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Parametric Built-Environment Design for Post-Disaster Settlements:

Parametric-Based Design Framework to Design Refugee Camp Built Environment, Utilising Hierarchical Order of Spatial Structure within Refugee Camps

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Parametric built-environment design for post-disaster settlements

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LIST OF ABBREVIATIONS

NGOs	Non-governmental organisations
UNHCR	United Nations High Commissioner for Refugees
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
USAID	United States Agency for International Development
OFDA	Office of United States Foreign Disaster Assistance
OCHA	Office for the Coordination of Humanitarian Affairs
IOM	The UN Migration Agency, International Organization for Migration
DRC	Danish Refugee Council
DP	Displaced Population
IDP	Internally Displaced Population
CLA	Covered Living Area
L	Length
W	Width
PBR	Plot Built-Up Ratio
SPB	The Number of Shelters Per Block
CPB	The Number of Clusters Per Block
SPC	The Number of Shelters Per Cluster
UBP	Urban Block Population
UBD	Urban Block Density

GLOSSARY OF TERMS

Host Communities

They are communities that host large populations of refugees or internally displaced persons, typically in camps or integrated into households directly.

Household

A group of persons who share accommodation.

Humanitarian Assistance (Relief)

Aid addresses the immediate needs of individuals affected by crises and is provided mainly by non-governmental and international organisations.

Human Rights

Agreed international standards that recognise and protect the dignity and integrity of every individual without any distinction. Human rights are part of customary international law and stipulated in various national, regional and international legal documents generally referred to as human rights instruments. The most prominent are the United Nations Charter and the UN Bill of Rights made up of the Universal Declaration of Human Rights, the International Covenant on Civil and Political Rights, and the International Covenant on Economic and Social Rights.

Settlement

Area and location of dwelling units and systems to maintain them.

Spontaneous settlements

occur when persons of concern populate areas without agreement, assistance or guidance from the local government or the humanitarian-aid community. Such settlements are located on land the displaced population does not officially have the right to occupy.

Shelters:

A habitable covered living space provides a secure, healthy living environment with privacy and dignity to those within it.

Housing

Shelter for human habitation. The immediate physical environment, both within and outside buildings, is where families and households live and serve as a government project to provide shelter to low-income groups.

Reconstruction

The action of constructing one or more new buildings to replace buildings which have suffered damage, or repair of damaged buildings.'

Family Plot

a small piece of land allocated to an individual family for their management

“The world will not be destroyed by those who do evil, but by those who watch them without doing anything.”

— Albert Einstein

1 PROLOGUE

1.1 PROBLEM STATEMENT

As the number of refugee increase, the housing demand increase likewise. The world today is reaching the highest number of displaced populations, reaching 103 million people; according to the United Nations High Commissioner for Refugees (UNHCR), the response to displacement varies, but the need for housing remains unquestionable. Refugee camps are one of the six proposed displaced population housing options, and it is considered the least favourite due to their adverse effects on refugees. According to UNHCR reports, living in refugee camps can weaken refugee dependency, perpetuate past trauma, distort communities, and increase the risk of sexual and gender-based violence and negative environmental impact.

Although refugee camps are an unfavourable housing option, camps are still part of the reality that cannot be ignored. Today, many camps exist in vast regions of the world, some established and operating more than 70 years ago. Therefore, the main aim of this research is not to propose refugee camps as a solution but rather to improve an existing one. The research's primary focus is introducing a generative and parametric-based integrated design framework that can be used in the early stages of refugee camp design to optimise the design outcomes and provide various design scenarios that could be evaluated and optimised best to fit the requirement and context of the camp's layout promptly.

Built environment design and planning, like any applied scientific field, evolves with the development of its technology. By technology, we refer to the application of new scientific knowledge, including but not limited to paradigms, models, tools, equipment, technics, and skills to optimise the process outcomes. As parametric and generative design paradigms change the built environment planning and design process flow, modifies the prerequisite knowledge of design. Therefore, it is necessary to re-examine refugee camp

design paradigms and develop a new framework and design processes that best fit parametric and generative refugee camp design processes and tools.

Many challenges arise during the different stages of refugee camp design, starting with the limited planning time, the sudden occurrence of disasters, slow response times, and the involvement of many parties and organisations in the refugee camp life cycle, which result in time-demanding coordination. Furthermore, refugee camp design is currently following traditional paradigms that focus on local and global professional expertise, making the design process human knowledge dependent. In response, humanitarian organisations, governments, and professionals developed design and planning standards and guidelines to accelerate the design process, minimise human error in design, and create standardised designs that are easy to build and operate.

As standards and design guidelines developed in the past 40 years, research shows the various standards can be further coordinated to provide a coherent set of design standards and provide a comprehensive approach which achieves optimal solutions for the needs of refugees. A new camp design framework is vital to adapt and fit camp design, and the framework needs to be flexible, sustainable, and adaptable to different scenarios.

The study's first aim is to explore the design and planning standards and guidelines of refugee camps established by different parties focusing on studying the historical chronological development of design standards and roles of various agencies, comparing them based on numerical standards and indicators, in addition to analysing existing design challenges and processes.

Second, the research examines existing cases of refugee camps developed in the past fifty years and creates a database to statistically analyse and evaluate the built environment's physical characteristics and how it abides by the established standards and guidelines.

Third, the research examines parametric design methods and tools for humanitarian aid and built environment design. In addition, it studies existing tools and the possibility of application in the design and planning of refugee camp design.

Fourth, the research establishes a design process framework based on the refugee camps'-built environment structural hierarchy top-down process-based design framework. In addition, it defines numerical parameters, parameters correlations, and constraints that will be later applied in a parametric design framework.

Fifth is testing the design framework using the previously established parameters and their constraints and relationships. Furthermore, compare it to the original case by applying parametric assessment tools.

1.1.1 Research question

Research questions are formulated into three main themes: analysing existing refugee camps standards, analysing existing practice, and establishing a design framework:

Design standards:

- What design standards, themes and qualities? How do the standards apply, and are they coherent?
- What is the current state of the design and planning processes of refugee camps' built- environment?

Existing Practice:

- What is the current condition of refugee camps? How compatible is the design outcome with standards?
- Can the existing refugee camps represent good practice, and can they provide source data or refugee camp design and planning?

Design framework:

- What conceptual framework could be used to develop a parametric refugee camp planning and design tool?
- Can digital tools and parametric design processes positively impact refugee camp planning?
- How can parametric, generative and algorithmic design support the design process of a user-friendly, humanitarian, timely and adequate refugee camp while reducing design flaws and deficiencies and facilitating a flexible design process that ensures the achievement of design standards and optimises the design process resilience for amendments and alterations when needed without jeopardising the quality of the design?
- What is the parametric design framework? How can the framework apply to the design process of refugee camps?
- How can we assess parametric design alternatives, and how can we optimise design options?

1.2 RESEARCH PROPOSITION

The research proposes using generative design and parametric-based integrated design processes, which can be used in the early stages of the design of refugee camps to optimise the design outcomes and provide various design scenarios that could be evaluated and optimised best to fit the requirement and context of the plan promptly, by creating new design framework and establishing new numerical standards that can be adapted in the proposed design framework. Both framework and numerical standards are based on the statistical analysis of existing design standards and case studies.

1.3 SIGNIFICANT AND POTENTIAL BENEFITS

I. Establish a database that could be used to measure existing designs and define new correlations and relationships between the design

components that could be used together later on as a base of parametric and generative design.

II. Design a process that offers a symbiotic approach between design and computational aspects of computer-aided design and shows that including parametric design in the design process does not necessarily require high levels of programming knowledge from the designer.

III. The research intends to establish a design process that conceptualises a parametric-based generative design method translated into a systematic, adjustable, easy-to-modify used in the initial stages of the design process of planned refugee camps.

IV. The aim is to establish a design method that responds to the issues found in the existing practice, which would be a great asset to developing subjective design outcomes as a conscience.

1.4 SUMMARY

The prologue briefly states the research problem and questions, provides insight into the following sections of the script, and proclaims the research's significance and potential benefits.

The following part of the script states the research thesis and provides insight into the research methodology and the work done to demonstrate the research thesis.


IHH
IHH

2 BACKGROUND

2.1 THE CURRENT STATE OF DISPLACEMENT

2.1.1 Global refugee burden

In 2022 the number of forcibly displaced people worldwide is 82.4 million (UNHCR, Refugees, & Section, 2021), affecting 1% of the global population. Currently, people are forcibly displaced from their homes at a very high rate; nearly 20 people are affected every minute (United Nations High Commissioner for Refugees, 2021). People are forced to flee due to "human rights violations, generalised violence, persecution and torture, or because of ethnicity, religion, sexuality, or political opinions, or are displaced as a result of event seriously disturbing public order as an armed conflict or another type of crisis

According to the United Nations (UN) reports, by May of the current year, 2022, the number of displaced people reached 100 million people (United Nations High Commissioner for Refugees, 2022) (United Nations High Commissioner for Refugees, 2021). The displaced population number is escalating at an unanticipated rate, breaking records; the United Nations High Commissioner for Refugees (UNHCR) reported that nine million people had been newly displaced in the past year (United Nations High Commissioner for Refugees, 2021). In 2021, over 91 million people were under the care of the (UNHCR) worldwide. 1.25% of the earth's population suffers directly from the displacement crisis (MIGRATION DATA PORTAL, 2021).

The 91 million displaced population is categorised as the following list in Figure 1 :

- **Internally displaced persons (IDP)s** 53.2 million, according to The UNHCR, are defined as "A person who has been forced or obliged to flee from their home or place of habitual residence, in particular as a result of or to avoid the effects of armed conflicts, situations of generalised violence, violations of human rights or natural or human-made disasters, and who has not crossed an internationally recognised

State border" (Status Determination And Protection Information Section, Division Of International Protection, United Nations High Commissioner for Refugees, 2006).

- **Refugees:** 27.1 million, according to UNHCR, defined as "persons **outside their countries** of origin who are in need of international protection because of feared persecution, or a serious threat to their life, physical integrity or freedom in their country of origin as a result of persecution, armed conflict, violence or serious public disorder" (Status Determination And Protection Information Section, Division Of International Protection, United Nations High Commissioner for Refugees, 2006).
- **Asylum seekers:** 4.6 million, according to UNHCR, defined as "a general term for any person who is seeking international protection" (Status Determination And Protection Information Section, Division Of International Protection, United Nations High Commissioner for Refugees, 2006)an asylum seeker term is used to describe a person before or in the process of a submitted refugee status application, therefore; not every asylum seeker is ultimately recognised as a refugee, but every refugee is initially an asylum seeker.
- In addition, there are more than 10 million **stateless persons**. The UNHCR is defined as "A person who, under national laws, does not have the legal bond of nationality with any State" (Status Determination And Protection Information Section, Division Of International Protection, United Nations High Commissioner for Refugees, 2006) A stateless person might not have left the country they were born in or currently residing in. However, they still do not have citizenship status in any country or state.

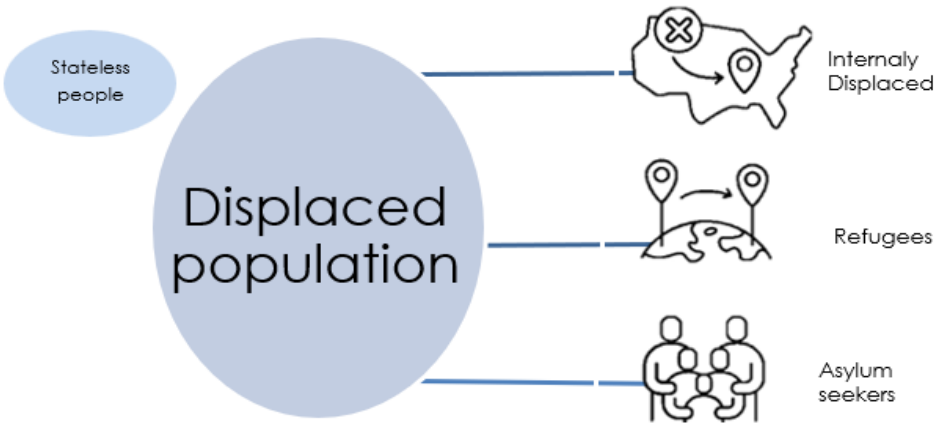


Figure 1 Displaced population taxonomy

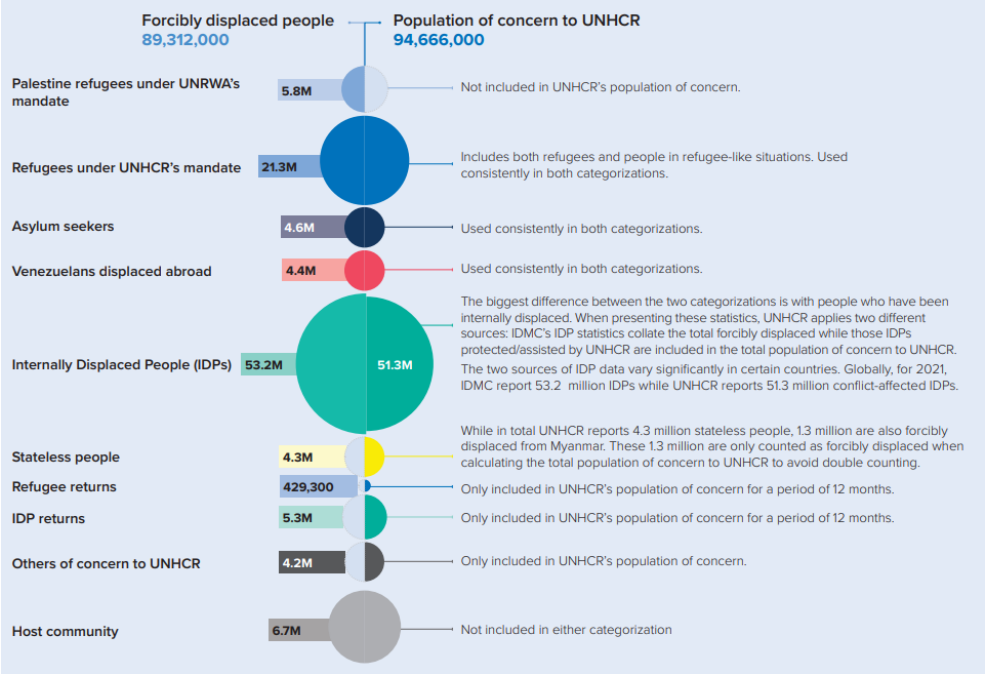


Figure 2 Statistics for forcibly displaced people, (United Nations High Commissioner for Refugees, 2021)

In this context, it is essential to differentiate between **immigrants** and displaced populations (DP), according to the UN Migration Agency (IOM) defines "migrant as any person who is moving or has moved across an international border or within a State away from his/her habitual place of residence, regardless of (1) the person's legal status; (2) whether the movement is voluntary or involuntary; (3) what the causes for the movement are; or (4) what the length of the stay is". Although no universal acceptance

of the migrant definition is internationally accepted, the term immigrant is usually associated with the economic movement of a population. In addition, the term can be paired with well-defined legal categories such as immigrant workers, smuggled migrants, or international students who do not have a legal-defined movement (International Organization for Migration (IOM), 2019).

Eighty-five per cent of the displaced people are settled in developing countries (Department of Economic and Social Affairs, Development Policy and Analysis Division, United Nations, 2018). In addition, 102,800 refugees resettled in 138 countries, over half of whom are under 18 (United Nations High Commissioner for Refugees, 2018). People are forced to flee due to "human rights violations, generalised violence, persecution and torture, or because of ethnicity, religion, political opinions, or sexuality, or are displaced as a result of event seriously disturbing public order as an armed conflict or another type of crisis (MIGRATION DATA PORTAL, 2021).

2.2 FUTURE RISK OF DISPLACEMENT

Once every two seconds, a person becomes forcibly displaced; those who are displaced will often stay displaced for many years—the average time of displacement is approximately 20 years (UNHCR U. N., 2018). According to the Internal Displacement Monitoring Center (IDMC), the number of DP caused by natural hazards is more significant than that caused by conflicts and other forms of violence.

According to the global displacement forecast for 2022, the displaced population is expected to increase by 2.9 million (Danish Refugee Council (DRC), 2022). The number is projected for 2023, with an increase of 3.9 million. This increase shows that the number of DP is looking to double in 10 years between 2014-2023. Furthermore, global risk reports indicating the risk factor of world countries show an increase of risk globally which directly influences the displacement state of the population. Risks are analysed into

five main themes, Climate transitions, Digital dependencies and cyber vulnerabilities, barriers to migration, crowding and competition in space, and refreshing resilience (World Economic Forum, 2022). Both reports indicate an increase in DP in the coming ten years, raising the importance of disaster management and preventive planning for displacement.

The forced displacement is caused by a series of connected factors, which can be expressed in a Bayesian network analysis developed by DRRC and International Business Machines (IBM)

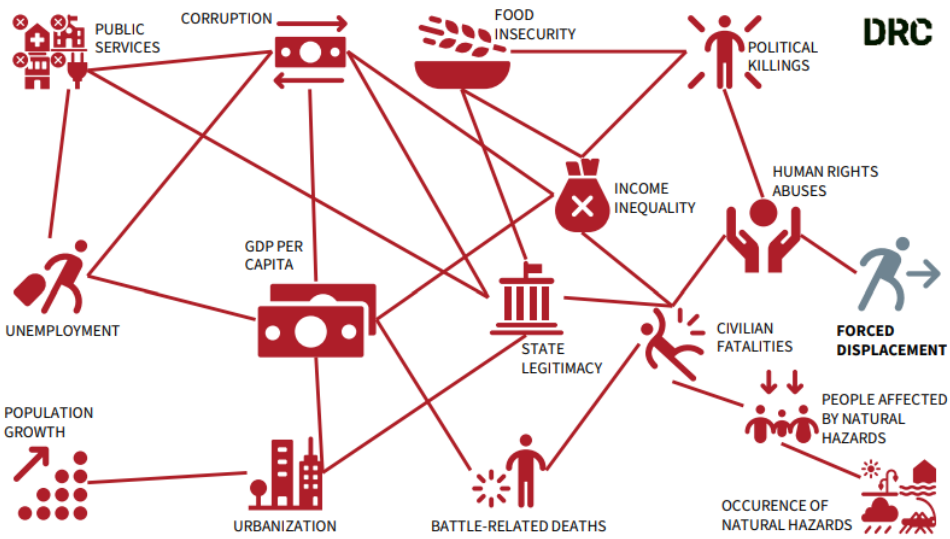


Figure 3 Bayesian network analysis summarising the complex network of factors leading to displacement (Danish Refugee Council (DRC), 2022)

2.3 SHELTER AND SETTLEMENT AID

In response to the humanitarian crises of forced displacements, humanitarian aid is allocated to provide access to shelter, protection, emergency relief, registration, legal aid, food, and essential services such as healthcare, counselling, nutritional assistance, clean water, sanitation, and education (European Commission, 2021) The operation of different aids is held by a vast group of organisations, governments, and NGO's requiring a lot of coordination and management.

Refugee Shelter is crucial for survival, restoring personal security, self-sufficiency and dignity (European Civil Protection and Humanitarian Aid Operations, 2017) (Global Shelter Cluster, 2020). Shelter and settlement aid are offered in a wide range of various forms. Camp is a settlement solution provided to refugees, IDP and asylum seekers. According to UNHCR, refugee camps are *"temporary facilities built to provide immediate protection and assistance to people who have been forced to flee their homes due to war, persecution or violence."* (UNHCR, 2021).

According to humanitarian organisation standards and guidelines for disaster management and planning, there are six types of transitional settlements used as shelter options for displaced populations (Corsellis & Vitale, Camp planning guidelines 07b. Incomplete draft, 2007), (Corsellis & Antonella, Oxfam - Transitional settlement displaced populations, 2005) Figure 4. They can be explained as the following:

Dispersed settlements

- **Host families** are "the displaced population is sheltered within the households of local families, or on land or properties owned by them."
- **Urban self-settlement** "displaced individuals or families settle in an urban environment, often occupying unclaimed properties or land, or settling informally."
- **Rural self-settlement**, "displaced peoples settle on rural land owned collectively or privately."

Grouped settlements

- **Collective centres** are also "called mass shelters; displaced people are sheltered in pre-existing structures, such as schools, worshipping centres, stadiums, community centres, gymnasia, hotels, disused factories and unfinished buildings."
- **Self-settled camps**, "the displaced community settle as a group in camps. Self-settled camps are often sited on state-owned or communal

land without formal negotiations with the local population over use and access."

- **Planned camps**, "where displaced people find accommodation on purpose-built sites, where services infrastructure is provided, including water supply, food and non-food item distribution, health care and education."

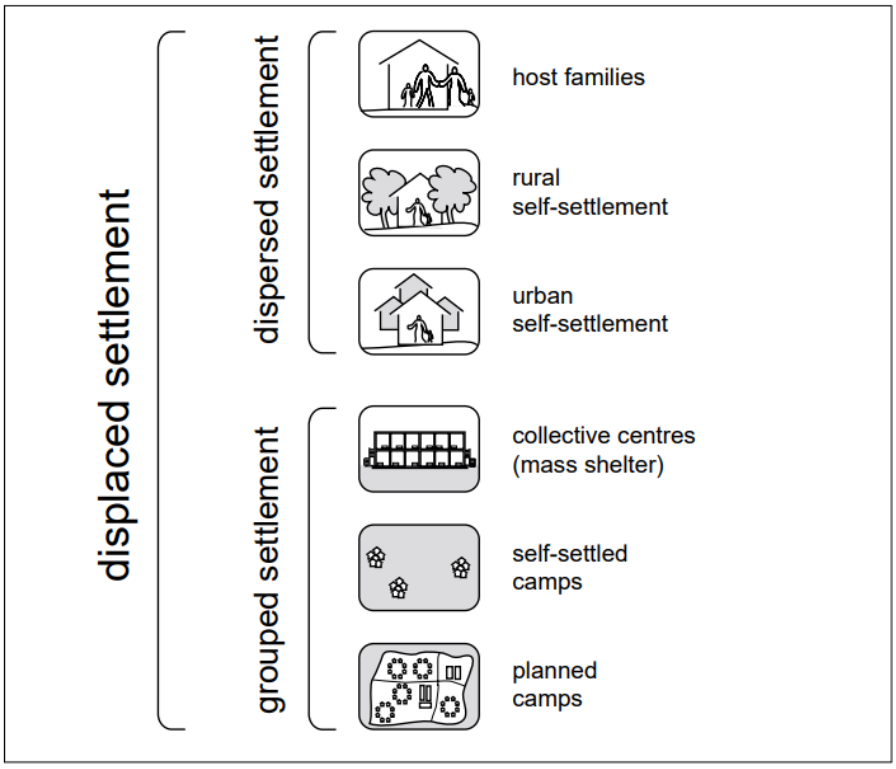


Figure 4 Six transitional settlement options (Corsellis & Antonella, Oxfam - Transitional settlement displaced populations, 2005)

Post-disaster settlements in all forms are being built in over 138 countries. These settlements vary in area, population, location, shelter material, environmental condition, topography, urban fabric, and many more physical, social, economic and managerial characteristics (Kennedy J. , 2008). Planned camps characterised by high dynamics, small-scale and temporary shelters require specific design requirements and guidelines (Pelizari, et al., 2018).

In the case of shelter in 2021, Kenya, Jordan, Bangladesh, and Sudan, host some of the largest refugee settlements in the world, with a population

exceeding 6.6 million refugees. However, the vast majority of refugees live in urban areas. According to UNHCR, 22 per cent of the world's refugee population is settling in camps, and the camp's population is estimated to be 6.6 million people. In addition, 5 million are living in planned and managed camps, while 2 million are sheltered in self-settled camps (UNHCR, 2021).

Governments of the host nation almost often forbid building structures that give a refugee camp a more permanent appearance or feel. Even though refugee camps have a temporary framework, individuals may remain there for several years while getting food, education, and medical assistance until it is safe enough for them to return to their country of origin. Many asylum-seeking nations do not respect the human rights of refugees, who are frequently forbidden from working, putting their children in school, or using the local medical system. Refugees often live in constant fear of being detained, arrested, and deported. Many nations treat refugees as convicted criminals despite the appeals of human rights organisations to do otherwise because of the current wave of terrorism.

Although camps are intended to be a temporary solution, some have existed for decades. Two-thirds of all refugees worldwide have been displaced for over three years, known as being in 'protracted displacement. In addition, 50% of refugees – around 10 million people – have been displaced for over ten years (United Nations High Commissioner for Refugees, 2022), housed in a closed refugee camp, and left on the margins of society. Palestinian refugee camps in Lebanon are some of the world's oldest, most densely populated refugee camps. After more than six decades, Palestinian refugees live in poor conditions and under a host of restrictions that, among other things, limit where they can live and work (Loescher & Milner, 2006), (Mohamed, et al., 2020).

