures and expected performance of the material.

With the advancements in materials engineering, in the future it will hopefully be possible to make use of environmentally friendly and recyclable materials that be both durable and economically feasible for post-disaster housing.

Recommended development

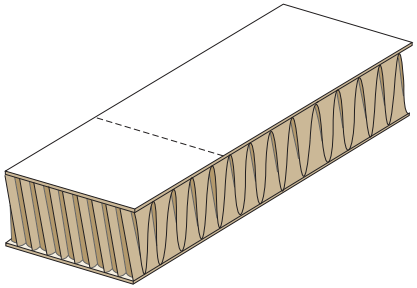
Re-board shelters have potential to become a sustainable and ethically justifiable alternative as post-disaster housing solutions. The great selling point of the project as a commercial product relies mainly in its simple and fast manufacturing process.

Being similar to transitional shelter for higher durability of the material, the product can be distributed in an initial stage because of its light weight but still exceptional strength. These properties, combined with the possibility to print on the material, as tested for the 3rd prototype, allow to adapt the shelter's appearance to a multitude of climatic and cultural contexts. We imagine that in the future it will be possible to formulate a range of different designs and packages adapted for different contexts.

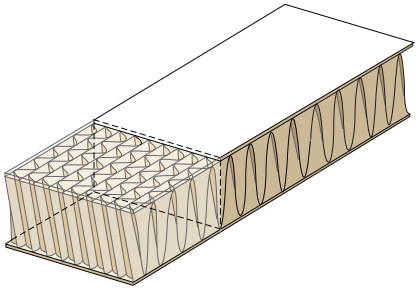
Sealing Re-board in manufacturing

The development of Re-board for outdoor use still has some way to go to be able to offer a sealed and watertight product, which can be durable for two years or more.

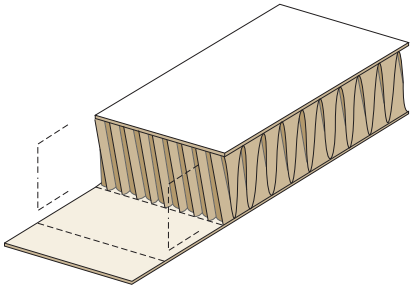
Imnus™ is still in a start-up phase but have the ambition in a few years to have a product ready for a pilot project.



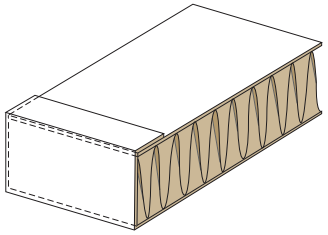
1. The surfaces cover both sides.



2. A "kiss cut" is removing 1 liner + core.

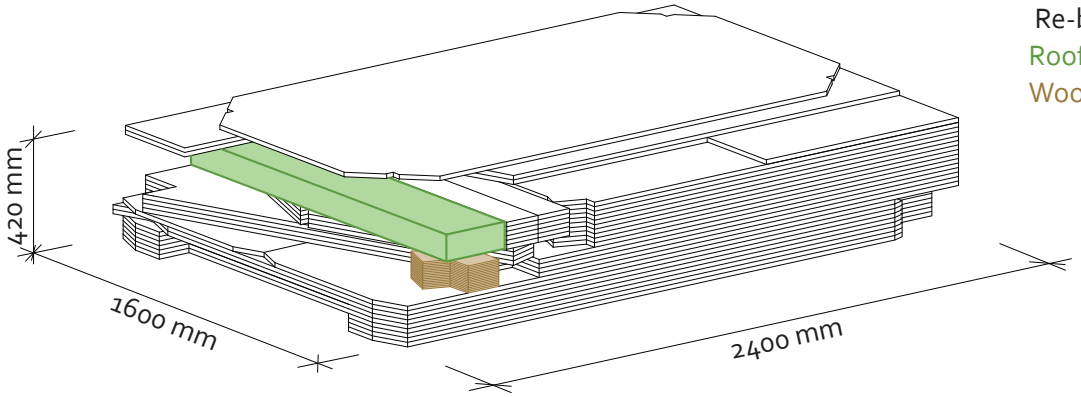


3. The liner is folded up...



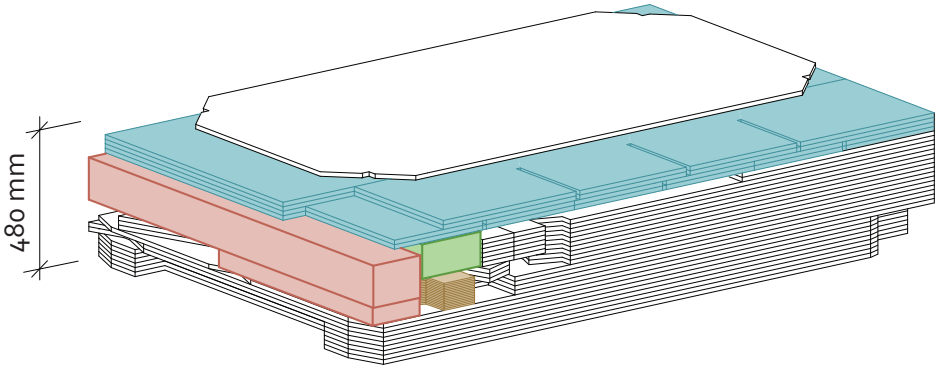
4. ...and attached with adhesive.