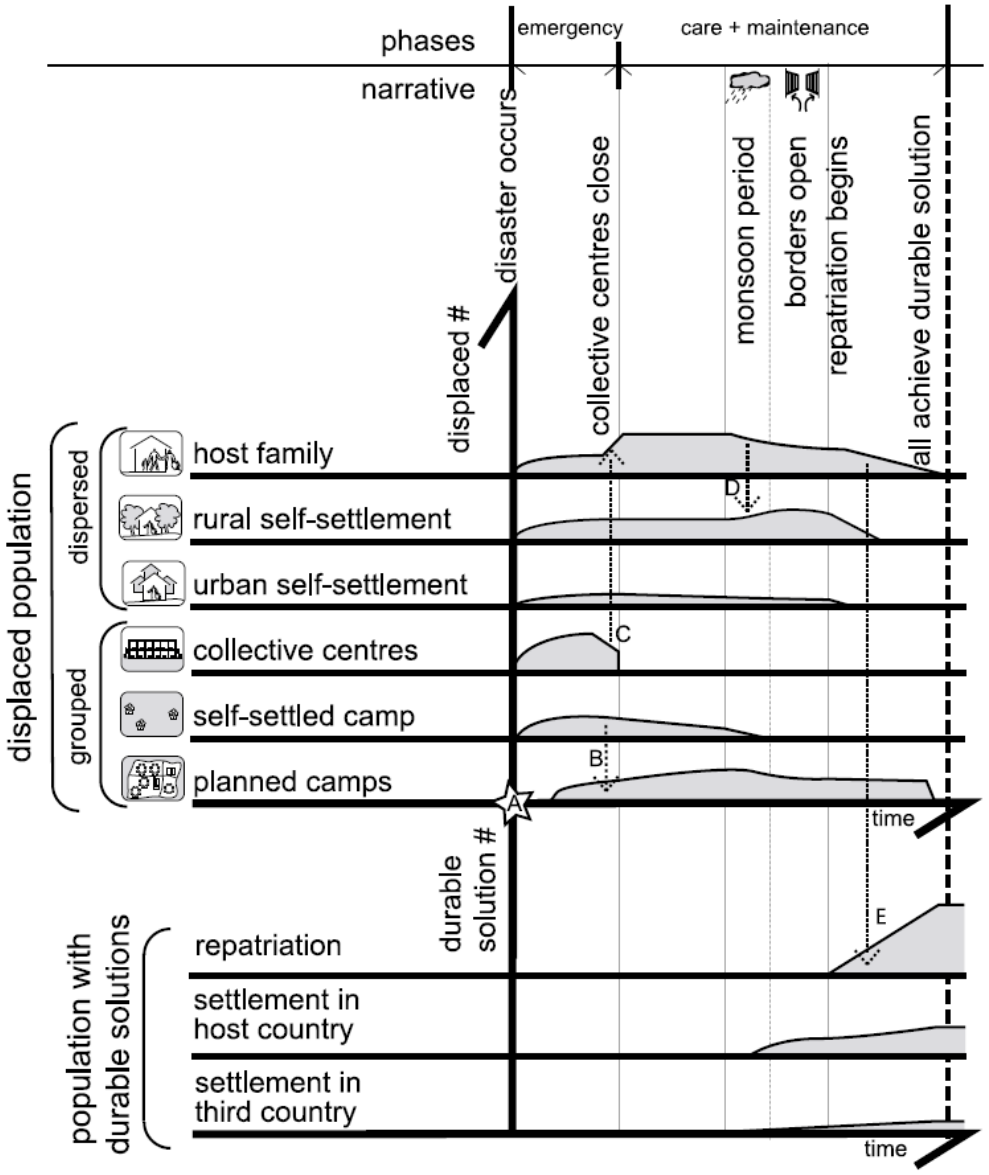


Figure 5 Schedule of operations diagram (Corsellis & Antonella, Oxfam - Transitional settlement displaced populations, 2005)

2.4 EMERGENCY CAMPS CHALLENGES

Although refugee camps are planned as temporary facilities built for immediate protection and support of forcibly displaced people, an emergency can extend for long periods prolonging displacement periods resulting in expanding the functions of camps to provide better living conditions and livelihood opportunities shifting the temporary camps into permeant homes (UNHCR, 2021). According to the UNHCR, *"refugees may spend years and*

even decades living in camps, and it is common to have entire generations growing up in the camps" (UNHCR, 2021).

In the case of refugee camps as shelters, international organisations like UNHCR, governments of host countries and NGOs such as the Red Cross offer different types of support, including camp funding, protection, design, planning and management. However, refugee camp planning, design, and management is a complex challenge integrating the vast number of parties and considerations, making it a very intricate process. Moreover, due to the sudden occurrence of emergencies, most emergency camps are planned, designed and built in an impromptu fashion (Gunn & Atiyeh, 2017), leaving a great chance of range errors resulting in poor and inadequate living conditions.

2.5 THE SCALE OF SHELTER AND SETTLEMENTS ASSISTANCE

The latest reports addressing the state humanitarian shelter released by the Global Shelter Cluster report (International Federation of Red Cross and Red Crescent Societies, United Nations High Commissioner for Refugees, 2018) indicate significant developments in policies and practices of accommodating displaced populations and covering a vast number of vulnerable populations. In addition, the development of humanitarian response for long-term displacement and adapting sustainable solutions. However, the gaps remain after 40 years of development. The three significant gaps can be summarised as inconsistent and lack of funding, political restrictions, and the scale of and size of the concerned population and levels of intervention.

Despite the humanitarian organisations providing housing and settlement aid to over 10 million individuals each year, most people who get aid do not receive comprehensive help. For example, according to the statistics of the Global Shelter Cluster, in 2021, the were 20 million people targeted with shelter assistance. Still, only seven million received it, which means that 65% of the target group did not receive any assistance (Global Shelter Cluster,

2022). Other important humanitarian aid providers include community and civil society groups, the government, and remittances from the diaspora. However, many crisis-affected individuals will not get the help they need to take care of their basic needs and adequately support their rehabilitation.

2.6 WHY IS SHELTER AND SETTLEMENT ASSISTANCE CRITICAL?

Shelter and settlement support is the cornerstone of humanitarian aid and essential for reestablishing families and communities. Shelter and settlements aid attempts to help those who are compelled to evacuate their homes at every stage: before the crisis ever arises. At the same time, they are displaced while recovering and reestablishing a feeling of home and community. Assistance with housing and relocation may both save and enable lives.

Protecting the health, security, privacy, and dignity of families and communities impacted by crises are the main goals of shelter and settlement aid. However, in addition to saving lives, shelter and settlement aid are essential in rebuilding the psychological, social, livelihood, and physical aspects of life - or, to put it another way, all the elements required for people to progress from mere survival to exercising their rights and realize their potential effectively.

According to Global Shelter Cluster, the value of shelter and settlements assistance lies in its ability to provide:

- **A physical dwelling** protects families' health, security, privacy and dignity and brings communities together.
- **A stable location** is an 'address' where other services can be accessed, including healthcare, education, nutrition and safe and dignified water and sanitation facilities. A home can occasionally be a valued asset that is the foundation for a more considerable investment. Additionally, it offers a location to relaunch economic recovery and livelihoods.

- **A sense of identity**, a place that enables refugees to establish a sense of belonging and allows them to gather belongings, family and community, a neighbourhood to feel related to, a place in which one can consider the past and rebuild a sense of future.

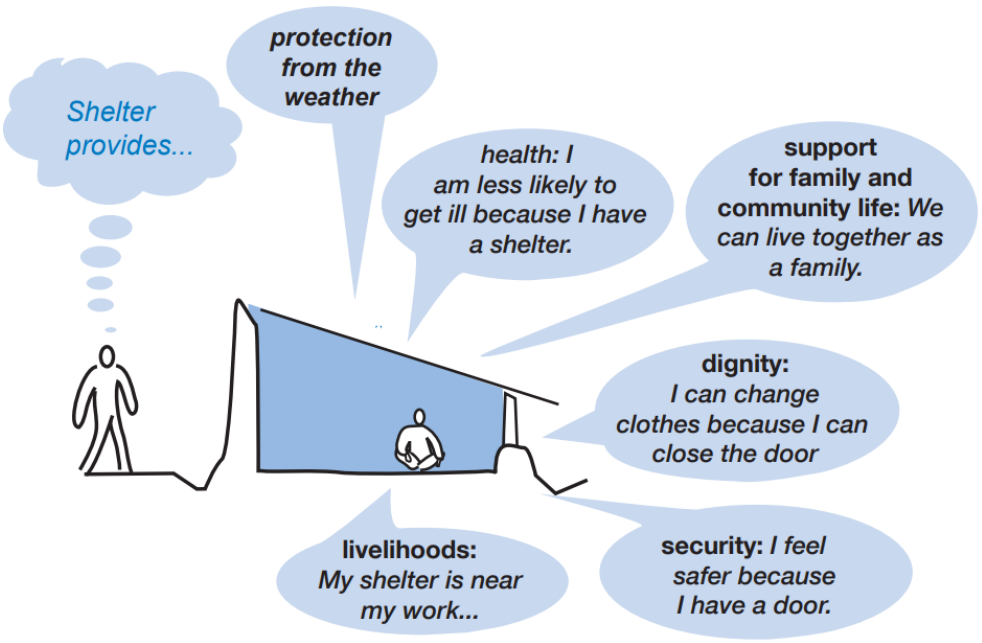


Figure 6 Some of the functions of appropriate emergency shelters. Shelter programmes should support families to meet these needs. (International Federation of Red Cross and Red Crescent Societies, 2021)

The phrase "shelter and settlements" is used because it is impossible to talk about individual dwellings without considering the place and context in which they are located.

2.7 HUMANITARIAN HOUSING SHELTER PROBLEMS

Before talking about the housing and shelter problems, it is essential to show the chronological process a person of concern receiving humanitarian aid goes through, the options of shelter that are open for them, and how they can be merged back into city-like urbanisation. As Figure 7 shows, the settlement

route of the displaced population first starts after leaving home within the country of the disaster, second arriving at a way station in the country of the urban disaster settlement, and third moving to a transit centre in the country of the disaster. After that, the displaced population is transferred to a way station in the new safe zone of the hosting country, sixth transferred to another transit centre and later to a reception centre.

After arriving at the reception, the centre displaced population can settle into one of the six options. Still, in the case of evacuation centres, the displaced population are waiting to be evacuated or deported. In the case of collective centres, these centres are considered temporary and displaced populations can be retransferred to another type of settlement from those above.

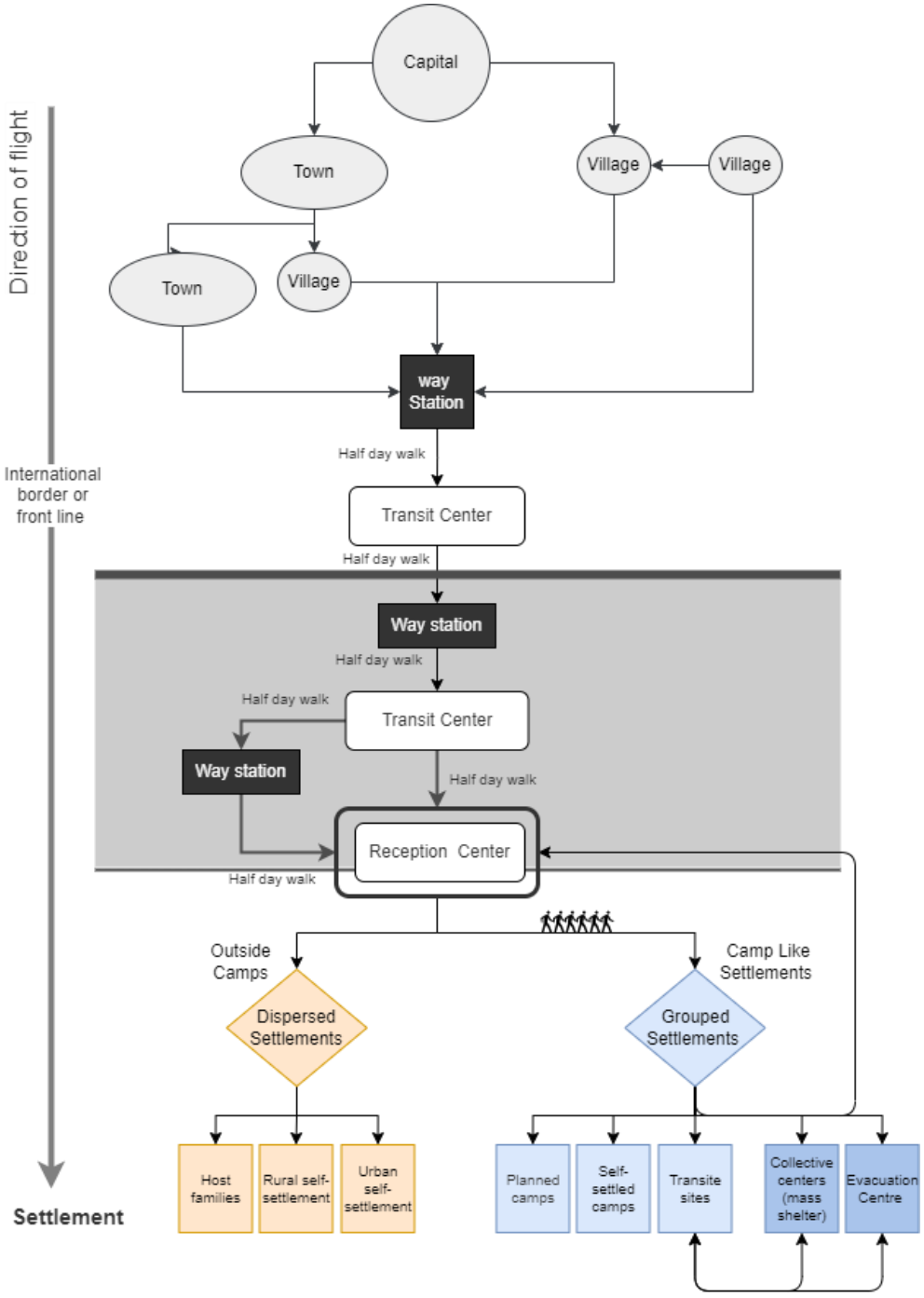


Figure 7 Settlement route and options for the displaced population

2.8 DEFINE THE CURRENT STATE OF THE DESIGN PROCESS PROBLEMS

2.8.1 Refugee camp general Problems

Refugee camps typically sprout up on the spot. They are often made to provide refugees, internally displaced people, and occasionally other migrants with short-term, acute housing and services. Governments, the United Nations, international organisations (such the International Committee of the Red Cross), or NGOs are often in charge of creating and managing them (such as the Red Cross). However, there are also unofficial refugee camps where people are mostly left without the protection of governments or international organisations, such as Idomeni in Greece or the jungle of Calais in France.

To avoid placing the burden of care on the government and primarily because of internal political reasons, the Lebanese government has resisted the formation of refugee camps for the Syrians. Therefore, Syrian refugees have scattered over 1,000 municipalities, mostly in impoverished urban areas where services are severely strained.

2.8.2 Potential challenges of camp design

Timing.

The multisectoral, multi-method, and context-specific nature of settlement-based needs assessment often takes longer to design and undertake than standardised sector-specific assessments. Therefore, assessments take sufficient time to consult with local stakeholders and sector experts to contextualise the data collection tools. This can extend the planning period, especially in the case of displaced populations or contexts for which the lead organisation does not have prior expertise.

Information sharing.

Foster local ownership of assessment data and make sure it is widely available. Broadcasting and information-sharing channels usually used by humanitarian organisations are not always easily accessible to local institutional stakeholders and community groups participating in the assessment.

Assessment fatigue.

Assessment fatigue is a commonly reported challenge in both protracted and sudden-onset crises.

3 DESIGN PROCESS, STUDIES ON ARCHITECTURE IN THE CONTEXT OF REFUGEE CAMP DESIGN

3.1 DESIGN OF REFUGEE CAMPS

Refugee camp design is a complex procedure that involves many sectors and has many considerations due to the nature of the refugee camp's ownership, planning, construction, occupation, and management.

In the establishment of the post-disaster settlement, its essential to understand the process and the elements of the process. The establishment starts when a country is declared in the yellow stage of risk, and it estimates a year before the disaster occurs. The refugee camp planning officially started combined with two factors number of displaced population and the start of the disaster. So it is estimated that the refugee camp began after two years after declaring a yellow risk case when the displaced population of the case exceeded one million persons. This planning time is insufficient for developing a fit design with adequate living conditions.

Short planning periods have a tremendous amount of after-effects on camp living conditions and sustainability, as project process and management research has shown (Midler, 1995)that the design cost can be significantly reduced at the earlier stages of the design process. On the other hand, the freedom of design and the opportunity to include sustainable solutions are declining with time, according to (Midler, 1995), Figure 8.

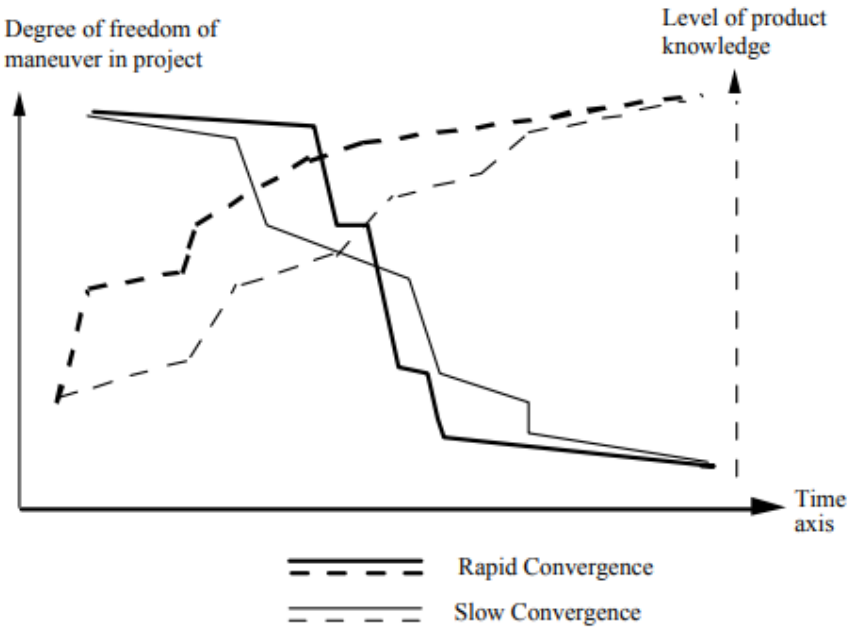


Figure 8 Accelerating the project cycle (Midler, 1995)

3.1.1 Roots of refugee camp design

The research raises an important set of questions regarding what type of parameters are required to develop research regarding the development of post-disaster settlements. Unfortunately, the nature of the design makes it hard to determine the proper assessment criteria. Until now, many organizational and institutional criteria still have gaps in the application or framework. Therefore, to determine what information should be included or not, some limitations were applied as the following:

- Track the development of other related design fields, such as emergency shelter and planning.
- Study the influence of significant points of other policies and laws regarding post-disaster settlements. Such as A change of refugee law or THE initial construction of refugee camps.

3.1.2 The phases of post-disaster design development

According to INFC (International Federation of Red Cross and Red Cres, 2012), the phases of post-disaster settlement responses can fall under four significant shifts, mainly linked to major political and international events. In

addition to the adoption of strategic design concepts and imperative approaches to post-disaster settlements, they are as the following:

- Start of post-disaster settlements
- Development of “Community Module” camp design type (1971-1982)
- Adaptations of the “Community Module” type, 1982-1995
- Minimum standards for camp design, 1995-2007

3.1.3 Start of post-disaster settlements

The United Nations Universal Declaration of Human Rights in 1948 and then the United Nations Convention Relating to the Status of Refugees in 1951 marked the first time that there was an assertion of positive and universal rights for refugees, which has expanded in adoption to cover the majority of the sovereign nations on the planet. In the early 1970’s refugees within Africa would, for the most part, resettle permanently in the host country. At that time, no significant discussion on the design of refugee camps was made; through that time, the development of post-disaster settlements was mainly influenced by urban planning theories and public health guidelines. ((OHCHR) & OHCHR, 2013).

Whilst still the start of the 1970s, there was no formal documentation of any early settlements of refugees or displaced people. Some photos of the transitional shelter came as a result of the Francisco Earthquake of 1906. Figure 9 shows tents placed as a grid in the shape of a military settlement. (Davis, 1978)

Figure 9: Military-style tent camps after the San Francisco earthquake of 1906.

Later on, the various political situation around the globe, such as the collapse of the Ottoman Empire, and the Japanese invasion of China in Asia, occurred in correlation to other similar circumstances in Europe, such as World War I and the Russian revolution. These global conflicts threatened the safety of humans in multi-countries which played a significant role in major refugee movements and forced immigration around the globe between 1906 and World War II. Nevertheless, in all the cases, built camps were too transitory, self-settled, or with no official records. In 1970 the spark of the first post-disaster designs appeared when Alvar Aalto designed the first prototype of a multi-family shelter for people subject to displacement by the London Blitz at the start of the 1940s Figure 10. (Stohr, Kate; Sinclair, Cameron, 2006)

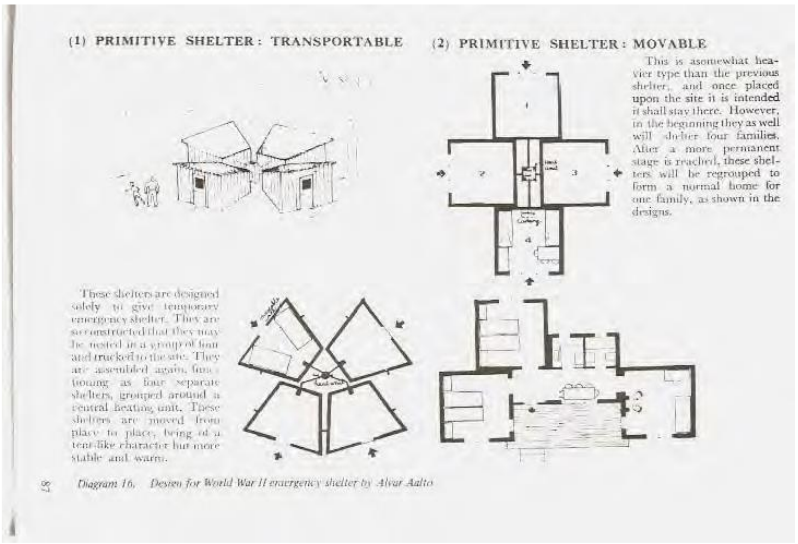


Figure 10 Alvar Aalto emergency shelter prototype (Davis, 1978)

Although the number of post-disaster camps increased, most camps were a response to natural disasters, and their population were displaced people, not refugees. As a result, refugee camp design developed by transmitting natural disaster design principles to refugee camp planning guidelines and standards (International Federation of Red Cross and Red Cres, 2012).

3.1.4 Development of "Community Module" camp design type (1971-1982)

International NGOs and humanitarians organisations such as Oxford Committee for Famine Relief (Oxfam) or Cooperative for Assistance and Relief Everywhere (CARE) during World War II period played a significant role as they provided assistance and support to victims of disasters, and they positioned themselves as "Disaster response". However, they lacked the experience needed to support large-scale disasters. The number of people interested in humanitarian issues increased rapidly. Nevertheless, Fred Cuny was one of the first people working as a researcher in Oxfam, and his first work was the booklet "Oxfam Technical Guide Plastic Sheeting: Its Use for Emergency Housing and Other Purposes" (Jim Howard, Ron Spice, 1973), till now it is considered one of the best Oxfam internally produced documents.

Fred Cuny started his company in 1971, called "Intertect Relief and Reconstruction Corporation", which indicated the technical sectors of humanitarian work: shelter, water and sanitation, and logistics. Cuny's company work was one of the first documented attempts in the shelter and site planning field, which will remain the most influential work organization to this day. Cuny's work with Biafra, described as the "first large-scale humanitarian efforts of the post-colonial Period" (Shawcross, 1995), taught him two lessons which are still advocated by today's site planning writings, the first, thinking with post-disaster is a comprehensive and holistic, the second affected communities aims and self-support should be considered through the design phases.

Cuny collections of a refuge camp planning, design, and construction were documented by USAID funding. The collection consisted of a wide range of plans, guidelines, and reports that discussed and evaluated many design themes and approaches by examining cases from around the world. The documents included one of the first design approaches published in the second report on Refugee Camps and Camp Planning (Camp Development programming). The approach itself is centred around the scale of urban planning (Cuny, Refugee Camps and Camp Planning. (201)); the planning approach consists primarily of 7 stages, feasibility and program, analysis, design, design development, Construction, assessment, occupation, and optimization as seen in the following Figure 11.

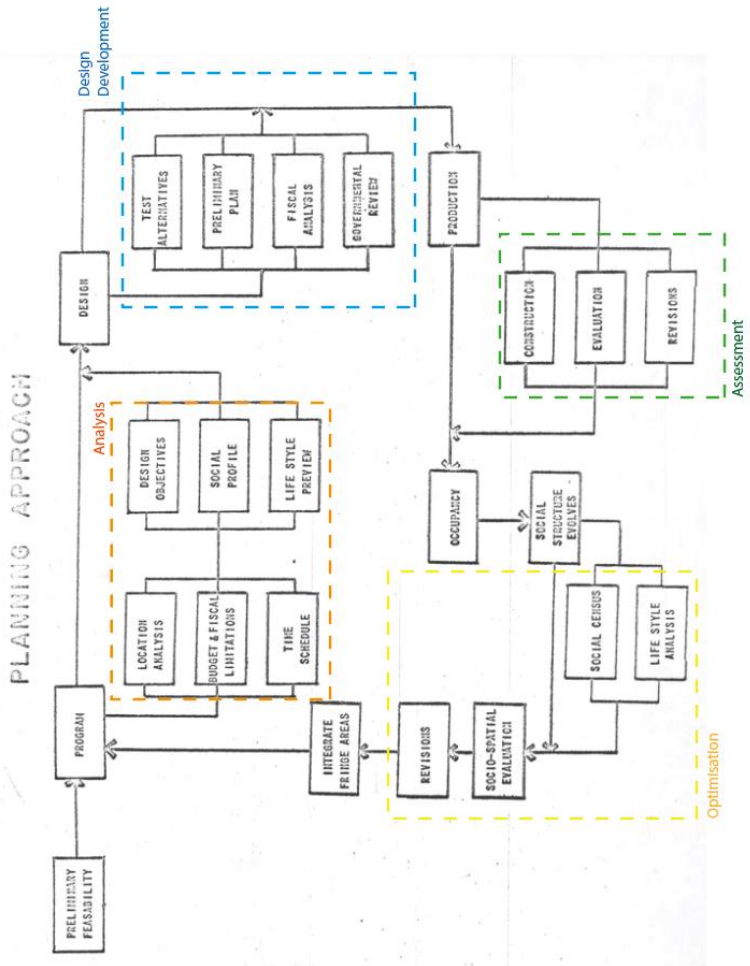


Figure 11 Cuny's refugee camp planning approach

Cuny got involved in developing camps in Managua; this document was the first to describe and display camp settlements and elements. Davis' documents were the first to contain the embryonic vocabulary describing camps as Cluster and military-style time. (Davis, 1978)

Figure 12 Davis' example of the opposite and inferior approach to that taken by Cuny in Managua (Davis, 1978)

Later, he designed the El Coyotepe camp for 880 people; the significant work of the El Coyotepe camp design was carried out to create and adopt general guidelines in camp design later and followed by his work on a camp in Khulua District in Bangladesh. His approach to camp design slowly draws the guidelines and standards for the first post-disaster settlements.

3.1.5 Adaptations of the community module type, 1982-1995

The work of Cuny and his company remained active after 1981, while other humanitarian organisations started to grow even more. UNHCR was not any different. The number of members increased rapidly. However, the post-disaster camp design was not developed, and there was no further documentation or significant development of the topic, which remained the same for over a decade. Then, in the mid-1990s, things started to change, and humanitarian organisations became involved in camps design due to the global crises. One of the leading examples of the guideline was the production of the first "Contingency Planning Manual" for the USAID/OFDA draft.

Nevertheless, it lacked any numerical guidelines concerning post-disaster camps' design.

In 1981 the UNHCR announced the completion of the Handbook for Emergencies (Hartling, 1981). That is when design layouts started to shift to a larger scale, where previous module-based designs were not developed enough to stand anymore. As a result, a camp designed in this period would host more than sixteen times as many as those in El Coyotepe camp in 1973. Although that the UNHCR was able to create two other drafts in the same period of time, "Refugee Camps, a Primer for Rapid Site Planning" and "Refugee Settlements, a Primer for Development" (Nabeel Hamdi, Reinhard Goethert, 1988a) (Nabeel Hamdi, Reinhard Goethert, 1988b), both of these documents remained unpublished in the document collections.

3.1.6 Minimum standards for camp design, 1995-2007

The phase held significant changes regarding the releases of multiple editions of the "Handbook for Emergencies" between 1981-1998. The number of numerical studies and minimum design standards evolved in all design fields within site planning. With the efforts of the largest humanitarian organisations and humanitarian consortia in 2000, the first Edition of the Humanitarian Charter and Minimum Standards in Disaster Response, now colloquially known as 'Sphere', was released (Saunders, 2004).

The Sphere Handbook gave wide comprehensive states for minimum standards not limited to Shelters and camps design but another five crucial sectors: food, shelter, water, nutrition, and health clear. The humanitarian Charter and Minimum Standards in Disaster Response states that camps are the third response for shelter, and it even indicates explicit warnings of the negative consequences of such decisions. As The Sphere Handbook does not answer the main questions concerning the camp design itself, its comprehensive and holistic nature gives a wide range of solutions for all shelter programs. (International Federation of Red Cross and Red Cres, 2012)

3.1.7 Refugee camp response approach

Scanning design and planning guidelines and standards, three primary approaches are mentioned in the camp and temporary settlement design cluster approach, settlement approach, and master plan approach. Each focuses on specific aspects of the design and detailed strategic planning and design considerations, policies, indicators, and standards Figure 13.

3.1.7.1 THE CLUSTER APPROACH

Although the cluster approach by name might indicate spatial guidelines, it does not focus on the spatial layout of the settlement but instead on the shared responsibilities between a cluster of organisations. In 2005, International Accounting Standards Committee (IASC), in response to the UN Secretary-General, commissioned an independent Humanitarian Response Review (HRR) to establish an initiative to improve the predictability, accountability, responsibility, and partnership of humanitarian responses in cases of internal displacement. As a result, the cluster approach was formed as a critical element of the action plan.

As referred to in the Camp Management Toolkit (International Organization for Migration (IOM), Norwegian Refugee Council (NRC), UN Refugee Agency, 2015), Clusters are groups of humanitarian organisations, both UN and non-UN, in each primary sector of humanitarian action. They are chosen by the IASC and assigned specific coordination activities. The Cluster Approach seeks to guarantee adequate global humanitarian capacity and the effectiveness of the response.

3.1.7.2 SETTLEMENTS APPROACH:

The settlements approach offers principles and practical solutions for humanitarian settlement response; it focuses on establishing collective solutions based on different sectors' expertise to address the cross-cutting factors of planning and design and to achieve sustainable outcomes. The settlement approach provides a socio-spatial framework to guide the entire

stages of the settlement life cycle while maintaining localised and context-based solutions.

With the aid of more than 30 case examples, the Settlements Approach Guidance Note combines recent developments and practical knowledge. Under the auspices of the Global Shelter Cluster, with funding assistance from the USAID Bureau of Humanitarian Assistance and input from other cluster partners, NGOs, and funders, it was created collaboratively and peer-reviewed by subject-matter experts. It is anticipated to serve as a starting point for more debate and operationalization in pertinent situations, including improved cooperation between sectoral actors, national and international stakeholders, and humanitarian and development organisations.

3.1.7.3 MASTER PLAN APPROACH:

According to the UNHCR Master-Plan Approach Guiding Principles booklet (Division of Programme Support and Management Shelter and Settlement Section, 2018), "Approach to settlement planning provides a framework for the spatial design of humanitarian settlements. It establishes a unique response vision aligned with national, sub-national and local development plans. The Master Plan Approach acknowledges the contributions of humanitarian responses toward long-term development". In 2018, the GLOBAL SHELTER CLUSTER (GSC) meeting included a session for a group discussion to examine and explore the "Master Plan Approach – Guiding Principles" the session outcomes recommended the implementation of the first draft and expected delivering impact in 2020. However, the current was not available to the public. UNHCR staff members only access it.

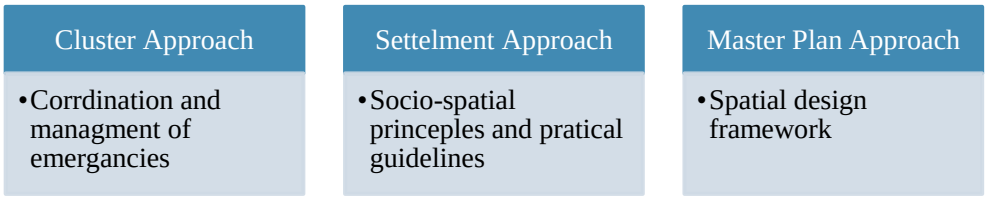


Figure 13 Design approach core theme

The following section examines only the spatial design framework according to the master plan approach since it is the most recent and comprehensive design principle for refugee camps. In accordance, the design principles are described in 10 guiding principles as the following Figure 14:

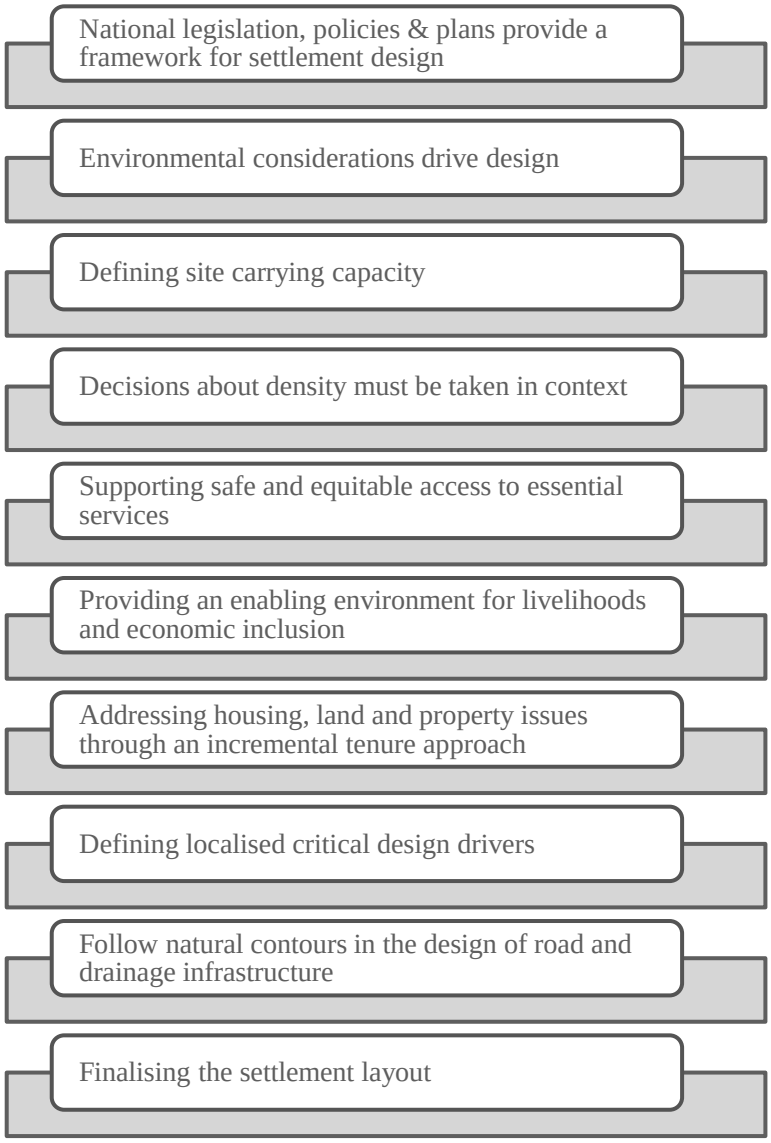


Figure 14 Master Plan Approach design principles

3.1.8 Refugee camps' problems inherited by design

According to the design standards reviewed in the previous sections. Although the standards provided a base ground for refugee camp planners and

a solid base that is easier to negotiate and bargain land and design layouts upon, the standards are approaching the design process with almost no consideration of camp life span or context. As mentioned in chapter 1, the problem of camps mainly stands with identifying them as temporary structures. Still, the average life span of refugee camps is 17-26 years (Moore, 2017), (Division of Programme Support and Management Shelter and Settlement Section, 2018), in some cases, 50 years, like in the Palestinian refugee camps in Jordan. Therefore, in this section, the main focus is the micro-level of the master plan planning, which evolves around the spatial relationships of the refugee camp and how it can accommodate the future expansion of refugee camps.

As Jim Kennedy discusses the design problem of refugee camps, he points to three main concerns (Kennedy J. , 2005):

First is the inconsistency of numerical standards and lack of any standards regarding the natural growth of the camp's population. The standardisation of the refugee camp design makes the design outcomes rigid. With a lack of standards for expansion, the camps end up being overpopulated and very dense, with open space areas below standards. For example, according to the standards, a family of 5 people where each needs 4.5 m2 to need a living space of 22.5 m2, but in fact, that space will not be enough in 7 years, assuming a natural growth of the family of 5 will grow to be a family of 7 which means that the space needed for a family is 31.5 m2 which forces the displaced population to extend the living space on the existing plot reducing the garden space as a result and adding load on infrastructure such water, energy, disposal and sanitation services in the urban cluster, and as a result in urban blocks and the camp as a unit.

Second, the bottom-up design approach depends on replicating the smallest unit of the design to achieve the master plan. The bottom-up design approach results in urban grid fabric and typology, making adjustments to the look, size and atmosphere very difficult, resulting in unfixable layouts and non-

resilience spaces, which are vulnerable to any changes in the spatial relationships after users' occupation of the space.

The third is the hierarchy of space, where camps consist of 2 types: large community spaces and small private plots (Kennedy J. , 2005). The lack of transitional spaces creates an unstable social context, especially for refugees living on the camp's borders or in areas far from the camp's centre. The humanitarian expert Kilian Kleinschmidt, who worked with the UN for over 25 years and managed camps in Africa and Asia, describes camps in Dezeen's talk as "storage facilities" (Kleinschmidt, Boer, & Provoost, 2017). Kleinschmidt points to the fact that the refugee camps space is designed for temporary storage, which is not even adequate for livelihood. In a previous interview, he debates that refugee camps are tomorrow's cities. Therefore, they should be designed by planning and developing all inherited and acquired activities in a city or urban setting.

3.2 MODULAR DESIGN OF REFUGEE CAMPS

Modular design is defined as a method that separates a complex system into more manageable units (modules) that can be independently produced and then used to modify and alter multifarious features in different systems. Based on the design approaches of the refugee camp and the hierarchy of space and module-bases standards, the modular design approach is considered indispensable, primarily due to the high demand for humanitarian shelters in short periods and the need for low-cost solutions.

3.2.1 Modular planning according to UNHCR Emergency Handbook

The modular design suggests using the smallest unit of the refugee camp as the design base and further using the refugee, not as a user but as a moving factor of the design process; the UNHCR describes the needs of a family in a refugee camp as the need to adequate and easy reach to water and sanitation facilities which can be classified as basic needs. In addition to the easy access

to social needs, such as reaching other members and social units in the boundary of the refugee camp, such as relatives, clans, or ethnic groups, or social and communal facilities such as markets and religious structures.

The guidelines suggest developing a community layout that is based on those needs. Instead of starting with a preconception of the entire site layout and breaking it down into smaller entities, developing the community layout that functions efficiently and then taking into consideration the more critical issues of the overall site layout is likely to yield noticeably better results.

Therefore, the site's physical organization and planning should begin with the smallest module, the family, before progressing to larger units as follows: models starting with minimum covered space for one person to family space where a family is approximately estimated to be between 4-6 people, then the cluster module which consists of 80-100 people or 16 family unit, and then urban block which is the result of combining 16 cluster unit, and then sectors which consist of 4 blocks and then complete refugee camo the consists of 4 sectors.

Modular planning does not mandate that the site be laid out in a grid. However, due to its ease of design and quick execution, the linear or grid pattern with square or rectangular sections divided by parallel roadways is frequently utilized. Nevertheless, every attempt should be made to avoid a strict grid design that ignores community interaction and layout and makes it impossible to find appropriate community-based places for amenities like latrines, water stations, and showers, among other things. Furthermore, grid design does not promote ownership of services, which is essential for good use, cleaning, and maintenance. Additionally, it discredits protection worries, such as the enormous distances refugees must travel to get services and their vulnerability to abuses.

As a result of the social disadvantages and security inefficiency resulting from the rigidity of using modular design, the UNHCR recommend that some of

the key elements that affect how a site is physically laid up can be modified based on the social and cultural background and family structure. Therefore, when using modular design, the module and its arrangements need to change and be altered based on the experts' knowledge of existing practices and establishing a socioeconomic study of the refugee community, which will be crucial for futural planning, especially for self-reliance and long-lasting solutions.

3.3 PARAMETRIC DESIGN

3.3.1 Definition of parametric design (computational design)

Patrik Schumacher, the pioneer of the Parametricism style, admits that:

> *—In the general description, Parametricism means that all the elements of architecture become parametrically variable, not rigid fissures anymore, and plastic fluid malleable can be recognised and react to their form. Forms start to set relationships with each other which is power beauty, meaning-making the element and figure are parametrically variable and moving from a word of platonic solid cube cylinder, which is used to compose everything in classical architecture as well as modernism. It is always district objects that add to each other and never influence each other they never notice and sense to each other*‖.

In the context of design, parametric design is a design approach that focuses on the process leading to design outcomes, which are created entirely or with the aid of the system. In parametric design, most design decisions are made with computational tools.

3.3.1.1 Parametric design definition

The word parameter is defined as "relating to or expressed in terms of a parameter or parameters" in the Oxford Dictionary, as well as "a limit [...] which defines the scope of a particular process or activity." The word parameter is also defined as "a numerical or other measurable factor forming one of a set that defines a system or sets the conditions of its operation."

3.3.1.2 Application of parametric design

> Essentially all models are wrong, but some are useful
>
> (James & Bruns, 2014)George Edward Pelham Box

Parametric design is a tool that should be in the context of the designer and the planner. Although the designer must never forget the reasons for parametric modelling, models of parametric design can help reduce the complexity of a design, extract information and feed data into the design, better understand the relationship between design components, and can predicts design flaws and improve design decisions and provide a logical, systematic design process that can be easily communicated to other parties involved.

We define models as wrong because they only represent a partial part of the reality

3.3.2 Principles of parametric design

The principles and limitations are expressed differently in each design and architectural style, and parametric design is no exception. Nature is the primary source of parametric design and the leading factor of its inspiration; nature is the ideal source due to its harmony between simplicity and complexity and its widely varied orders, patterns, and systems. The interaction of many different subsystems works together to produce a design outcome. The main issue is creating a second nature or an alternative product constrained by the original order of the parameters but still having a new

form. Numerous natural forms are generated as a result of this variety of shapes (this endless richness can be created by complex rules that are computational). The design alternatives are unlimited, and there is a flexible dynamic between shifting from physical to digital and a return to physical, offered by the nature of the parametric design approach (Schumacher, 2011).

3.4 SUMMARY

This chapter examines architectural design approaches regarding refugee camp planning and design. It explores the refugee camp design approach in addition to modular design in the case of a refugee camp and parametric design. The section displays the design approaches' definitions, general roots, and principles. Finally, Table 1 shows similarities and potential of combining design approaches to solve the inherited problems of the design approach as a framework for designing future refugee camps.

Table 1 Design approach comparison matrix

	Camp Design	Modular design	Parametric design
Time for decisions	Long	Short	Short
Prior planning	Short	Long	Long
Complexity	Complex	Simple/complex	Simple/complex
Source of principles	Human right charter	Module	Design parameters and constraints
Modifications	Not flexible	Not flexible	Flexible
Context embedding	Not embedded	Not embedded	Embedded
Correlation of system elements	No correlation	Simple correlation	Complex correlation
Subsystems	Multi subsystem	Multi subsystem	Multi subsystem
Constraints	Ridged	Ridged	Flexible
Cost efficiency to design	Must be affordable	Reduce the cost of a module	Depends on constraints
Direction of design approach	Bottom-up design	Bottom-up design	Bottom-up/ top-down
Assessment	Hard to assess	Hard to assess	Easy to assess
Expansion	Hard to expand	Easy to expand	Easy to expand

Positive
Negative
Neutral

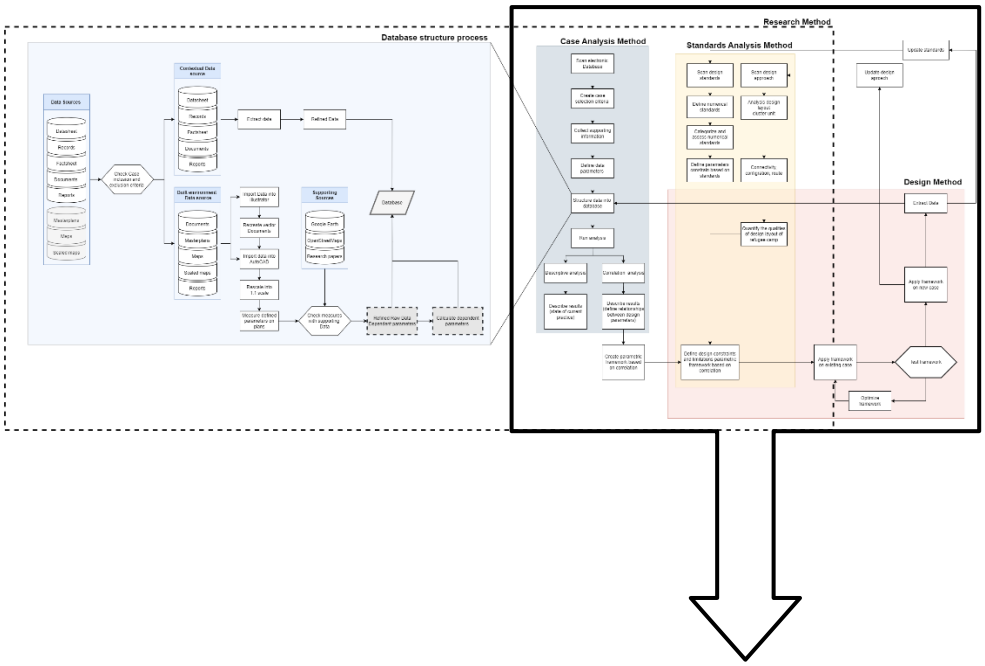
4 RESEARCH METHODOLOGY

The research methodology is based on two main processes: case analysis and reviewing design methods. The two processes work together hand in hand to establish a framework for efficient refugee camps design workflow using parametric design tools.

The case analysis method is used to comprehensively understand current design practices and outcomes and reconstruct case studies design practices into a numerical database as a reference for the future design of refugee camps. First, the research scans the humanitarian database, selects 37 cases to analyse, and defines design parameters which take a crucial role in shaping a refugee camp's design outlines and urban pattern. Later, the analysis measures numerical parameters to quantify the urban structure, structural hierarchy, and refugee camp physical system elements. The case study analysis is divided into two sections. The first section is the descriptive analysis which focuses on assessing current practices and how they comply with today's standards and design guidelines, and correlation analysis which examines the linear relationship of all parameters in relation to each other and represents the correlation using linear mathematical equations.

At the same time, the design method is based on reviewing contemporary literature on refugee camp planning and design theories and existing appurtenant refugee camp design standards to actual practitioners and refugee camp designers. Furthermore, analyse and classify refugee camps based on their built environment's characteristics and explicitly use the urban pattern.

Finally, the two methods are used to construct a refugee camp design framework which can be updated based on current practice and classification of refugee camps' urban patterns. Moreover, the new parametric design framework can be used to set parameter constraints and assessment tools. A summary of the research methodology can be illustrated in Figure 15.



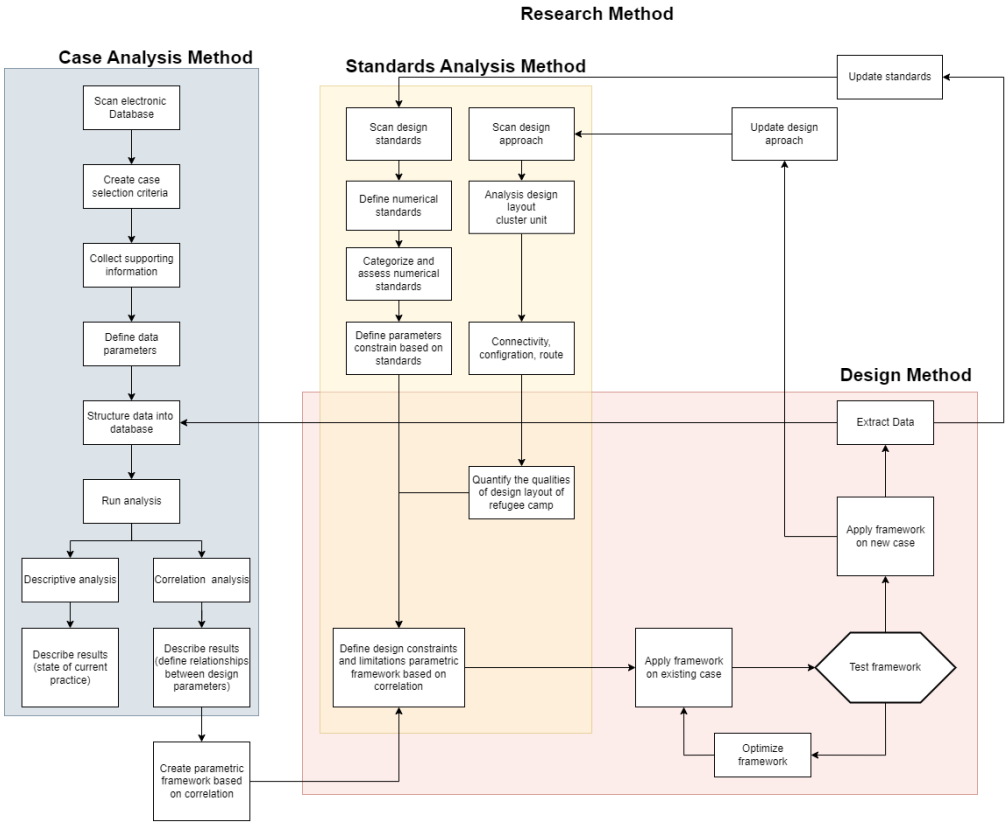


Figure 15 Research methods

Theses I

THESIS I: STANDARDS REVIEW

While the standards have improved tremendously in the past 40 years and included various themes and indicators, the numerical measures could be more specific and specific, making design goals unobtainable and hard to achieve.