Example of packages adaptable to varying contexts



Re-board
Roof tarpaulin & guy ropes
Wooden plates

a) Basic package 23 m² Re-board shelter



Re-board
Roof tarpaulin & guy ropes
Wooden plates
Re-board beds
Sandbags

b) Extended package 23 m² Re-board shelter

chapter **4.2**

REFLECTION

38

Increasing need of aid relief

The last 50 years, since 1964, natural disasters have increased by more than 10 times and refugees due to war and conflicts have more than doubled (Leaning & Guha-Sapir, 2013). With the predicted amplification of the greenhouse effect the need of emergency relief will grow caused by increasing draught and conflicts over limited resources (IPCC, 2014). The necessity of more durable but still affordable shelters in planned camps is a critical issue when the number of refugees and internally displaced peoples is increasing.

The architect's perspective

Studying the basic living needs of people in relief situations can provide insight on how we as architects could improve living conditions, not just for emergency shelters but in all types of living. This thesis has discussed the correlation between the fulfilment of human needs and subjective well-being, and their connection to the essential qualities in the home. Emergency shelters are restricted to provide only the most basic qualities in a limited space. Comparing the floor area of 3,5 - 5,5 m² per person in refugee dwellings with Sweden where we today in average live 2,1 people on 92,8 m² (SCB 2008), it could be questionable if this large space is excessive. In the last century there has been an ambition in developed countries to reduce the amount of overcrowded accommodation and improve living comfort. However, today we reached a turning point were we need to lower the energy consumption by reducing abundant space. Summarizing our research we have found out that there are factors far more vital in homes than a large space, for example the feeling of safety and adequate privacy.

The environmentalist's perspective

The field of post-disaster housing unites the principles of social, environmental and technological sustainability together with economics, logistics and politics. By looking into smarter and more compact living we as architects are also addressing sustainable development. This is an important responsibility since we in the developed countries live above our means in terms of affecting our environment. Today we are using resources 3 times faster than Earth's ecosystems can be renewed and we are emitting more than 10 times of the greenhouse gases allowed yearly for the atmospheric content to stabilize until 2100. Of this approximately a third is related to housing (SNF 2013). In a more environmental aware society we have the insight to question if this improved living comfort and consumption in the long-term cause far worse global effects on climate, economy and welfare.

Ecological materials like Re-board

The low level of greenhouse gas emissions from Re-board compared to alternatives as plastic and metal frames speaks in favor for the material made of cellulose and water based adhesives. However, it can be questioned if transporting emergency shelters fabricated in the Nordic countries down to equatorial-located disaster-affected countries is the best thing to do. Locally produced material is a good option if they are not harming the environment due to deforestation or pollution. But due to major emergencies where thousands of people becoming homeless there is often no other option for aid organizations than to fly or ship in shelters from the nearest located warehouse, often thousands of kilometres away.

Collaboration with a company

Writing a master thesis in collaboration with a company creates a realistic and pragmatic atmosphere of design development. Having Imnus™ assisting us in carrying out the design prototypes and giving us supervision was very helpful; the collaboration was close with reciprocal feedback. However, getting constant reminders of financial and organizational restraints was sometimes repressive for elaboration in the design process. Many of our design solutions were neglected after a discussion with Imnus™, realizing it was too complex for the user to assemble or too expensive to fabricate. In the end the process became a long chain of choices against a simplified design. From an objective perspective the final outcome could be perceived as a shelter that more resembles a shoebox than a home if one is unfamiliar with the subject matter. There was however an extensive development of the concept where we found some important design principles that should be kept: the simplicity in assembly, the adaptability to cultural context through varying appearance and level of privacy, modularity to adapt to family size and climate, and the indoor comfort of added flooring (preferably locally built). Thus the result may seem simple, yet there was a complex process behind it with many carefully weighted solutions.

The implementation of emergency shelter aid is a conservative industry unwilling for large changes. The largest aid organizations demand documented assurance that the shelters have been tested to fulfil the requirements. Imnus™ is in the start-up phase as company and still have some time of improvement and testing before they have a shelter ready for pilot project endorsed by an aid organization partner. From Imnus™ side, employing two architectural students to develop the shelter design, they agree that the aim of the thesis has been complied with satisfying result.

The team of Imnus™ Emergency Housing.

Presentation at the mid-term seminar.

Personal reflections

Reflecting on what experience we as students had at the start of this thesis and where we reached afterwards, we see a significant growth in our deeper knowledge on the subject of post-disaster housing. The insight of complex logistics, politic issues with numerous stakeholders involved and an abiding deficiency in funding have made us more modest to the fact that so much is in need of improvement.

Speculating on future plans for Imnus™ has been done under *Recommended development* in the last discussion chapter. Future work to be done in general terms of research on how to improve living conditions for displaced people is recommended, especially from an user perspective. Personally we would have liked to research further on the essential qualities of the home and the connection to health recovery of traumatized people, since it is relevant for many architectural fields, both housing and healthcare.

To sum up this thesis approaching an end we will try to personally answer the question: what has been the most valuable learnt lessons from this project?

"I see the strength of the design development in the close collaboration with Imnus™ and the construction of three prototypes which made us realize some simple things; for example that assembling with plastic screws manually most likely result in blisters and that you value something much more that you built yourselves."

Jonas Lundgren, 2014

"I learnt that such a complex issue as post-disaster housing requires new solutions of shelters that encompass spaciousness, stability and durability; an approach which has a strong impact beyond aesthetic features. Our work with Imnus has been fantastic and we hope to see our design come to reality one day."

Francesca Tassi Carboni, 2014

Self-assembly at its very best.

Satisfied home owners of the 2nd prototype.

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2nd prototype of Imnus™ Re-board shelter. Assembled in March 2014.

Department of Architecture
Chalmers University of Technology
Gothenburg, Sweden 2014