Numerical standards could be more coherent and realistic in the case of minimum space for a person. Moreover, it cannot be implemented, and lacking numerical design parameters is not supported by illustrative guidelines, making the standards ambiguous and unattainable in refugee camps design and planning practice.

SUB THESES: Existing standard

- The research scans five global built environments design standards, handbooks and design guidelines and trace their chronological development. The scanned standards and guidelines focus on various themes supporting refugees' safety, quality of life, and needs.
- It categorises refugee camps' built environment standards and investigated numerical standards, existing numerical standards, and their limitation.
- And investigates design guidelines limitations, planning conflicts, and discrepancies in refugee camps' design guidelines.

SUB THESES: Existing design methods

- This section analyses design methods and approaches
- Examine master plan approach, grid, and cluster layout, both their design elements and design,
- And analyse the structural hierarchy of the built environment and the modular arrangement of the refugee camp structure.

5 STANDARDS REVIEW

5.1 REFUGEE CAMPS DESIGN STANDARDS

As previously stated, the numerical standards of refugee camp planning started in the last 30 years, which were divided into the stages of design site selection, schematic planning, design, and later occupation of the camp.

This section examines the existing planning standards and compares them to each other to find similarities and differences; this section will focus on the five standards guidelines or handbooks established by NGOs. The first document is The Sphere; the second is the UNHCR Emergency Handbook. These two sets of guidelines are the primary set of standards used for camp planning and design; both target UN workers in addition to many cross-cutting parties involved in the planning, design, and management of refugee camps. In these two sets of documents, it is essential to mention both lack and illustration for design. It consists primarily of written instructions, which can give a misleading image of the camp design outcomes.

Third, the IOM and the Shelter Cluster SITE PLANNING guideline; fourth, the OXFAM transitional settlement displaced populations guideline; fifth, the Shelter Centre Camp planning guidelines draft 07b. These three guidelines are part of numerous NGO documents established to provide aspects of consideration when providing humanitarian aid. The documents are analysed for their increasingly influential role in the refugee camp lifecycle and because they include illustrations representing the layout of refugee camps. However, due to the publishing organisation's type of aid, the guidelines' theme, principles, methodology, and aims are linked point-blank to the embodiment of the humanitarian aid type provided by the publishing organisation. Table 2 summarises general information about the documents included in the standards analysed in this section.

Table 2 Refugee camp design standards and guidelines

	The Sphere	IOM	Shelter Centre	OXFAM	UNHCR
Edition	Third	Third	Incomplete draft	First	Third
year	2018	2018	2007	2005	2007
Title	Humanitarian Charter and Minimum Standards in Humanitarian Response	SITE PLANNING Guidance to Reduce the Risk of Gender-Based Violence	Camp planning guidelines 07b	Transitional settlement displaced populations	Handbook for Emergencies
Theme	Water, Food, Shelter, Health	Gender-based violence	Strategic planning, self-settled and planned camp	Transitional settlement	Emergency policies and standards
Organisation	Sphere Association and Groupe URD	International Organization for Migration (IOM)	Shelter Centre, Médecins Sans Frontières	University of Cambridge shelter project, Shelter Centre, Oxfam GB	Office of the UNHCR for Refugees for general distribution
Pages	458 Pages	68 Pages	126 Pages	240 Pages	595 Pages
Goals	The Sphere community sets standards for humanitarian action and promotes quality and accountability.	It provides basic information about site planning and gender-based violence risks and offers practical guidance for reducing risks to affected populations in and around camps and sites.	Providing step-by-step guidance on camp planning for specialists and non-specialists, as well as local government bodies concerned with camp planning	overview of the issues relating to transitional settlement and the six settlement options, it offers technical information for the implementation of transitional settlement options	Answering people's urgent need for protection and humanitarian assistance anywhere in the world has been an essential part of UNHCR's work for the past three decades
Type	Standards	Guidelines	Guidelines	Guidelines	Standards
Stage of Involvement	Planning, Location and settlement planning, Living space, household items, technical assistants, security of tenure, environmental sustainability	Planning, Site selection, Living space, Infrastructure	Strategic planning	Process, Implementation	Emergency management, Operation, Support operations
Illustrations	Not included	Included	Included	Not included	Not included

After examining the five sets of standards and guidelines, the analysis shows a lack of numerical standards and policies, specifically in camp physical elements dimensions and layout configurations. The following Table 3, summarises the standards included in the five documents, the primary standards, and the types of standards provided.

Table 3 physical elements and standards themes

		The Sphere	IOM	Shelter Centre	OXFAM	UNHCR
Planning	Numerical	-	-	-	-	-
	Nonnumerical	✓	✓	✓	✓	✓
Location	Numerical	✓	✓	-	-	-
	Nonnumerical	✓	✓	✓	-	✓
Living space	Numerical	✓	✓	-	✓	-
	Nonnumerical	✓	✓	-	✓	✓
Environmental sustainability	Numerical	-	-	-	-	-
	Nonnumerical	✓	-	✓	-	✓
Shelter blocks	Numerical	-	✓	-	-	-
	Nonnumerical	-	✓	✓	✓	✓
Camp Layout	Numerical	-	-	-	-	✓
	Nonnumerical	-	✓	✓	✓	✓
Infrastructure	Numerical	-	-	-	-	-
	Nonnumerical	-	✓	-	✓	✓
Density	Numerical	-	-	-	-	-
	Nonnumerical	-	✓	-	-	✓
Drainage	Numerical	-	✓	-	✓	-
	Nonnumerical	-	✓	✓	✓	✓
Access	Numerical	-	✓	-	-	-
	Nonnumerical	-	✓	✓	-	✓
Water Supply	Numerical	✓	-		✓	✓
	Nonnumerical	✓	✓	✓	✓	✓
Refuse	Numerical	✓	-	-	✓	✓
	Nonnumerical	✓	-	-	✓	✓
Sanitation	Numerical	✓	-	✓	✓	✓
	Nonnumerical	✓	✓	✓	✓	✓

5.2 NUMERICAL STANDARDS

After defining the numerical guidelines, the standards and guidelines are compared based on the categorisation of the guidelines included in the evaluated documents. Later, a comparison matrix was established to build the most comprehensive and liveable standards to be utilised in the assessment of case studies in chapter 5. The comparison matrix consists of four main

themes; planning and living space, expansion, safety, and utilities found in those categories are detailed similarly to include all numerical analyses.

According to chapter 12 in the UNHCR Emergency Handbook (United Nations High Commissioner for Refugees, 2007), The principles of response set to achieve the NGOs are as the following:

- "Use longer-term planning principles, even when the refugee situation is expected to be only temporary."
- "Decisions on site selection and camp planning are tough to reverse, therefore when in doubt, seek technical support."
- "Avoid high population density in settlements and shelters.
- "Avoid substantial emergency settlements; refugee camps should usually be considered as a last resort."
- "Involve refugees in all phases of settlement and shelter planning and construction."
- "Use a bottom-up planning approach, beginning with the smallest social units, preserving traditional social arrangements and structures as far as possible."
- "Develop a comprehensive master plan, with the settlement layout developed around sanitation and other services, providing room for expansion."

5.2.1 Planning and living space

The standards are mainly focused on two scales, the scale of the master plan and the scale of the plot unit. Moreover, the standards ignore the hierarchy of spaces Figure 16 and neglect the configuration in between, such as; cluster, block, and sector unite standards lacking dimensional, spaces relations, and layout guidelines leaving design outcomes enigmatic and impossible to compare with standards. Therefore, to assess the rationality of the criteria, the following assumptions are made to re-model the refugee camp urban system according to the living space area standards summarised in Table 5. The

standards recommend a minimum usable area per person of 45 m^2. The surface area per person includes the area necessary for roads, footpaths, educational facilities, sanitation, security, firebreaks, administration, water storage, distribution, markets, relief item storage, and of course, plots for shelter with kitchen/ vegetable gardening. (Sphere Association, 2018) (United Nations High Commissioner for Refugees, 2007) (Corsellis & Antonella, Oxfam - Transitional settlement displaced populations, 2005) (International Organization for Migration (IOM), 2014) (Shelter Centre, Médecins Sans Frontières, 2007) and the minimum area per person is further expressed as Actual Surface area per person (30 m^2) and Garden Space per person (15 m^2) expressed mathematically as per Equation 1:

Equation 1 Camp minimum surface area per person (m^2)

$$Minimum\ surface\ area = Actual\ surface\ area\ per\ person + Garden\ space$$

Moreover, the standards determine the maximum camp capacity of 20,00 persons. Still, on the other hand, it does not provide the maximum area of the camp, which can be easily calculated based on a simple mathematical equation as expressed per Equation 2:

Equation 2

$$Camp\ area = Minimum\ surface\ area * population$$

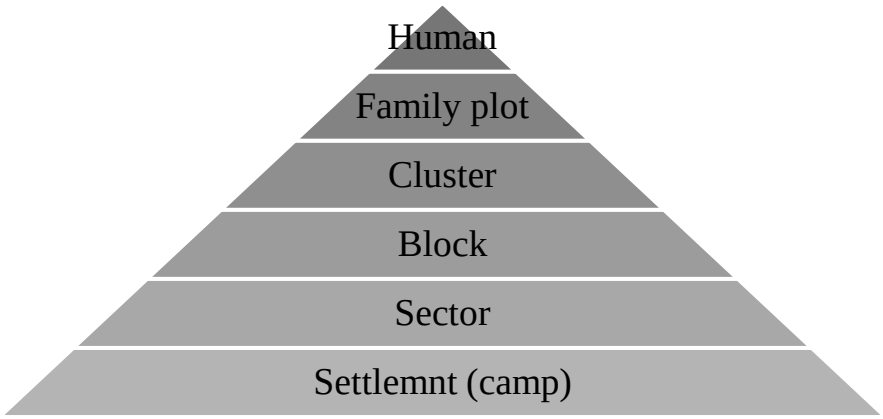


Figure 16 Refugee camp spatial hierarchy

The spatial hierarchy of camps modules is later used to build the structural hierarchy of the system that identifies the refugee camp. Moreover, the refugee camp's spatial hierarchy is arranged and structured by the street network of the camp in addition to the population and urban density. Table 4 summarises the urban pattern and density of refugee camps modules of spatial hierarchy.

Table 4:Urban pattern structural hierarchy

MODULE	STRUCTURE	APPROXIMATE NUMBER
Plot (family)	1 x family	4 - 6 Persons
Cluster (community)	16 x family	80 Persons
Block	16 x cluster	1,250 Persons
Sector	4 x block	5,000 Persons
Settlement	4 x sectors	20,000 Persons

Examining the numerical standards of various organisations is significant to understanding the urban system of refugee camps. Therefore, the numerical parameters and constraints were collected and compared in Table 5, which focuses on the general living space standards. It is evident that some standards are established along all global documents, were others were excluded or unmentioned. For example, the minimum ratio between covered space and plot size is only mentioned once in the sphere handbook; however, the plot's size was never mentioned even once in the same document.

Table 5 Refugee camp planning and living space numerical standards mentioned in The Sphere, Site planning (GBV), Camp Planning B07, Transitional settlement OXFAM, UNHCR Emergency Handbook

		Standards	The sphere	SITE PLANNING (GBV)	Camp Planning B07	Transitional settlement OXFAM	UNHCR Emergency Handbook
Camp	Camp	The minimum usable surface area, including household gardening space	45 m^2 per person (p.257)	45 m^2per person (P.17,24)	46 m^2 per person (P.47, 86, 123)	45 m^2 per person (P.373, 374)	45 m^2 per person (P.210)

		The minimum usable surface area (communal services and plots for shelter)	30 m^2 per person (P.257)	30 m^2 per person (P.24)	30 m^2 per person (P.47)	30 m^2 per person (P.373, 378)	30 m^2 per person (P.210)
		Household gardens in site plan per person	*	15 m^2 (P.24)	*	15 m^2 (P.378)	15 m^2 (P.210)
		Maximum camp size	*	*	20,000 people (p.86)	20,000 people (p.373)	20,000 people (p.211)
		Gradient	*	*	1% - 6% (P.123)	*	2% - 4% (p.212)
		Family plots size	*	*	*	> 200-300 m^2 (p.57, 386)	shelter area =3x6=18 m2 (p.214)
		The minimum ratio between covered space and plot size	1:2-3, but 1:4 - 5 is preferable (p.250)	*	*	*	*
		Space between buildings	2 m; or double building height (P.259, 528)	2 m; or double building height (P.22)	Minimum twice structure height (p. 47)	2m (p.378)	< 1-1.5 m between neighbouring tents on all sides (p.549)
		Family plot front setback	*	*	*	*	5 - 7 m from roads (p.219)
	Shelter	Minimum covered floor area per person	3. m^2, 4.5–5.5 m^2 in cold climates (P.259)	3.5 m^2 in tropical or warm climates, 4.5m^2 to 5.5m^2 in cold climates (P.24)	At least 3.5 m^2 except in extreme circumstances (p.47)	< 3.5 sq. meters per person (p.381)	< 3.5 sq. meters per person (p.64)
		Internal floor-to-ceiling height	> 2 m (2.6 m in hot climates) (P.257)	> 2 m at the highest point (P.24)	*	*	*
	Access	Road and Access	*	Major roads must be for two vehicles, pedestrians, drainage, and activities (P.23)	*	*	*

5.2.2 Expansion

When comparing expiation standards and considerations listed in Table 6, they are explicitly lacking in the Sphere, Camp Planning draft B07, and the transitional settlement guidelines of OXFAM, even though the UNHCR states that expansion of 3-4% population growth needs to be taking into consideration when planning. Moreover, we can see a numerical standard set in the GBV site planning guidelines that require 5 square meters to be considered for each family plot. Nevertheless, the standards do not indicate how those 5 meters can be added or do not provide any design illustrations for the process of explanation, keeping in mind that the average time spent in a camp is 17 years. Therefore, when applied to the abovementioned standards, the population growth of an average household of 5 over 17 years is 4.3 new members, meaning that the camp area needs an increase of 80% to comply with the standards. In comparison, the GBV standards require a fraction of that area.

Table 6 Refugee camp extension numerical standards mentioned in The Sphere, Site planning (GBV), Camp Planning B07, Transitional settlement OXFAM, UNHCR Emergency Handbook

		Standards	The sphere	SITE PLANNING (GBV)	Camp Planning B07	Transitional settlement OXFAM	UNHCR Emergency Handbook
	Extension	Extension	*	$5m^2$ per family plot, multiplied over a camp for 2,000 families, added to the total. (p.24)	*	*	The population could grow as fast as 3 to 4% per year (p.211)

5.2.3 Safety

In terms of safety, the general meaning of safety is limited to fire safety, not security or social safety. Although the central theme of GBV standards is focused on keeping the safety of risk groups, the guideline itself focuses on general guidelines and universal recommendations rather than context-specific design considerations. Therefore the numerical standards are not

supporting the safety of risk groups within the camp but minimise the risk of fire spread within the urban settlement.

Fire safety standards are used to identify the unite spacing and the urban block dimensions and capacity due to the firebreak requirements, which limit the urban block to a maximum of 300*300 meters, assuring the maximum area of an urban block would be 90000 square meters. In reference to general standards in Table 5, when applying minimum area per person, an urban block with the abovementioned dominion can have the capacity of 2000 persons and limits the number of urban blocks in a camp to 10 urban blocks since the maximum camp capacity is 20,000 people

Table 7 Refugee camp safety numerical standards mentioned in The Sphere, Site planning (GBV), Camp Planning B07, Transitional settlement OXFAM, UNHCR Emergency Handbook

		Standards	The sphere	SITE PLANNING (GBV)	Camp Planning B07	Transitional settlement OXFAM	UNHCR Emergency Handbook
Safety	Firebreaks	The minimum distance between the block	30-m firebreaks every 300 m (P.257)	30-m firebreaks every 300 m (P.22)	30-m firebreaks every 300 m (p.47)	*	30-m firebreaks every 300 m (P.219)
		The minimum distance between clusters	6 m (P.257)	*	*	6 m (P.378)	*
		The minimum distance between buildings	2 m; or 2*building height (P.257)	2 m; or 2*building height (P.22)	*	2 m (P.378)	2 m; or 2*building height (P.219)

5.2.4 Utilities

The standards mention particular numerical standards related to users' travel distances when accessing common utilities such as water taps, stationaries, and refusers. However, the numerical standards are very generalised and lack supporting graphical illustrations. Table 8 summarise numerical standards related to common utilities. The most significant numerical standard is assigning 15-20% of the camp to public facilities; this recommendation is only mentioned once and in one of the standards guidelines documents in the UNHCR handbook.

Table 8 Refugee camp utilities numerical standards mentioned in The Sphere, Site planning (GBV), Camp Planning B07, Transitional settlement OXFAM, UNHCR Emergency Handbook

Utilities	Water supply	Minimum quantity of water (litres per person per day)	7.5–15 (p.98)	7.5-17 ** (P.20)	15-20 (p.47)	15 (p.378)	15-20 (p.546)
		People per tap-stand	250 (P.99) ***	250 -500 (P.20) ***	200-250 (p.48)	250 (p.378)	200 (p.549)
		Distance from dwellings to taps	< 500 m (p.97)	*	< 500 m (p.48)	<100 m (p.378)	< 100 m (p.549)
	Sanitation	Maximum people per latrine	20 people (p.105)	Four units per cluster (p.29)	5-20 people (p.48)	(1) family (5–10 people) (2) 20 people (p.381)	(1) family (5–10 people) (2) 20 people (p.549)
		Distance from dwelling to the toilet	< 50 m (p.108)	*	6–50 m (p.48)	6–50 m (p.381)	6–50 m (p.549)
		The minimum distance between latrines and water source	30 m (p.105, 106)	*	20 m (p.48)	30 m (p.379)	30 m (p.250)
		Distance from the bottom of the pit to the water table	minimum 1.5 m (p.105, 106)	*	Minimum 1.5 m (p.48)	Minimum 1.5 m (p.379)	minimum 1.5 m (p.269)
	Refuse	Distance from dwellings to refuse disposal	<100 m to communal pit (p.118)	*	<100 m to communal pit (p.48)	<15m to; or <100m to communal pit (p.379)	15 m (p.273)
		People per 100-litre refuse container	Maximum 10 families (p.118)	*	10 families or 50 persons (p.48)	10 families or 50 persons (p.379)	Maximum 10 families (p.273)
	Public Faciliti	Open space and public facilities	*	*	*	*	15-20% of the entire site

	**	Tap based on a flow of 7.5-17 litres/minute Hand pump based on a flow of 17 litres/minute Open well based on a flow of 12.5 litres/minute
	***	250 people per tap, 500 people per hand pump, 400 people per single user open well

5.3 CAMP LAYOUT PLANNING GUIDELINES

The planning of a refugee camp layout as recommended by the Shelter Centre in the "Camp Planning B07 draft" (Shelter Centre, Médecins Sans Frontières, 2007) suggests two main layouts: the grid layout and the cluster layout (cul-de-sac) Figure 18. In the case of a grid, the roads are arranged in perpendicular right angles forming urban blocks that are uniform in size and shape, creating a rigid urban pattern like the Azraq camp in Jordan Figure 17. On the other hand, the cluster layout is developed by establishing the main road with private branches. In which the community unit is arranged, the cluster layout is nowhere to be found in practice. However, it is still used in literature often as an upgrade to existing cases due to its advantages in improving privacy, security, and social interaction while reducing street network area. The global camp design and planning standards list some of the advantages and disadvantages of the two planning layouts, summarised in

Table 9. This section will further focus on the grid layout since it is commonly used in practice; the section explains and assesses the grid layout to scrutinise the coherence of standards when applied to the grid layout.

Figure 17 Arial view of Azraq refugee camp -grid layout

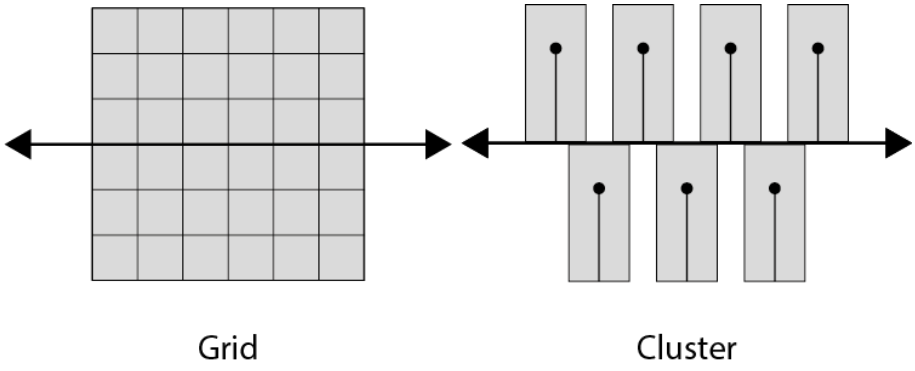


Figure 18 Refugee camp layout

Table 9 Advantages and disadvantages of grid layout and cluster layout

		Advantages	
Grid layout	It cannot be used on hills and gullies	Topography	It can be used on hills ad gullies
	Creates wind channels	Wind	Wind channels are short
	Lack of semi-private space	Community space	Creates a sense of community space
	Inefficient interaction	Interaction	Increase community interaction
	Less effective	Security	More effective
	Enforce water drainage	Drainage	Enforce water drainage
	Easy to distribute	Utility network	Easy to distribute
	It can expand in all directions	Expansion	Can expand along the main road
			Cluster Layout

To examine the rationality of the given standards, the following section is dedicated to discussing a hypothetical case applying the above numerical guidelines. The presumption is that the camp has a total capacity of 20,000 people and an average population growth of 4%. Furthermore, the camp layout is a square's most minimalist geometrical shape.

First, define the total camp area by applying Equation 2, where the population is 20,000 persons, and the minimum surface area per person is 45 m^2

Equation 3

$$Camp\ area = Minimum\ surface\ area * population$$

$$Camp\ area = 45 * 20{,}000$$

$$Camp\ area = \ 900{,}000\ m2$$

5.3.1 Grid Layout

If the camp layout is a perfect square, then the area of a square is:

$$Area = a^2$$

Where (a) is the square sides' length

If the cam area is 900,000 $m^{2,}$ the side length of a camp with a square layout is approximately 948.68 m., and every base is divided into four sectors, and every sector is divided into four blocks. Each block is divided into 16 clusters, and every cluster is divided into eight plots. Moreover, by applying 30 m fire breaks, the following layout expresses the camp's possible design Figure 19.

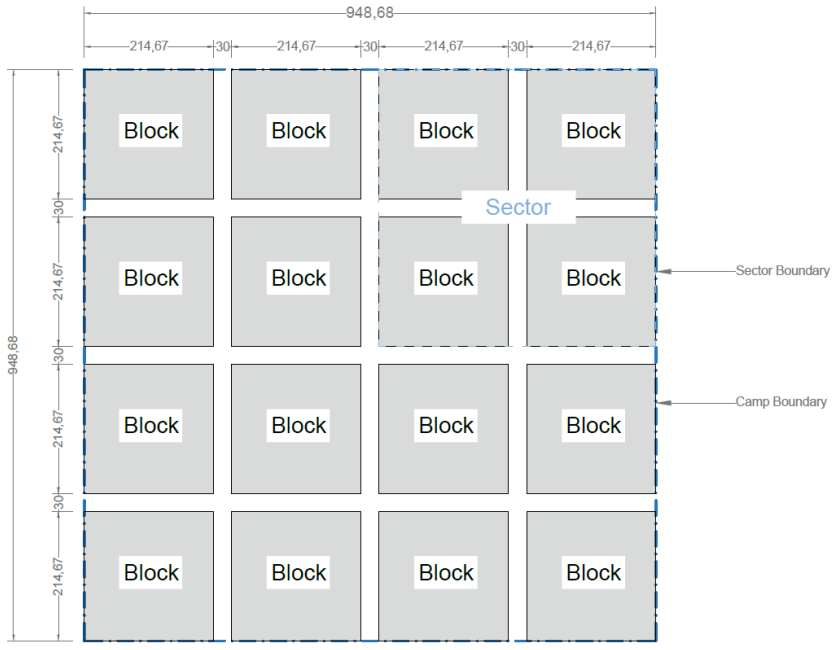


Figure 19 Camp layout, four sectors and 16 blocks with firebreaks

The layout consists of 6 firebreaks, each three running vertically and three runnings horizontally, intersecting in 9 junctions. Therefore to calculate the area of firebreaks, the following equation applies:

$$Firebreak\ area = (Area\ of\ one\ firebreak * number\ of\ firebreaks) - (area\ of\ intersection * number\ of\ intersections)$$

*Firebreak area= (948.68*30*6)-(30*30*9)*

Firebreak area= 162,662 m²

When all blocks are uniform in size, then the side length of the block is 214.67 m, as seen in Figure 19. As a result, the block area is 46,083 m^2.

Every block consists of 16 clusters. To plan the next level of the spatial hierarchy, we need to identify the distance required between clusters, while the UNHCD handbook does not offer any guidelines on the distance between clusters. The Sphere guidelines recommend spacing clusters by 6 meters, as seen in Figure 20.

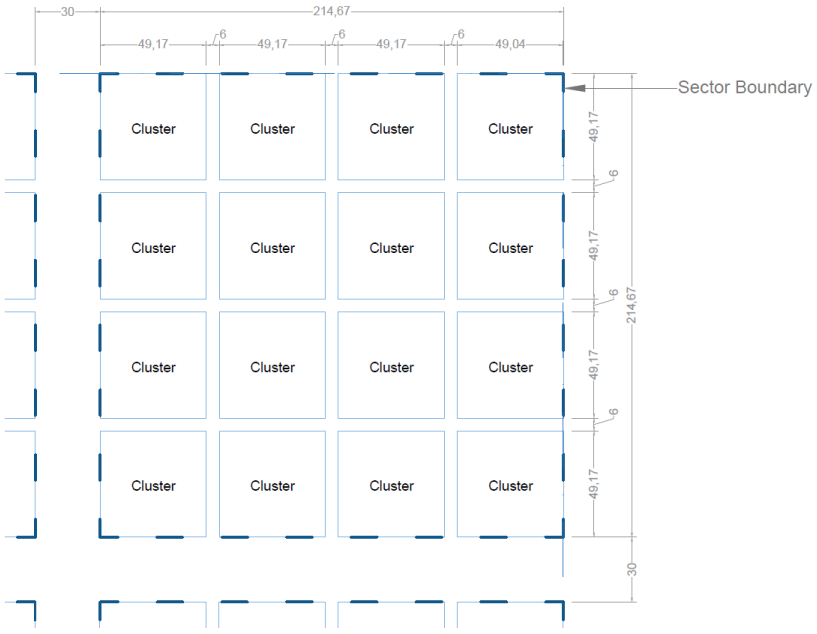


Figure 20 Camp layout, blocks and 16 clusters with pathways

The layout consists of 6 pathways, each three running vertically and three runnings horizontally, intersecting in 9 junctions. Therefore to calculate the area of pathways, the following equation applies:

Equation 4

$$Pathways\ area = (Area\ of\ one\ pathway * number\ of\ pathways) - (area\ of\ intersection * number\ of\ intersections)$$

$$Pathways\ area = (214.67*6*6) - (6*6*9)$$

$$Pathways\ area = 7{,}404\ m^2$$

This area is calculated for a single block. In order to call collate camps pathways area, we need to multiply the area by the number of blocks (16), therefore the area of the pathway in camp

Equation 5

$$Total\ pathways\ area = (Area\ of\ one\ pathway * number\ of\ blocks)$$

$$Pathways\ area\ *16 = (7{,}404\ *16)$$

$$Camp's\ pathway\ area = 118{,}466\ m^2$$

From the previous calculations, we can conclude that the roads and pathways area is 281,128 m^2, making 31.2% of the total camp area; this is not consistent with the UMHCR standards, which recommend that the road and pathway area must not exceed 20-25% of the total camp area. Furthermore, if that percentage of roads and paths was applied to the minimum area per person, the remaining area is (36.00- 33.75 m^2).

When all clusters are uniform in size, the side length of the cluster is 49.17 m, as seen in Figure 20. As a result, the cluster area is 2,417.5 m^2. According to the UNHCR hierarchical structure of space, each cluster is divided into 16 family plots, meaning that the area of a family plot is 151 m^2. The family plot is a property assigned to a family of 4-6 members, but the standards define the population of a cluster of a rigid number of 80 people. Table 10 shows the expected camp area per person and predicted camp population if the plot size is 151 m^2 in 15 years with a population growth of 4%. Table 10 shows that once the household size is larger than 4 members, the spaces and camp size is not complying with standards; in other words, camp planning standards are inherently not working and cannot be achieved. Moreover, within the average

time spent in a refugee camp (17 years), the camp population will be more than double the maximum camp size recommended by the standards. Therefore, ignoring camp growth and extension leads to unequivocal refugee camps' failure in planning, operation, and management.

Table 10 Camp population based on household size and population growth

		Household size	Area per person	Cluster population	Block population	Camp population
When established		4	37.75	64	1,024	16,384
		5	30.20	80	1,280	20,480
		6	25.16	96	1,536	24,576
Extension of a 4% growth	5 years	7	21.57	112	1,792	28,672
	10 years	9	16.77	144	2,304	36,864
	15 years	11	13.72	176	2,816	45,056

While the UNHCR Handbook indicates a percentage of open space in its tool kit appendix of 15-20%, it can hardly be achieved, as seen in the following diagram Figure 21, the difference between the assigned space by standards and by the rational implantation of the recommended standards.

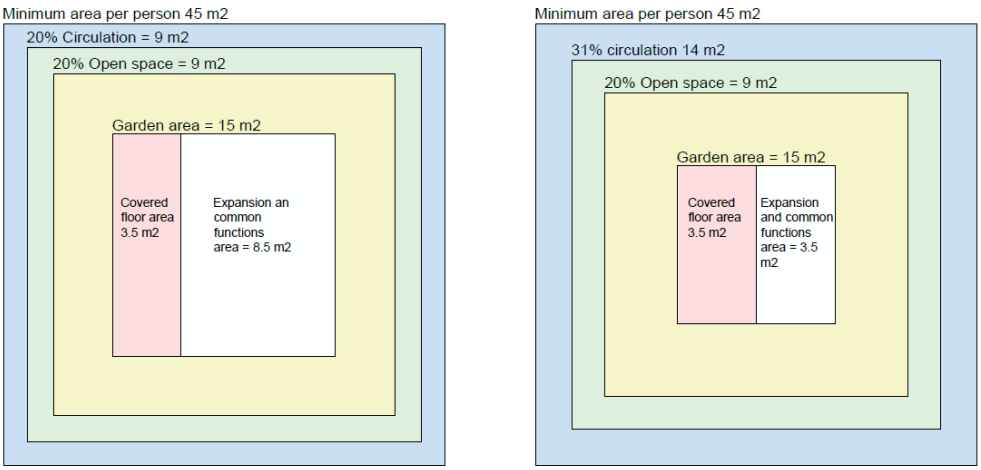


Figure 21 Detailed space function of minimum area per person, Left: as per standards, Right: as per rational calculation

As seen in Figure 21, the increase in circulation ratio in the camp layout directly influences the expansion and common functions; the area decreases

from 8.5 m to 3.5m which is more than half. This massive decrease in space adds pressure on the number of units and population of the family plot and, later on, cluster unit, which will be discussed in the following section.

5.4 COMMUNITY UNIT (CLUSTER UNIT) LAYOUT

Similar to the block configuration, the UNHCR Handbook and The Sphere offer no space layout or dimensional configuration of the community unit. The community unit layout relies on the Site Planning Standards (GBV) and Frederick C. Cuny's report Refugee Camp Planning: The State Of The Art, which includes six different layouts as the following, Figure 22:

1. Square block
2. Hollow square
3. Horseshoe plan
4. Short double line
5. Community road plan
6. Staggered block

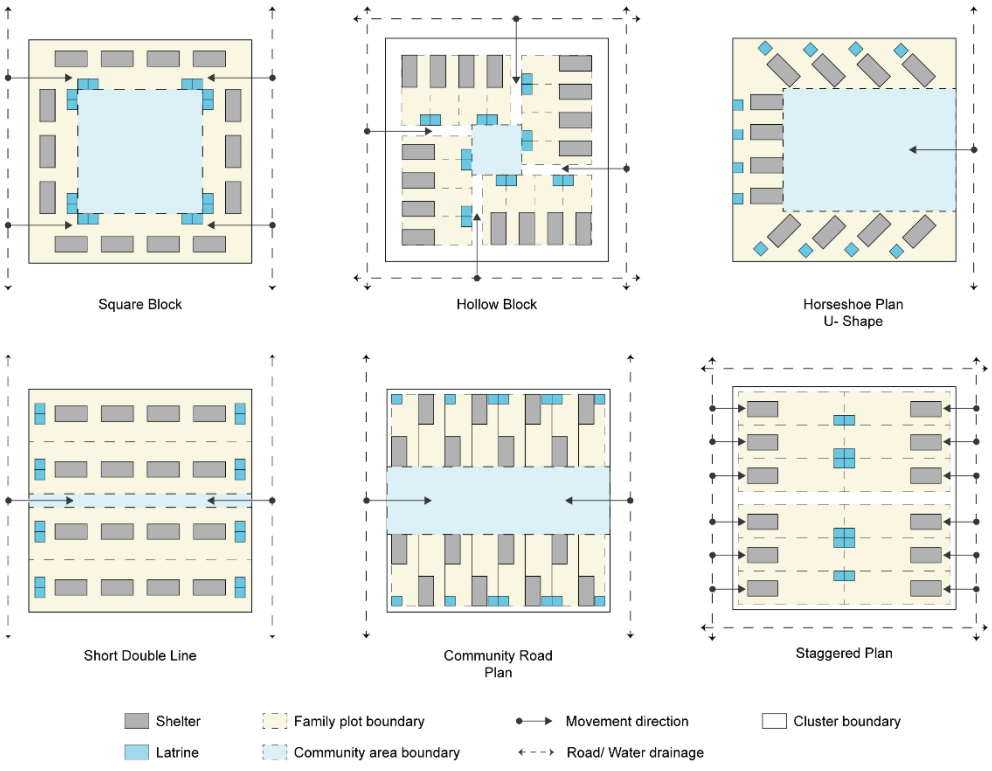


Figure 22 Community units layout based on standards

The standards used in detailing the community unit layout focus on the following:

- The communal facilities' capacities listed in Table 11. The cluster unit must have at least one water tap and two refusal drums. Moreover, each family unit must have at least one latrine.
- Safety standards listed in Table 7, assuming the minimum building height of shelter units to be 2 meters, the distance between shelters will be calculated as double building height (2*2m). Therefore the spacing between shelters would be 4 meters minimum.

Table 11 Refugee camp communal facility capacity

Communal facilities	*Maximum community size Transitional settlement OXFAM*	*Maximum community size UNHCR Emergency Handbook*
1 water tap	250 Persons	1 community (80 – 100 persons)
1 latrine	1 family (5-20 persons)	1 family (6 – 10 persons)
1 health centre	30,000 (1 bed per 2,000–5,000 refugees)	1 site, 200000 Persons
1 referral hospital	10 site (200,000 persons)	10 site (200,000 persons)
1 school block	1 sector (5,000 persons)	1 sector (5,000 persons)
4 commodity distribution sites	1 site (20,000 persons)	1 site (20,000 persons)
1 market	1 site (20,000 persons)	1 site (20,000 persons)
1 feeding centre	*	1 site (20,000 persons)
2 refuse drums	*	1 community (80 – 100 persons)

5.4.1 Square Block

The square block consists of 12 shelter units arranged around the cluster unit boundary creating an enclosure of latrines and public social space in the enclosed space; usually, in this configuration, shelters open towards the court or the enclosed public space. The square block layout provides a shared public space assigned to the cluster unit. As a result, for the residents of that specific cluster, the shared space can be used for gardening and improve the privacy of latrines and shower users; in addition, the layout is considered resilient in the case of expansion and increased cluster density where the community space can be used.

On the other hand, the square layout provides two units less than what is recommended in standards where clusters consist of 16 plots; second, the private plots are not clearly defined, which makes the public space hard to manage for residents if they lack any social relationship. Communal space is at risk of being controlled by the dominant family in the cluster, taking a right to garden from other members of the cluster unit. Moreover, in the case of private fencing of shelter units and surrounding areas, the fencing can create blind allies and increase the risk of abuse and attacks for vulnerable refugees such as women and children.

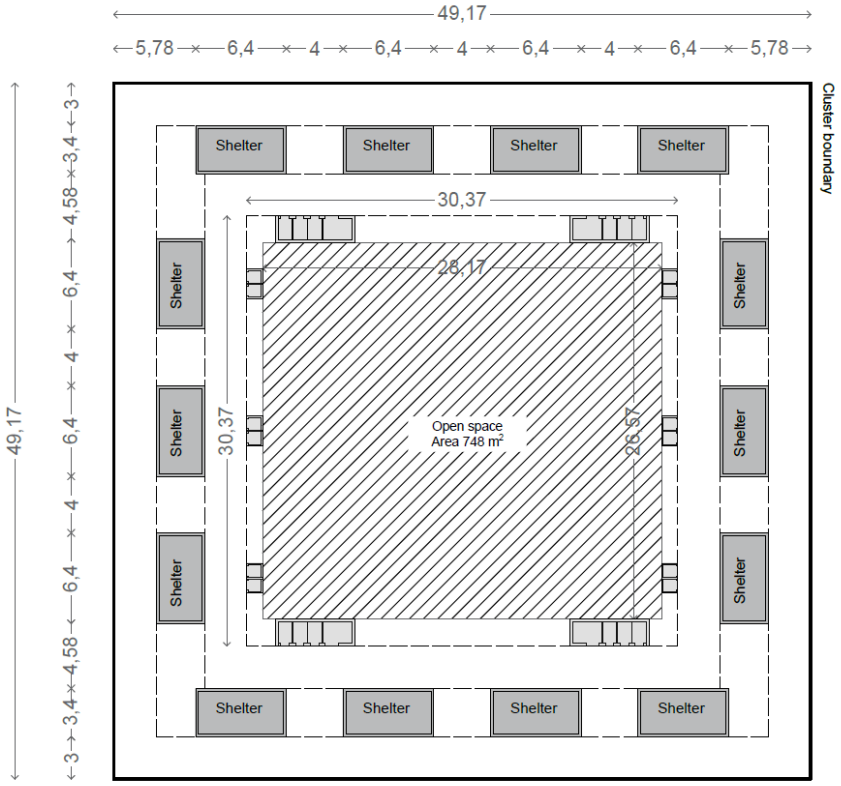


Figure 23 Square block cluster plan layout

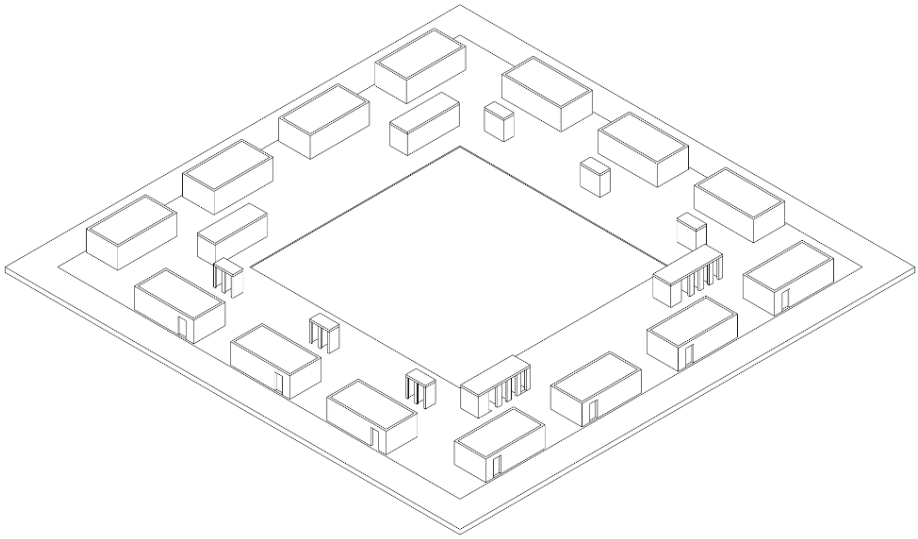


Figure 24 Square block cluster unit three-dimensional illustration

5.4.2 Hollow square plan

The hollow square plane consists of 16 plots arranged in an interlocking axis aligned to the borders of the cluster unit boundary; the hollow square provides public access to each plot in the layout facing an access route. While the rare end f the shelter faces a private space that helps reinforce safety and security as well as social interaction with other family plots within the cluster.

As a result of the arrangement, the resultant space forms a small public area in the middle of the cluster unit, which is suitable for locating the shared water tab and extra latrines when needed. Furthermore, locating the commonly used utilities within the cluster unit inforced the maintenance of the utilities by the community itself.

Furthermore, it can be observed that in this arrangement, the closest neighbour of a shelter is most likely to be on the opposite block, which is further away, which results in reduced social interaction and, as a result, a sense of community.

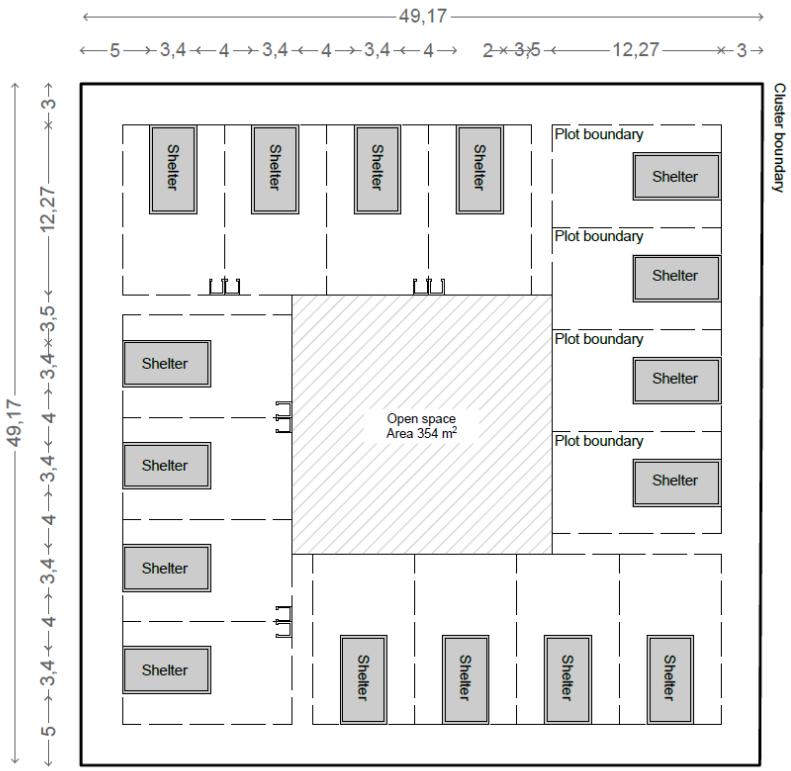


Figure 25 Hollow square cluster plan layout

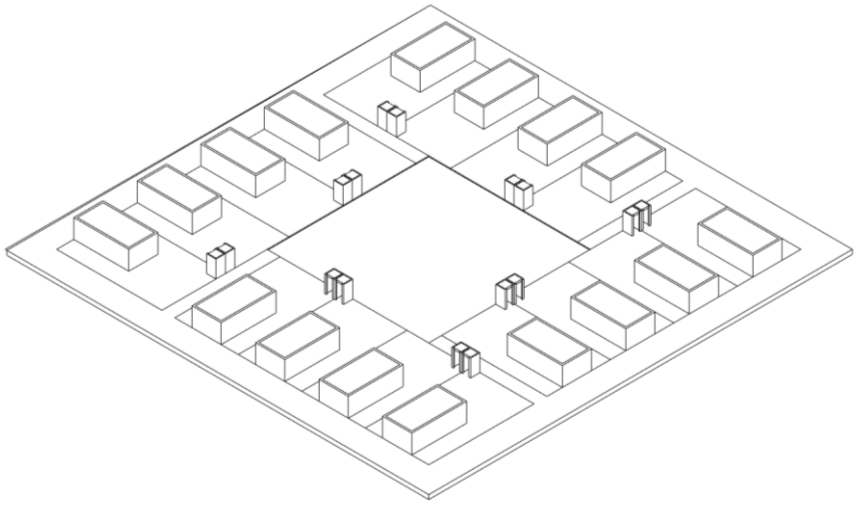


Figure 26Hollow square cluster unit three-dimensional illustration

5.4.3 Horseshoe block

The horseshoe, also referred to as the U-shape block plane, consists of 16 plots arranged in a U shape with the shelter's entrance facing the centre Figure

27; the shelters are arranged in a 45 degree. Although the centralised public area forms a protected open space used by the inhabitant of the cluster unit, the horseshoe cluster has the most significant public space of all cluster types, which promotes social interaction and provides extra space for the future expansion of the camp.

Horseshoe clusters can create conflicts between inhabitants since where the dominant family can take over the majority of the public space, and it limits the individual properties of a family, according to the (International Organization for Migration (IOM), Global Shelter Cluster, 2010) horseshoe cluster is the most challenging to build, time-consuming, and har to expand on large sites. And in the case of placing fences on family property, there is an increase in risk to safety for venerable individuals

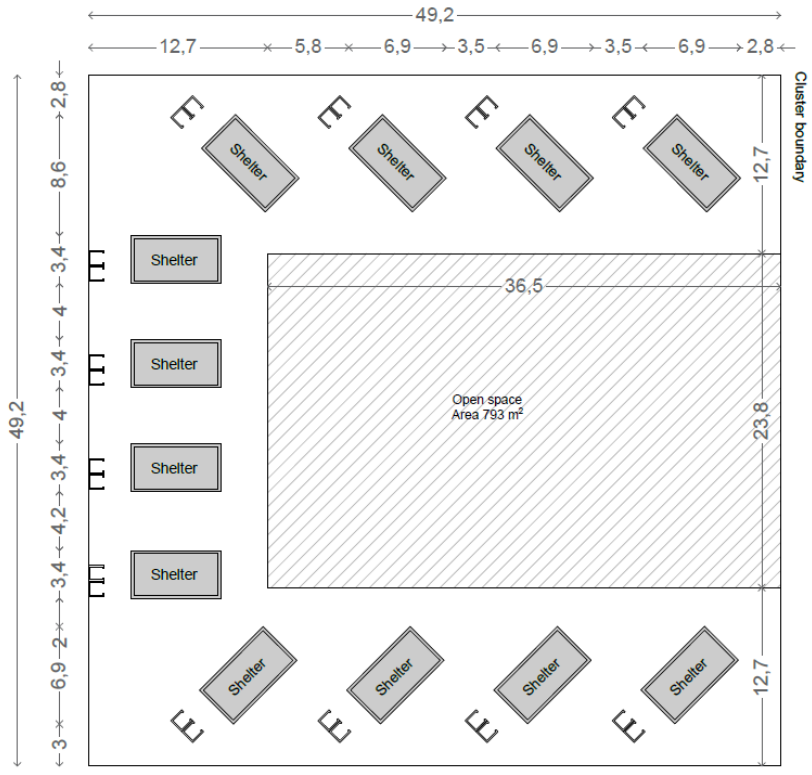


Figure 27 Horseshoe cluster plan layout

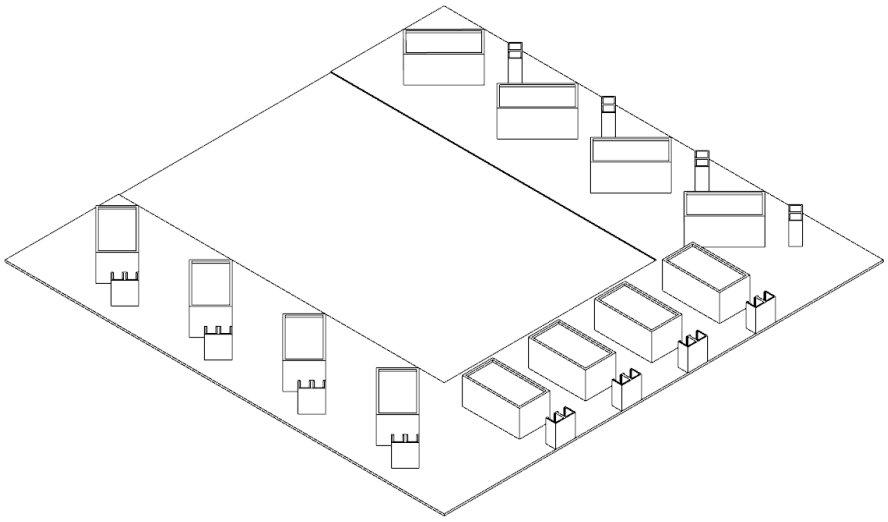


Figure 28 U-Shape cluster unit three-dimensional illustration

5.4.4 Short double-line cluster

The short double-line layout is one of the most straightforward layouts in time space and work capacity. The cluster consists of four rows of units, each having four shelters. A shared walkway passes through the long axis to provide accessibility to plots in the centre of Figure 29 and Figure 30. It divides the cluster space into distinguished family plots that can be upgraded to include private latrines and showers in each family plot. Provide sufficient security and monitoring space.

Nevertheless, the layout does not provide any public space and less space for future expansion of the camp, and latrines are not private, which might increase gender-based violence. Therefore, the guidelines later suggest mitigation of the layout, forming the staggered plan and community road clusters.

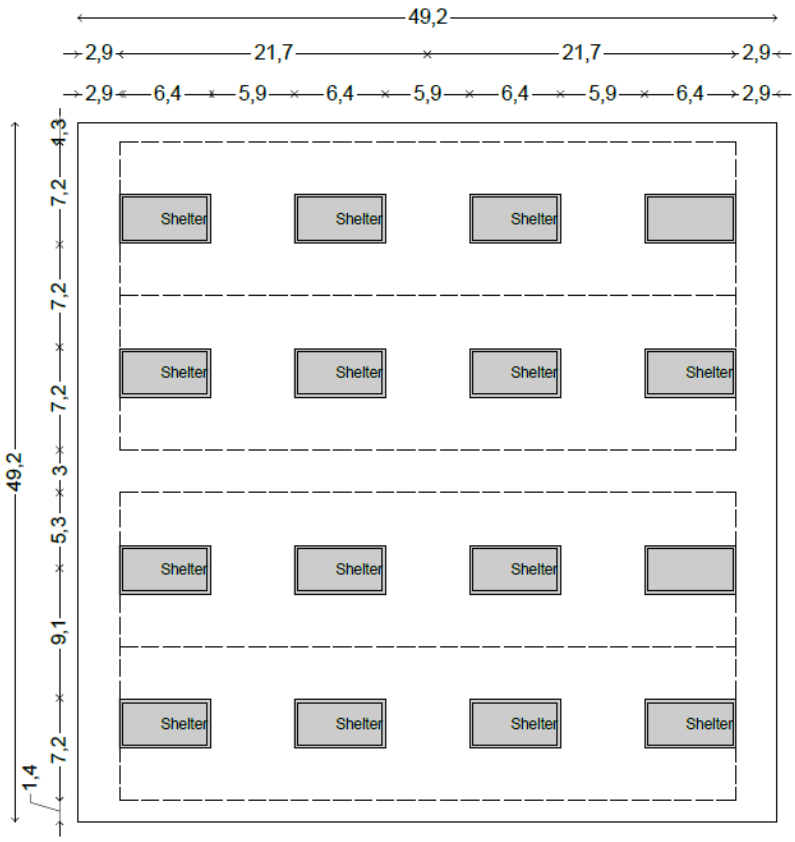


Figure 29 Short double-line cluster plan layout

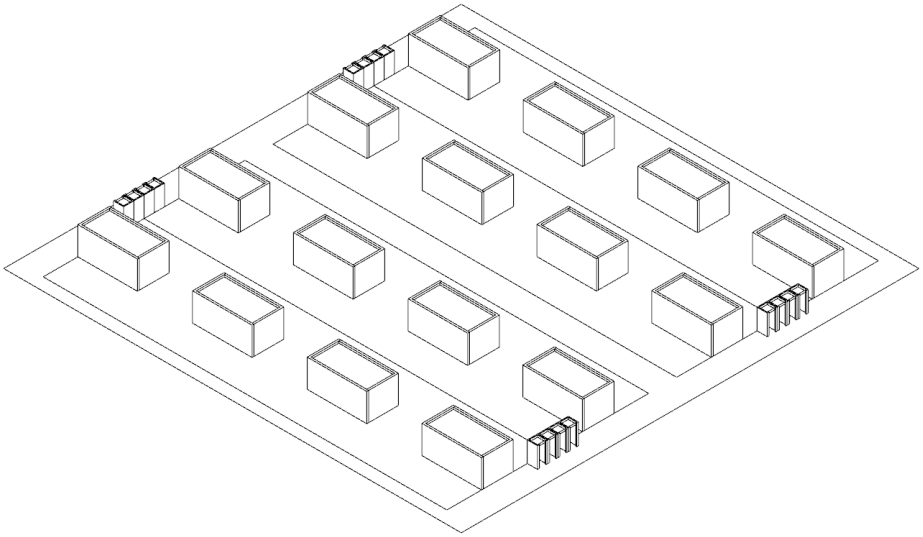


Figure 30 Short double line cluster unit three-dimensional illustration

5.4.5 Staggered square plan cluster

The staggered plan is arranged in two sections, each having eight family plots, similar to the double line plan, but the family units are arranged facing a dead-end street (cul-de-sac) street; the dead-street increases privacy of the street, improving the social control and safety of the community and enforce social interaction. While the rare side of the family plot is arranged in a back-to-back arrangement assuring family privacy, private latrines and showers are placed at the rear end of the family plot.

Arranging the staggered square clusters into urban blocks prevent forming of long street roads, which improves wind flow since it blocks long wind funnels and increases road privacy and security. In addition to the private position of latrines, it improves community maintenance of the shared facilities.

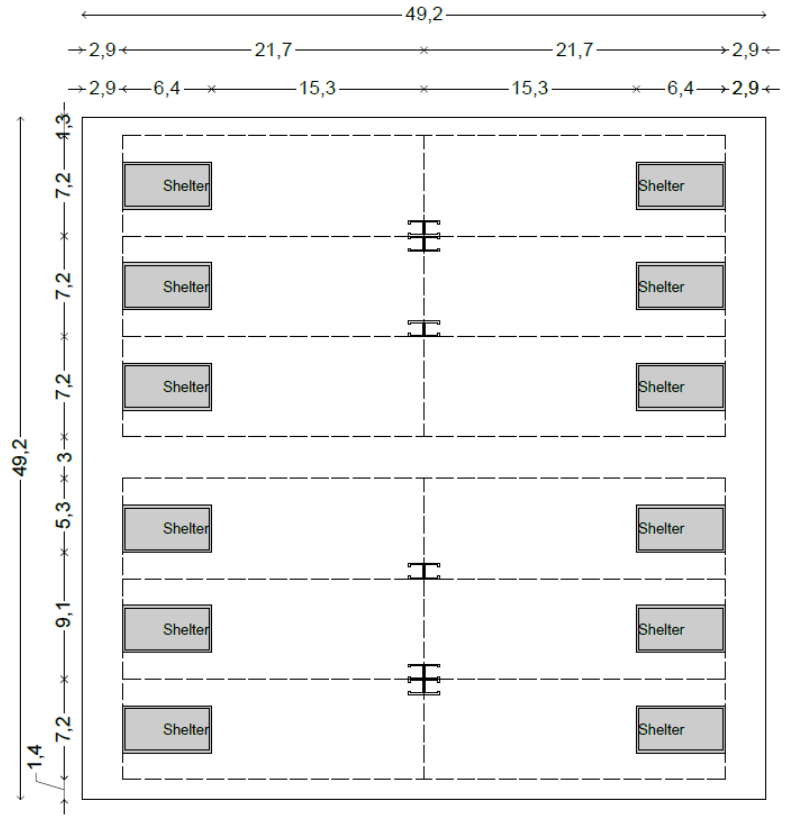


Figure 31Staggered square cluster plan layout

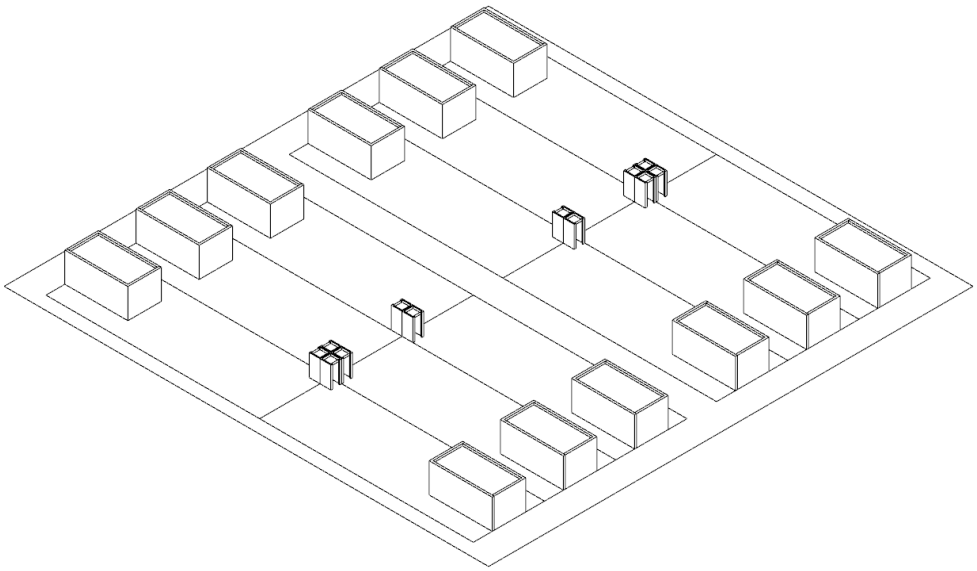


Figure 32 Staggered square cluster unit three-dimensional illustration

i. Community road plan cluster

In the community road cluster, the units are arranged facing the communal road, where they are set back to create a shared public space in the cluster's centre. The communal spaces increase the send of community and reinforce social interaction.

The family plots include private latrines to increase privacy and the risk of girls and children being attached; the alignment of the family plots allows the pairing of latrines, increasing the efficiency of the plumbing system and water source connection in the future.

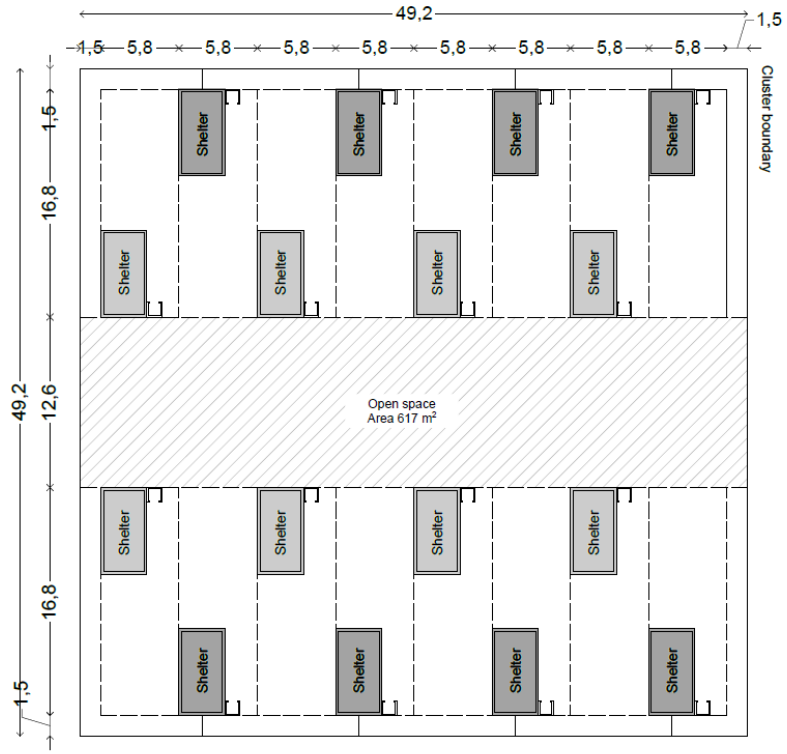


Figure 33Community Road cluster plan layout

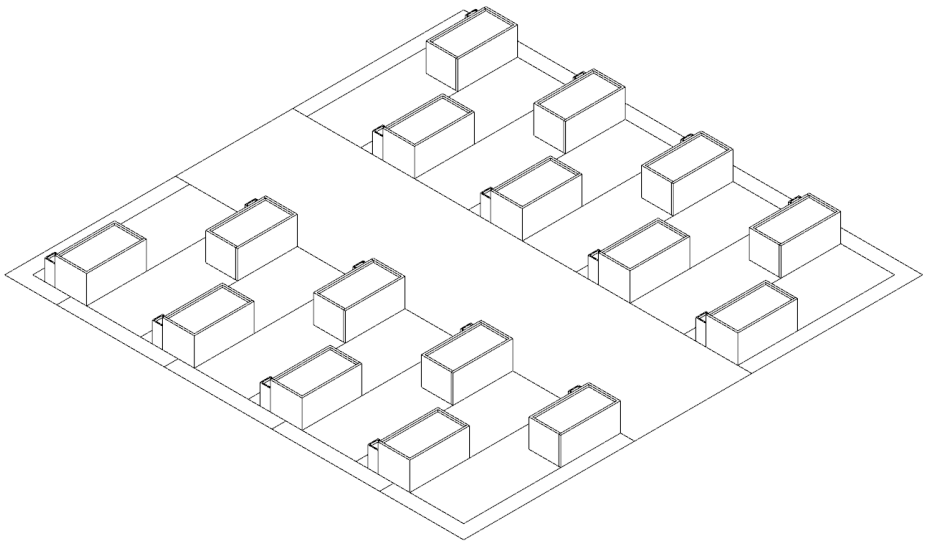
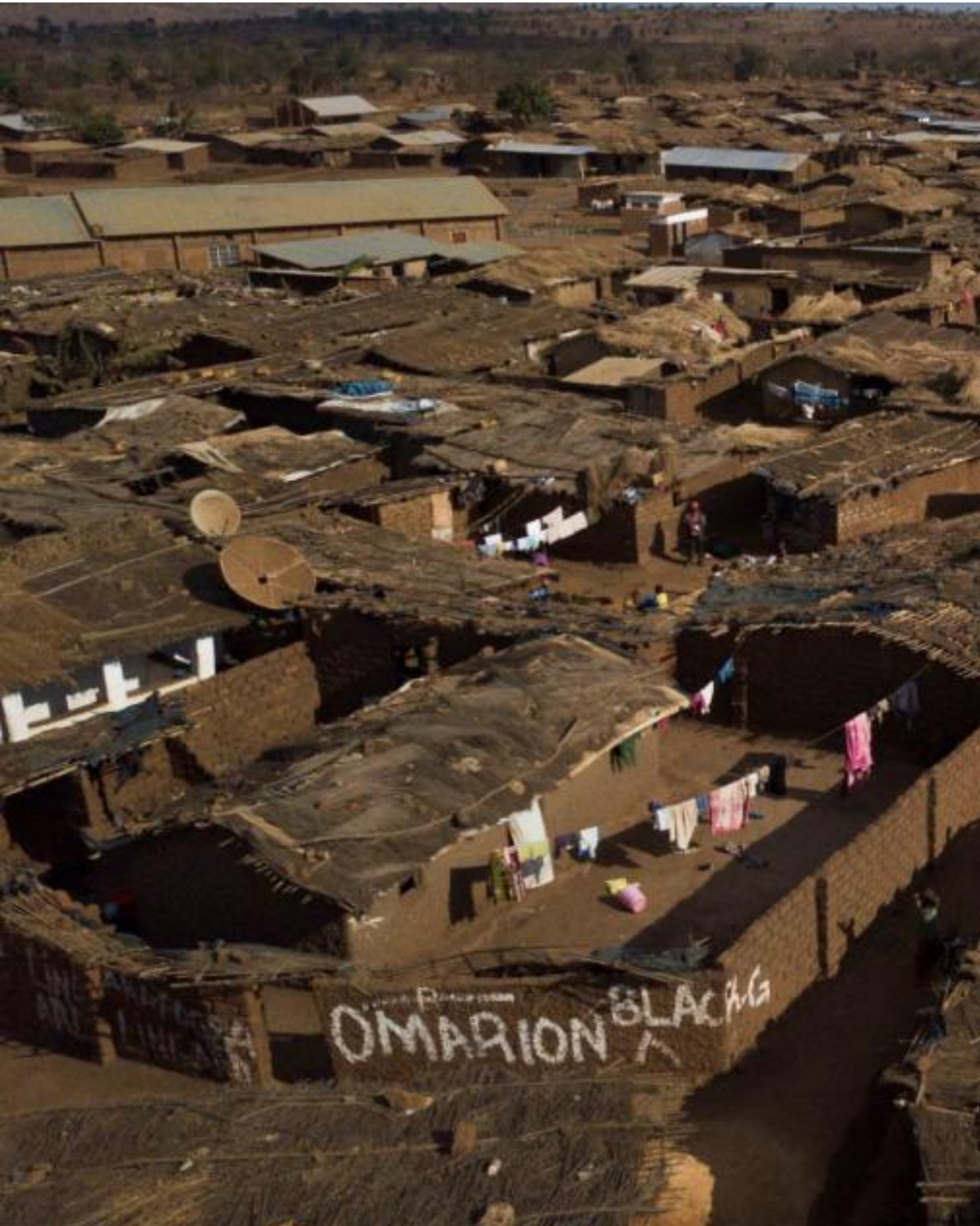


Figure 34Community Road cluster unit three-dimensional illustration


OMARION

THESIS II: CASE STUDY

While many refugee, camps are assessed and analysed, the existing analysis focuses on qualitative methods. The lack of quantitative methods can be easily spotted in literature and the documentation of humanitarian organisations that are the leading party in most refugee camp reports. That can be linked to the absence of a comprehensive numerical database. A numerical database created to measure the qualities of the built environment can provide statistical proof of the characteristic fitness of refugee camps. At the same time, quantitative analysis can show an unprecedented correlation between design elements which can be used to develop new tools for refugee camp design which are more efficient and systematic.

SUB THESES: Establishing a numerical database of preceding cases of refugee camps

- A numerical database of 37 refugee camp cases established worldwide in various periods.
- Categorised refugee camps built-environment characteristics.

SUB THESES: Refugee camp built-environment characteristics

- The following section identify planned camps' general and population characteristics (urban density, population size, household size).
- In addition, it categorises built environment characteristics based on the design parameters and indicators.

SUB THESES: Urban structural hierarchy and refugee camp hierarchical structure characteristics

- The research studied the existing cases and compared their built environment characteristics with planning standards.

6 CASE STUDY

6.1 CASE STUDY DESCRIPTION

In the past decade, the number of displaced populations has escalated tremendously. The United Nations High Commissioner for Refugees (UNHCR) estimates the displaced global population of 2022 to be 102.6 million ((UNHCR), 2022), which increased by 18% compared to the 2020 UNHCR reports, making it one of the most unforeseen humanitarian crises in the world. These significant increases in the past ten years were caused by the Syrian conflict starting in 2011, the conflicts in the Democratic Republic of Congo, Yemen, Iraq, and South Sudan, and later in 2017 massive wave of displacement from Bangladesh and Myanmar, and the pandemic situation worldwide in 2020, in addition to the most recent to the economic crisis of Venezuela, the political conflict in Afghanistan in 2021, and the massive flood of Ukrainian refugees at the start of 2022. Such crises force people to flee their homes to seek basic needs such as protection, food, water, and shelter. In the case of shelter for displaced populations, the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) published a manual that includes six options for shelter; Host Families, Urban self-settlement, Rural self-settlement, Collective centres, Self-settled Camps, Planned camps (Isabelle de Muyser-Boucher, 2010) Only 22% of the displaced population live in refugee-planned and self-settled camps. The population in camps is estimated to reach 22.5 million people; 70% of refugees dwell in refugee camps residing in planned and managed refugee camps (UNHCR, 2022).

Refugee camps are planned and managed as temporary facilities that act in the form of immediate response to crises or conflicts, aim to provide short-term accommodation, and keep refugees safe and protected. They are designed and planned based on the occurrence of the crisis and are mainly driven by economic and political concerns and restrictions (Rania, Claudia,

Busisiwe, & Makore, 2020). Although camps are designed as temporary settlements, refugees can stay in refugee camps for several years and sometimes decades. Refugee camps can be managed and planned by governments, United Nations (UN), international organisations, or non-governmental organisations (NGOs). Post-disaster development can be traced to The United Nations Universal Declaration of Human Rights in 1948, followed by the development of the "community model" from 1971 to 1982 Cuny (Cuny, REFUGEE CAMPS AND CAMP PLANNING THE STATE OF THE ART, 1977) Fred Cuny established his company "Intersect Relief and Reconstruction Corporation" in 1971, which became one of the first organisations that attempted to document the design and planning process of refugee camps at that time. Later in the mid-1990s, humanitarian organisations became more involved in the design of camps creating the first standards draft. One of the first drafts was the "Contingency Planning Manual" for the office of foreign disaster assistance United States Agency for International Development ((USAID)/OFDA). Furthermore, in 2000 the first edition of the humanitarian minimum design standards for disaster response was released, called "The Sphere."

Although the existence of refugee camps standards and design handbooks for the past 22 years, refugee camps standards seem not to be achieved in the realisation of the planning, which could be tracked to many reasons, starting with the lack of time and economic resources and the complications of political situations that are related to the individual state of each case, therefore this study aims to describe and analyse the physical characteristics of refugee camps and compare them to planning indicators included the UNHCR planning handbooks, to understand the discrepancies between the design guidelines and the existing emergency settlement, and evaluate if the implementation were adequate.

6.1.1 Case study Methods:

The study adopts descriptive statistics tools and methods to structure a database and analyse the scanned case studies to identify the urban fabric's physical characteristics, design parameters, constraints and pattern configuration generated by refugee camp planning.

6.1.2 Definitions

Refugee camps can be classified into different categories regarding planning, management, and time spent by refugees, such as planned or spontaneous camps, managed or self-managed camps, and transit or reception centres. This study uses the term refugee camps, as defined by The UNHCR as "Refugee camps are temporary facilities built to provide immediate protection and assistance to people forced to flee their homes due to war, persecution or violence." (UNHCR, 2022) This study addresses refugee camps defined in the UNHCR Emergency Handbook (UNHCR, 2022). Still, the module "Community" will be referred to as "Cluster". The family module will be referred to as the "Plot" since the study focuses on the refugee camp's physical characteristics and urban pattern, not its social structure. The terms cluster and plot can directly connect to the morphological aspect of refugee camp design, discarding any confusion related to the social structure that might be included in the "Community" or "Family" module. Table 12) contains the urban pattern structural hierarchy used in the research and shows the population size of different modules.

Table 12:Urban pattern structural hierarchy

MODULE	STRUCTURE	APPROXIMATE NUMBER
Plot (family)	1 x family	4 - 6 Persons
Cluster (community)	16 x family	80 Persons
Block	16 x cluster	1,250 Persons
Sector	4 x block	5,000 Persons
Settlement	4 x sectors	20,000 Persons

6.1.3 Search Strategy and Eligibility

The study examines cases of refugee camps. The selection criteria were based on a scanning database for refugee camps' master plans. The research focused on finding legible master plans that include drawing scale and high PDF resolution, traced as vector computer-aided software databases structuring process, summarised in Figure 35.

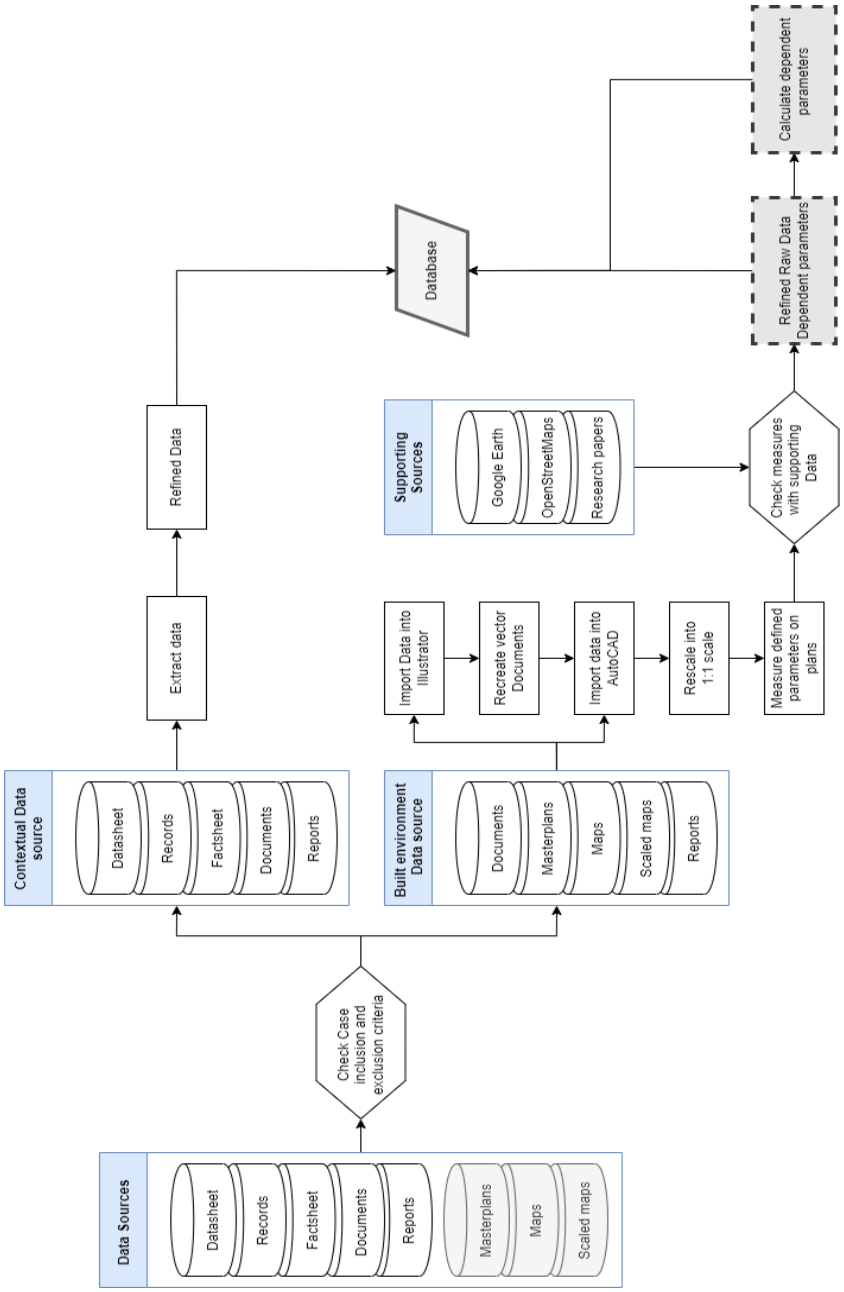


Figure 35 Databases structuring process

The target electronic databases are the Operational Data Portal (data2.unhcr.org), provided by the UNHCR, and the Relief Web data (reliefweb. int), provided by the United Nations Office for the Coordination of Humanitarian Affairs (OCHA). The databases were searched based on data format/document type "map" and using the terms ("camp", "refugee camp", "master plan", or "plan"). In addition, keywords were chosen to limit the database to only documents identified as refugee camps. Their primary scanning identified 54 possible cases, including maps, plans, or illustrations of refugee camps. However, the study excluded 17 cases and included 37 based on the criteria listed in Table 13.

Table 13: Cases' inclusion and exclusion criteria

CRITERIA	EXCLUSION	INCLUSION
File format	Not vector-based	Vector-based file format or/ and convertible to vector-based file
Raster graphics files resolutions	Information is hard to extract due to low-resolution raster graphics files.	High-resolution raster graphics files
Drawing information	A Linear (graphical) scale or drawing scale ratio is missing or not applicable.	Apparent scale ratio or/ and linear (graphical) scale
Supporting documents and data	The master plan lacks supporting documents and information about the population and area.	Supporting documents and data are available, and UpToDate

The case analysis consisted of 7 stages: (1) scanning databases, (2) selection of cases, (3) collecting supporting information on cases, (4) definition and listing of information and parameters that can be extracted from masterplans, (5) extracting information from a graphical master plan into a structured database, (6) analysing the database, and (7) describing the results

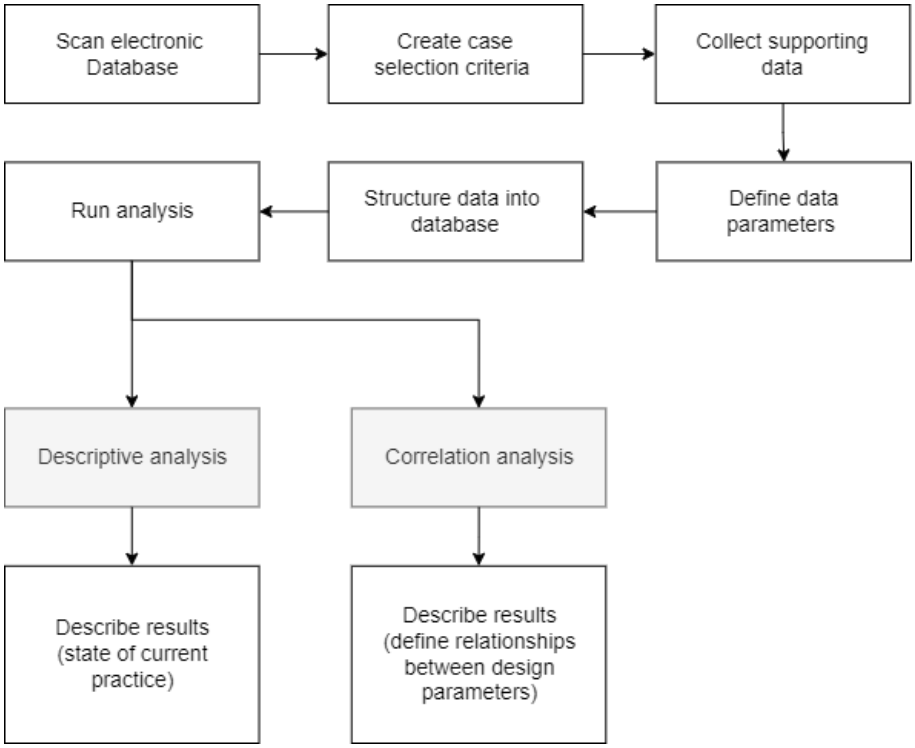


Figure 36: Cases analysis process

6.1.4 Data Extraction and Synthesis

The database included 37 cases listed in Table 15. It was structured into three categories of data in Table 14, first contextual characteristics (e.g., year of establishment, location, country/ region), second population characteristics (e.g., disaster, DP (Displaced population), settlement type), and third built environment characteristics which can be categorised into independent (e.g., camp area, number of urban blocks, plot width) and dependent data (e.g., urban density, block area, block void ratio). Built environment parameters were chosen to define the character of urban patterns and the living quality of the settlements based on minimum standards and planning indicators of the UNHCR Emergency Handbook.

Table 14 List of data categories and variables

DATA CATEGORIES	CONTEXTUAL	BUILT ENVIRONMENT-INDEPENDENT	BUILT ENVIRONMENT-DEPENDENT
DATA VARIABLES	Refugee camp name	Urban block geometry	The urban density of camp
	Year of establishment	Urban block width	Average camp area per person
	Region of the camp	Urban block length	Urban block aspect ratio
	Country of location	Number of clusters per block	Urban block area
	Type of disaster	Number of units per cluster	Urban block built-up area
	Settlement Type	Number of camp zones	Urban block built-up area ratio
	Area of the camp	Number of camp sectors	Urban block void area
	Population	Local street width	Urban block void area ratio
		Main collector street width	Urban block public space area
		Refugee shelters width	Urban block public space area ratio
		Refugee shelters length	Refugee camp public space area
		Average plot width	Refugee camp public space ratio
		Average plot length	Refugee shelter area
		Number of Blocks per Camp	Shelter aspect ratio
		Number of households per camp	Average plot area
			Urban plot aspect ratio
			Urban plot built-up area
			Average floor area per person
			Number of units per block
			Average household size

As illustrated in Figure 35, the three categories of data are processed as the following:

- Contextual and population characteristics were extracted from documents, datasheets, and factsheets found in the UNHCR database, including profile information on investigated case studies.
- The built environment-independent parameters are extracted from records, master plans, and layouts by measuring scaled maps and plans.
- Dependent parameters were calculated using independent parameters.

Table 15:Cases included in the study.

REGION	*NAME*	*REGION*	*NAME*
CENTRAL AMERICA	Coyotepe Camp	**Middle East**	Syrian Refugee Camps - Reyhanli
EAST AFRICA	Ifo Refugee Camp		Syrian Refugee Camps - Boynuyogun
	Hagadera Refugee Camp		Domiz1 Camp
	Nyarugusu camp		King Abdulla Park Refugee Camp
	Bokolmanyo Refugee Camp		Zaatari Camp's
	Hilaweyn camp		Basirma Camp
	Dagahaley Refugee Camp		Darashakran Camp
	PTP Refugee camp		Domiz2 Camp
	Kambioos Refugee Camp		Gawilan Camp
	D'un abala Refugee Camp		Kawergosk Camp
	Kalobeyei Settlement		Azraq refugee camp
NORTH AFRICA	Nyal Refugee Camp		Khazir IDP Camp [(1)]
	Doro Refugee Camp		Qushtapa Camp
	Cluster Bentiu PoC Site		Hajj Ali Camp
	Cluster Naivasha IDP [(1)]		Qayyarah Jad'ahCamps
	Tunaydbah Settlement		Qayyarah Airstrip Camps
WEST AFRICA	SOLO refugee camp	***South Asia***	Barasat Camp
	ZIAH refugee camp		Mirpur Camp
	Ferrerio camp		

The initial database is structured using Microsoft Excel, and the dependent parameters were calculated using mathematical relations from independent parameters Table 16. Afterwards, the database was reconstructed into Statistical Package for the Social Sciences (IBM SPSS) software to run two types of analysis, descriptive and correlation. Descriptive analysis aims to evaluate the existing refugee camps and how they reflect the implementation of design guidelines. In comparison, correlation analysis seeks to examine the relationships between the refugee camps' planning and design parameters to improve future design and support design decisions.

Table 16 Independent and dependent parameters and their relationship

Independent parameters	**Abbrev**	**Unit**	**Dependent Parameters**	**Abbrev**	**Unit**	**Equations**
Area of the camp	CA	Km2	Camp Density	Ud	Peron/ Km2	Population/Camp Area
Camp Population	CPop	Person	Average camp area per person	CAPP	M2/Person	Camp Area*10^6/Population
Urban block width	BW	m	Urban block aspect ratio	BAR	n/a	Block Length/ Block Width
Urban block length	BL	m	Urban block area	BA	m2	Block Width*Block Length

[1] IDP: Internally Displaced population

Number of clusters per block	CPB	cluster	Urban block built-up area	BBUA	m2	Shelter Area*Number of units per block
Number of units per cluster	UPC	unit	Urban block built-up ratio	BBUR	n/a	Urban block built-up area/Urban block area
Number of camp zones	CZ	zone	Urban block void area	BVoidA	m2	Urban block area - Urban block built-up area
Number of camp sectors	CS	sector	Urban block void ratio	BVoidR	n/a	Urban block void/Urban block area
Local street width	LSW	m	Urban block public space area	BOSA	m2	Urban Block area - (Plot area*Number of units per block)
Main collector street width	MSW	m	Urban block public space area ratio	BOSR	n/a	Urban block public space area/ Urban block area
Refugee shelters width	ShW	m	Refugee camp public space area	COSA	m2	Camp Area*10^6 - (Plot Area*Number of units per block* Number of blocks)
Refugee shelters length	ShL	m	Refugee camp public space ratio	COPR	n/a	Camp public space area/camp area
Average plot width	PW	m	Refugee shelter area	ShA	m2	Shelter width*Shelter length
Average plot length	PL	m	Shelter aspect ratio	ShAR	n/a	Shelter Length/Shelter Width
Number of Blocks per Camp	BPC	block	Average plot area	PA	m2	Plot Width* Plot Length
Number of households per camp	HHPC	Person	Urban plot aspect ratio	PAR	n/a	Plot Length/ Plot Width
			Plot built-up area ratio	PBUR	n/a	Shelter area/Plot Area
			Average floor area per person	FAR	m2/person	Shelter Area/Household size
			Number of units in a block	UPUB	unit	Number of Clusters per block*Number of units per cluster
			Average household size	HH	person/ plot	Population/number of households per camp

6.1.5 Case study characteristics

Contextual characteristics

Location

Selected case studies are distributed by region, as shown in Figure 37 highest percentage is in the Middle East with 16 cases; the second is East Africa with 10 cases, and third is north Africa with 5 cases; the fourth is west Africa with

3 cases, the fifth is south Asia with 2 cases and finally central America with one case

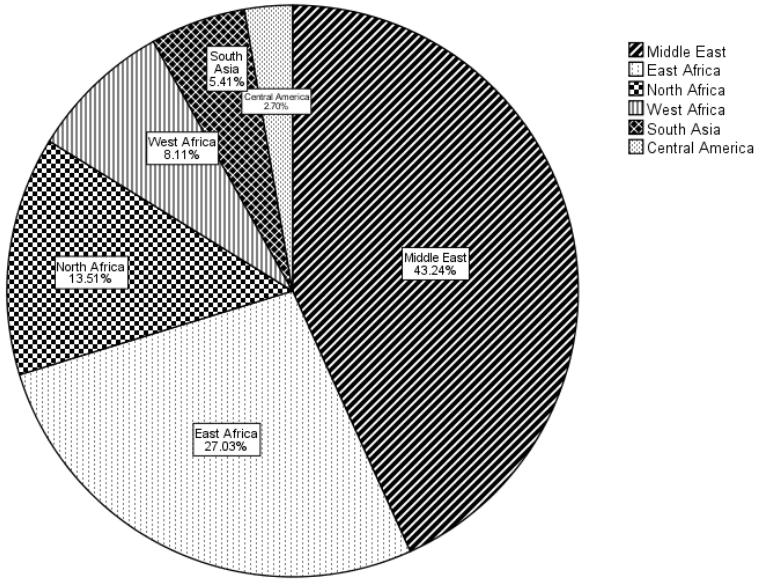


Figure 37 Cases distribution by region

Establishment year

The research included 37 cases, and the case studies were established between 1971-2018. It was found that 83.8% of cases were established after 2009, which can correlate with the increasing number of displaced people following 2011; based on the analysed cases, 81.1% of cases were found between 2011-2018; this can be connected to two primary reasons, the increase of DP numbers in the past 30 years and lack of documentation in prior periods. In addition, these numbers are associated with the start of the Somali conflict in 2009, following the contentious presidential election in Côte d'Ivoire in 2010 and the Syrian conflict that began in the first quarter of 2011.

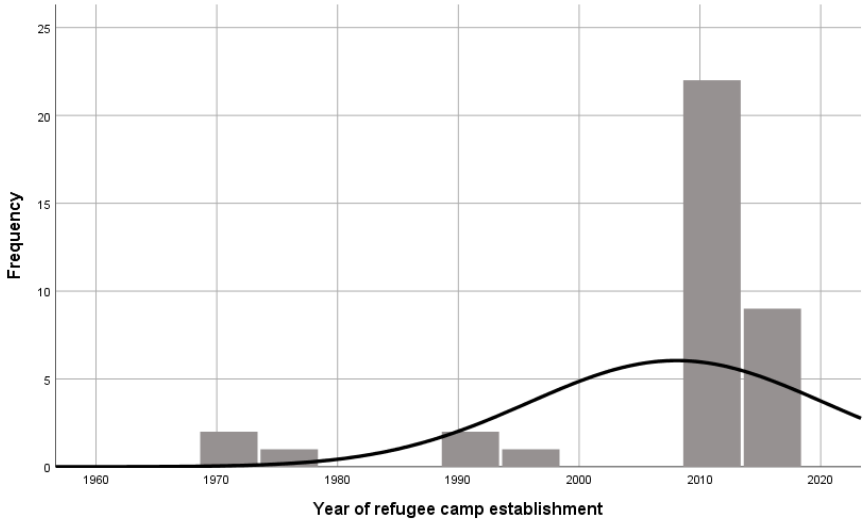


Figure 38 Histogram of the cases' establishment year

Settlement type

The study shows that 89.2% of the cases are Emergency settlements, with 33 cases, two spontaneous camps, and one transitional camp. **UNHCR defines emergency Settlements (Camps)** as "a form of settlement in which refugees or IDPs (Internally Displaced Population) reside and receive centralised protection, humanitarian assistance, and other services from host governments and humanitarian actors." In contrast, spontaneous camps result from displaced people occupying land without assistance or guidance from governments or humanitarian organisations (UNHCR, 2018).

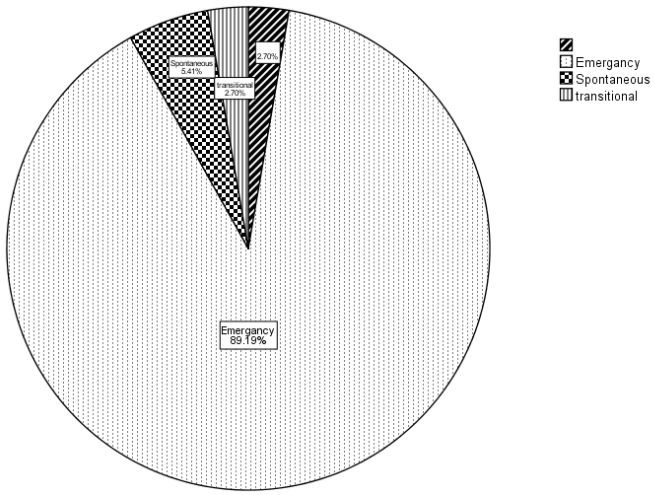


Figure 39 Settlement type

6.1.6 Case analysis module structure

The analysis is carried out based on five levels of urban structure hierarchy modules of the urban pattern (shelter, plot, cluster, urban block, and camp) shown in Figure 42 and analysed by considering the planning standard released by the UNHCR in the 2018 emergency handbook.

The organisation of post-disaster settlement is based on a Gridiron network pattern organisation as seen in the Azraq refugee camp (Figure 40) taken in 2014; the Azraq camp is considered one of the successful planned disaster settlement cases.

Figure 40:Aerial view of the Azraq refugee camp in Jordan (Google, 2019)

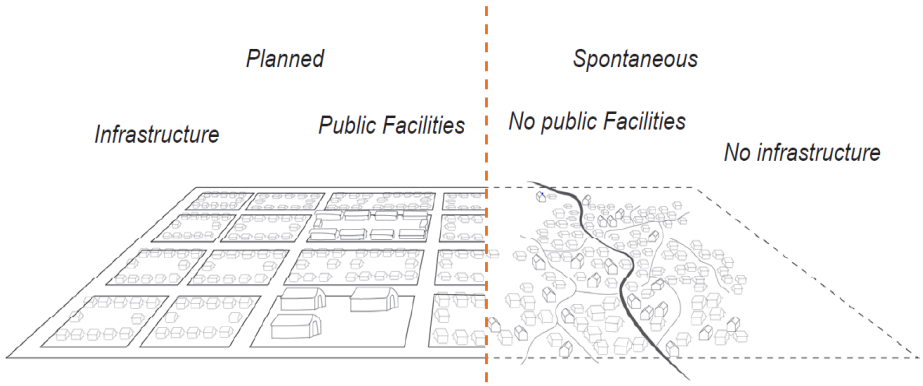


Figure 41 Planned camps and spontaneous settlements sites (International Organization for Migration (IOM), 2014)

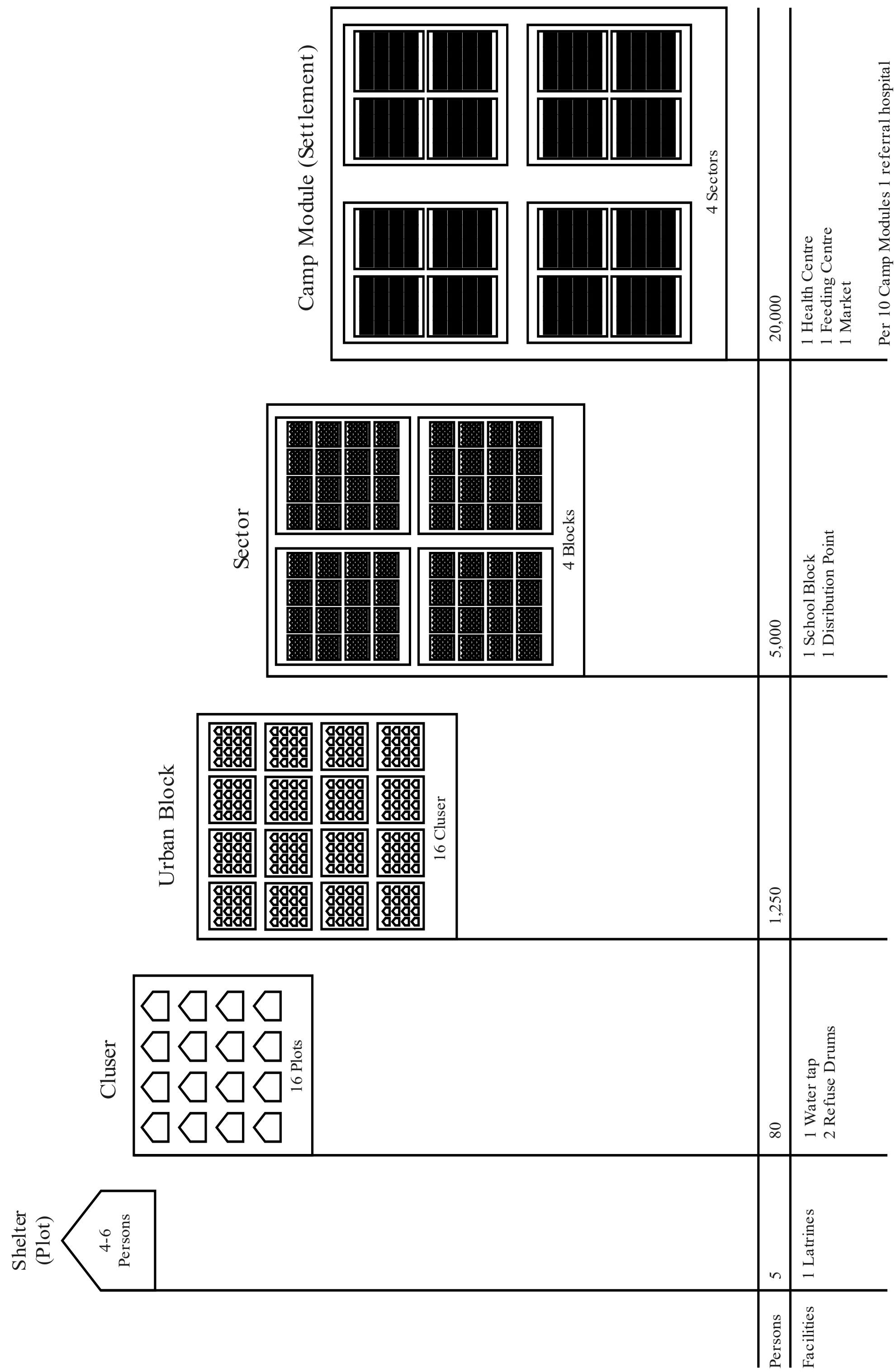


Figure 42:Camp organisation guideline based on UNHCR Emergency Handbook

6.2 SETTLEMENTS GENERAL INFORMATION

6.2.1 Area

The average area of cases is 3.06 km^2; the largest refugee camp is Kalobeyei Settlement in Kenya, which has an area of 16.8 km^2; the smallest is Coyotepe Camp, with an area of 0.02 km^2, an interquartile range (the range of the second and third quartiles of the distribution) is ranging between 0.25- 3.72 km^2. The camp area histogram is right-skewed. Kalobeyei Settlement 2016 and Azraq refugee camp 2014 were extreme outliers with inter-quartile range rule multipliers larger than three, Nyarugusu camp 1996, Ifo Refugee Camp 1991, and Hagadera Refugee Camp 1992 were outliers with inter-quartile range rule multipliers larger than 1.5 Figure 43.

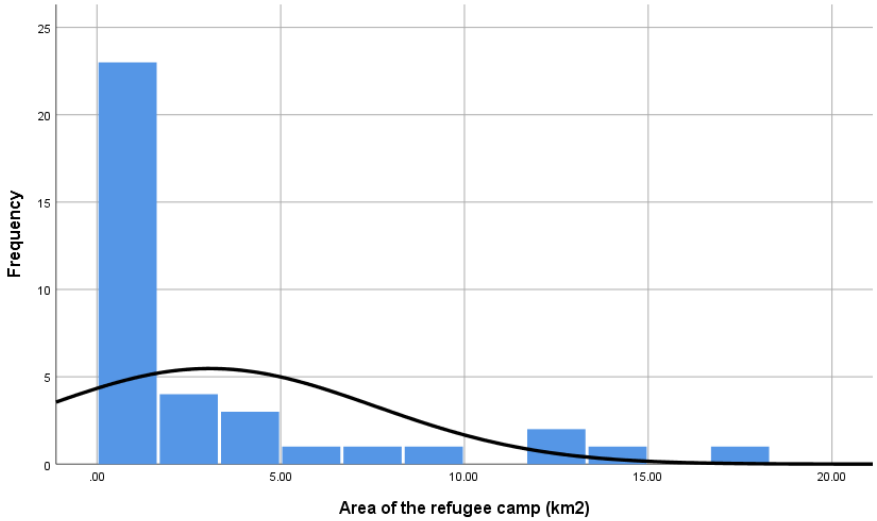


Figure 43 Histogram of the area of refugee camps

6.2.2 Population & Urban Density

The mean population is 40.000 persons, the lowest population was recorded in Mirpur Camp, with 168 persons, and the highest was in Kalobeyei Settlement, with 196,666 persons. Nyarugusu camp and Kalobeyei Settlement are outliers, while the population's standard deviation is 49,087.

The average number of possible sectors is two, with an approximately average urban density of 27.000 persons per km^2, while the highest urban density was

reported in Coyotepe Camp, with 167,232 persons per km^2. Coyotepe Camp and Reyhanli are extreme outliers, while the cluster of Bentiu PoC Site is an outlier.

6.2.3 Area Per Person

According to the UNHCR emergency handbook (UNHCR, 2022), the minimum standard for camp settlement size is 45 sqm per person. The cases show that the average area per person was 79 sqm. The average area histogram is right-skewed with a standard deviation of 76, and the interquartile range is 49. The Cluster of Naivasha (IDP), PTP Refugee camp, and Azraq refugee camp are extreme outliers, and Mirpur Camp is an outlier. Based on the UNHCR Emergency Handbook, 56% of the cases achieve the minimum requirement.

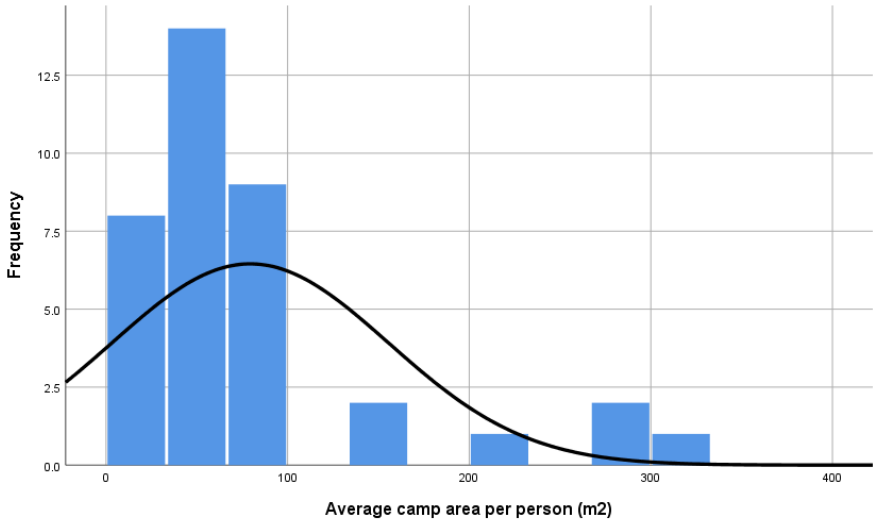


Figure 44 Histogram of average camp area per person

It was detected that 55% of the camps planned after 2011 did not reach the minimum average camp area per person recommended by the standard

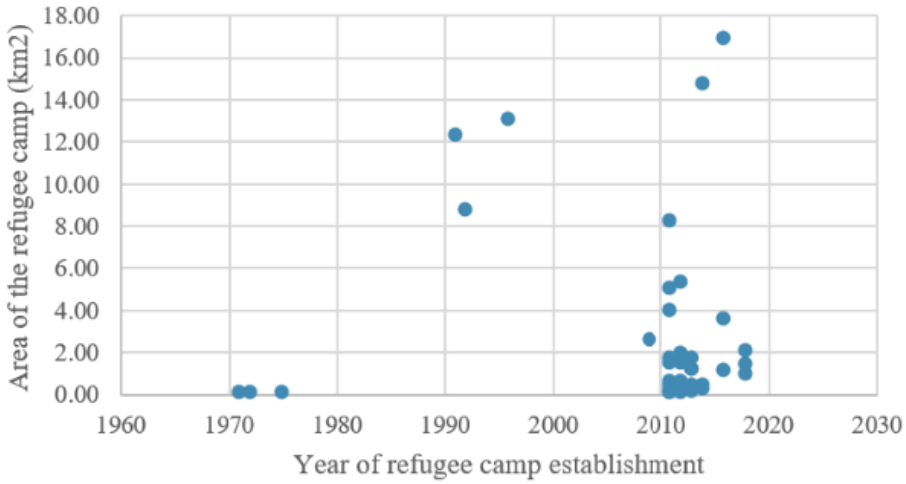


Figure 45 The relationship between refugee camp year of establishment and average area per person (m2)

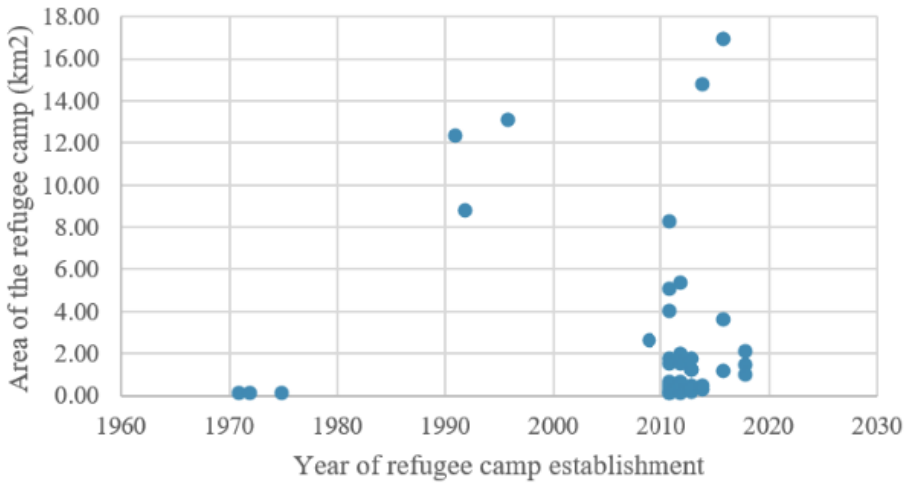

Area of the refugee camp (km2)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1960
1970
1980
1990
2000
2010
2020
2030
Year of refugee camp establishment

Figure 45 The relationship between refugee camp year of establishment and average area per person (m2)

6.2.4 Shelter

According to recommended guidelines for Emergency planning (UNHCR, 2022), the minimum standard covered living area (CLA) is 3.5 sqm per person. In cold climates and urban areas, more than 3.5 sqm might be required to reach 4.5 -5.5 sqm per person. According to weather conditions, people are expected to spend more time indoors due to the harsh climate conditions. The

analysis shows that the mean (CLA) is 5.4 sqm per person. However, 43% of the cases did not meet the minimum requirement of average (CFA), and 78% had less than 5.5 sqm per person. The largest area per person is recorded in the Cluster of Naivasha IDP, while the lowest is recorded at 1.8 sqm in the Darashakran Camp. The Cluster of Naivasha IDP, Hajj Ali Camp, PTP Refugee camp, Domiz2 Camp, Kalobeyei Settlement, and Mirpur Camp were outliers.

The shelter's mean area is 24 sqm, with a range that varies between the lowest of 6 sqm at both Nyal Refugee Camp and Barasat Camp and the largest of 70 sqm at Mirpur Camp, which is found to be an outlier along with Domiz2 Camp, Cluster of Naivasha IDP, Dagahaley Refugee Camp, Nyarugusu camp, and Tunaydbah Settlement, outliers camps recorded shelter area larger than 40 sqm.

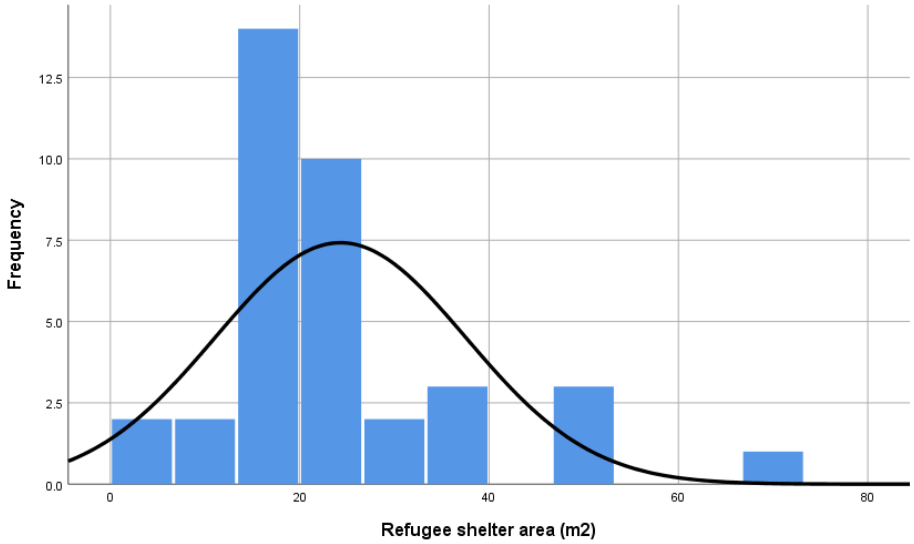


Figure 46 Histogram of shelter area

The mean shelter width is 3.8 m and has an interquartile range of 1. The values ranged between 2-7 m, while 78% of the cases recorded a shelter width less or equal to 4 m. The mean shelter length is 6.11 m and has an interquartile range of 3. The values ranged between 3-10 m, and 92% of the cases recorded a shelter width less or equal to 8 m. The shelter's dominant shape is

rectangular with a mean aspect ratio of 1.65; the aspect ratio ranged between 1-2.57, while 87% of the cases recorded a shelter aspect ratio less or equal to 2.

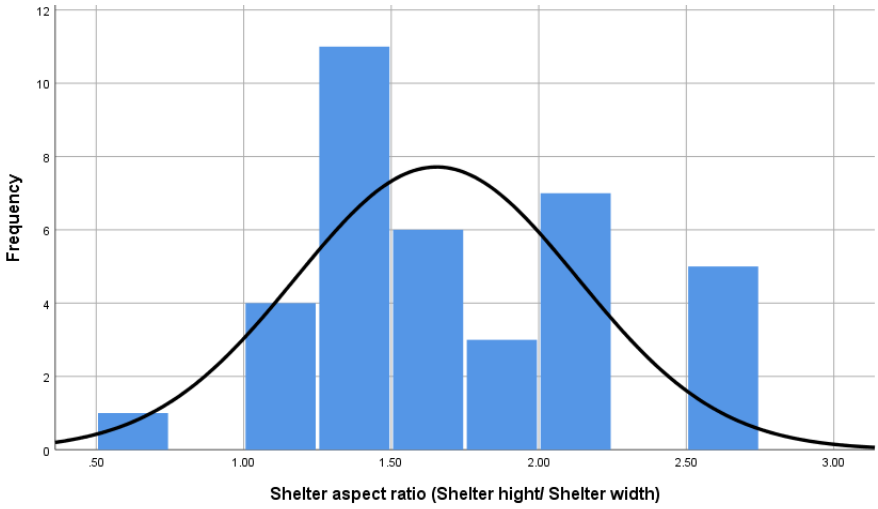


Figure 47 Histogram of shelter aspect ratio

6.2.5 Plot

The cases show that the average plot area is approximately 126.6 sqm, while Doro Refugee Camp and Mirpur Camp are outliers, with the largest plot area of 360 sqm. The average plot width of 8.8 m and the cases' plot width ranged between 4-18 m with an interquartile range of 5. The average shelter length is 13.6 m. The cases' plot lengths ranged between 4-30 with an interquartile range of 6.

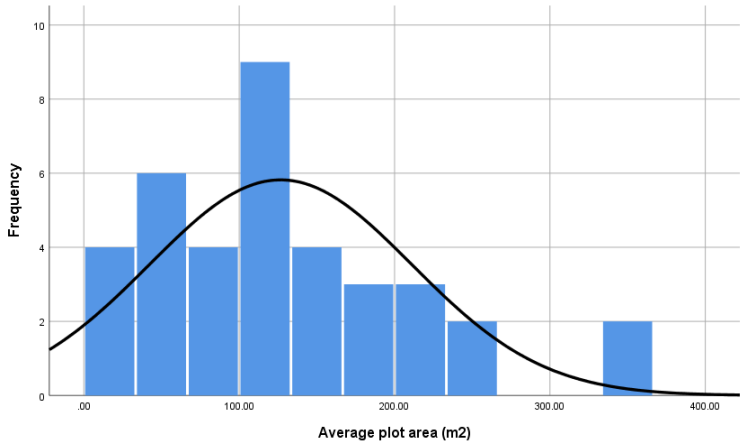


Figure 48 Histogram of the average plot area

The dominant plot shape is rectangular with an average aspect ratio of 1.62, an aspect ratio calculated as Equation 6). However, the aspect ratio varied between 1.00 - 2.5, while 82.4 % of the case studies had an aspect shelter ratio lower than 2. Therefore, the built-up plot ratio can be calculated as per Equation 7. While the average plot built-up ratio can be calculated based on Equation 8 is 24%, and the interquartile case range is 19.8%, with a maximum plot-built ratio of 55% at Qayyarah Jad'ah Camp and the lowest plot-built ratio of 4% at Nyal Refugee Camp.

Equation 6

$$Plot\ aspect\ Ratio = \frac{plot\ L}{plot\ W}$$

Equation 7

$$Plot\ built\ up\ ratio\ (PBR) = \frac{Shelter\ Area}{Plot\ Area} * 100\%$$

Equation 8

$$Average\ (PBR) = \frac{\sum_{n=1}^{n}(PBR)_n}{n}$$

Cluster

The cluster module was not applicable in the case of Basirma Camp, and Kawergosk Camp since the camps were divided into unequal blocks based on rows arrangement rather than clusters Camp. Figure. The cases show an average number of units (shelters) per cluster to be approximately 28 shelters and a median of 14 shelters. The number of units in a cluster range from the smallest cluster of 7 shelters to the largest of 216 shelters in Hagadera Refugee Camp and Ifo Refugee Camp. The camps did not have a defined cluster form or configuration in these two cases. Therefore, the urban block was not applicable. As a result, both camps are considered extreme outliers, while the interquartile range is eight units.

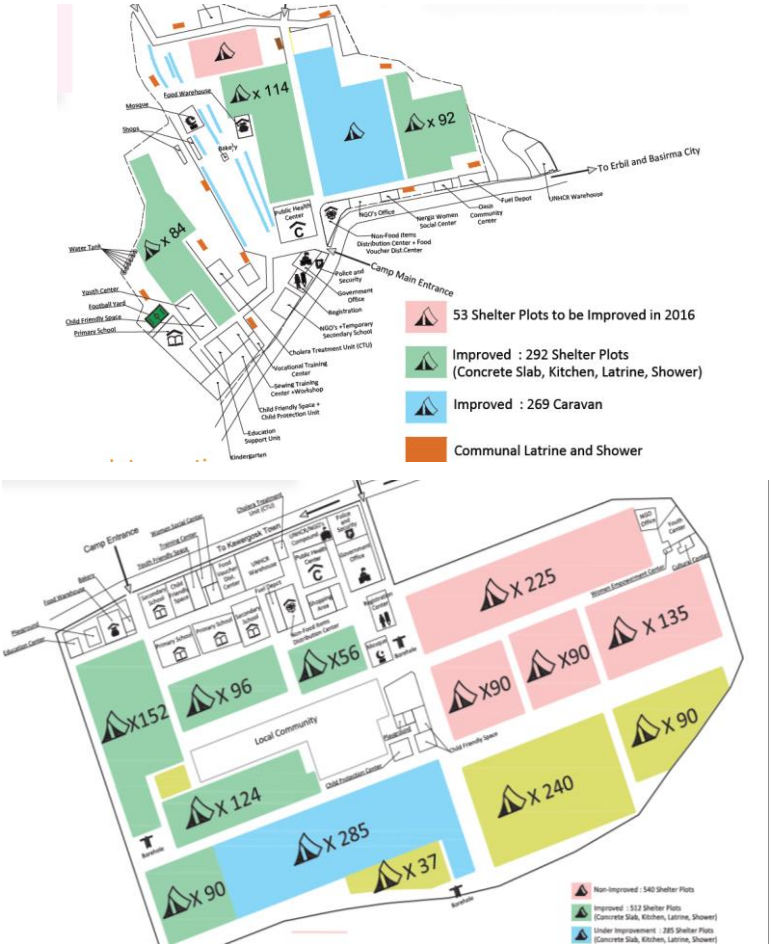


Figure 49 (a) Basirma Camp Layout, (b) Kawergosk Camp.

(UNHCR Technical Unit - Erbil, 2018), (UNHCR Technical Unit - Erbil, 2018)

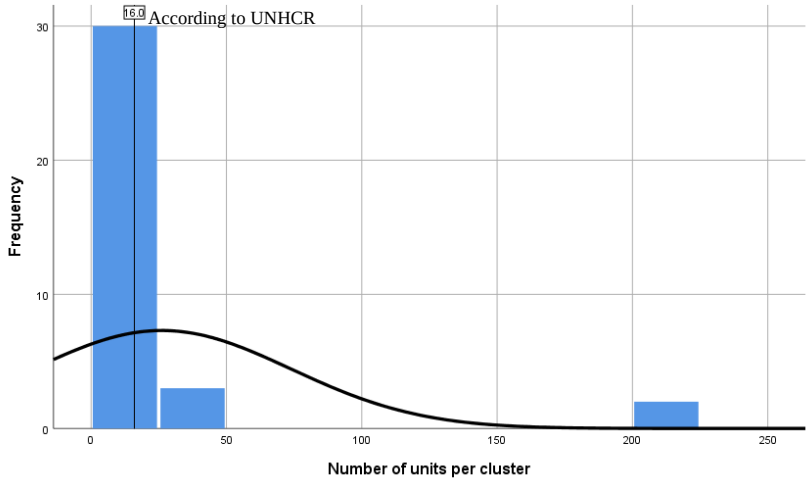


Figure 50 Histogram of the number of shelters (plots) per cluster, with an indication of the standard number of plots per cluster

The analyses show that 74% of the cases had less or equal to 16 shelters per cluster, which matched the standard of UNHCR structural hierarchy; eight camps recorded the use of the exact structural hierarchy of the cluster unit standard recommendation of 16 units per cluster. On the other hand, the number of clusters per block did not correlate with the standard; the average was approximately 12 clusters per block the cases ranged between 1-120 clusters per block. The Cluster of Naivasha IDP, Tunaydbah Settlement, and Domiz2 Camp are outliers, with more than 16 clusters per urban block. However, it was found that 91% of the cases were structured with less than 16 clusters per block, and the most frequent numbers of clusters per block were one with a percentage of 25% and eight clusters with a rate of 17%.

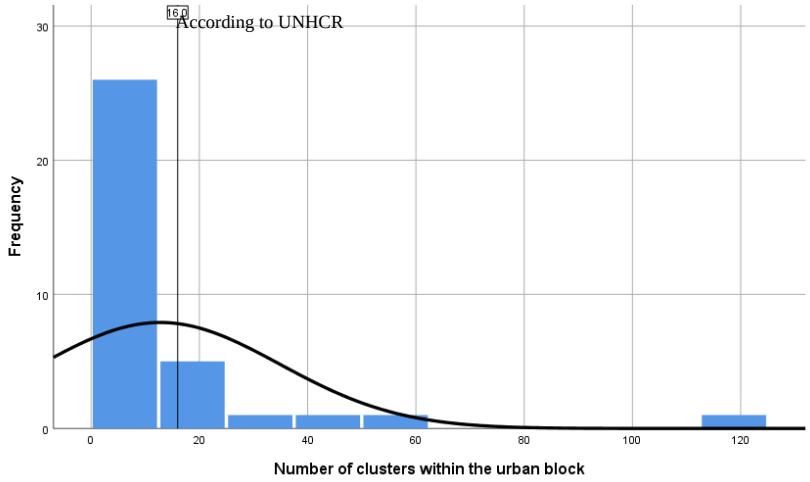


Figure 51 histogram of the number of clusters per block

The number of shelters per block (SPB) is a dependent parameter calculated based on the number of clusters per block (CPB) and the number of shelters per cluster (SPC) as per Equation 9 as the following:

Equation 9

$$SPB = CPB * SPC$$

The SPB mean is 169 shelters; the values range between 12- 1200 shelter units. The histogram is right skewed with a standard deviation of 216.

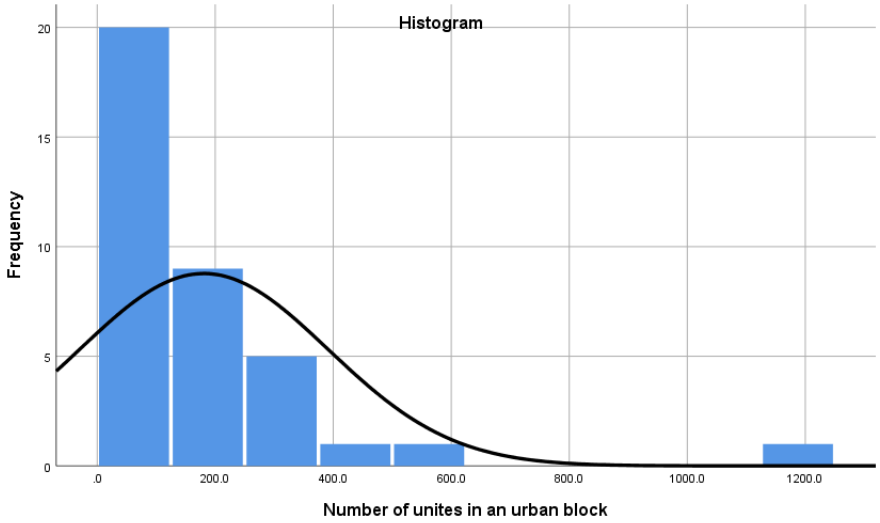


Figure 52 Histogram showing the number of units per urban

The analysis shows that 94% had an SPB lower than 400, and 43% of the cases had SPB less than 84 Shelters. SPB parameter could be used to calculate urban block population as per Equation 10) and density (UBD) as per

Equation 11. In addition to solid, void, and open space ratios, the following:

Equation 10

$$Urban\ Block\ Population\ (UBP) = SPB * Average\ household\ size\ (AHS)$$

Equation 11

$$UBD = \frac{Urban\ block\ population\ (UBP)}{Urban\ blocArea\ (UBA)}$$

6.2.6 Block

The cases show that the dominant geometry of emergency settlement urban blocks is rectangular, with a percentage of 62% of case studies. Although different cluster arrangements within the social structure of emergency settlement could affect the layout, the rectangular urban block geometry was found in spontaneous (unplanned) settlements and camps designed before releasing the emergency handbook in 2008.

Table 17 Urban block geometry

		Freq	Per cent	Valid Percent	Cumulative Percent
Valid	Complex	1	2.7	2.7	2.7
	D shaped	1	2.7	2.7	5.4
	Parallelogram	2	5.4	5.4	10.8
	Random	3	8.1	8.1	18.9
	Rectangle	23	62.2	62.2	81.1
	Square	5	13.5	13.5	94.6
	U-shaped community block	2	5.4	5.4	100
	Total	37	100.0	100.0	

The average block area is calculated according to the block geometry in the case of rectangular or square urban blocks as per Equation 12.

Equation 12

$$Block\ Area = Block\ W * Block\ L$$

The Basirma Camp and Kawergosk Camp have irregular urban block shapes showing missing data for the width and length of the urban block. The remaining cases show an average block width of 133 m; the urban block width ranged between 20-500 m; Domiz2 Camp, Gawilan Camp, and the Cluster of Naivasha IDP were outliers, while 68% of the cases indicated a block width below 130 m. The average block's length is 196 m, ranging between 26-890 m. Domiz1 Camp, Azraq refugee camp, and Khazir IDP Camp block lengths are considered outliers in 62% of the stated block width below 200 m.

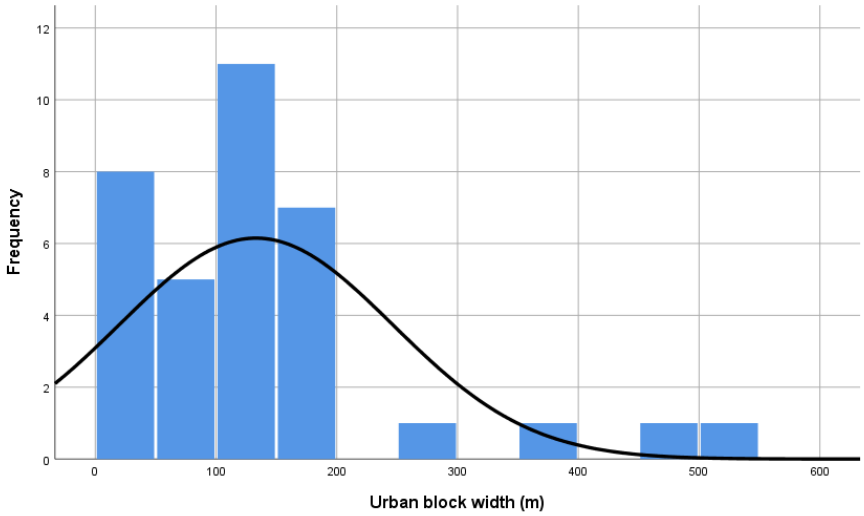


Figure 53 Histogram of urban block width

The urban block average aspect ratio is 1.7, calculated as per Equation 13, the aspect ratio varied between 1.00 – 7.1, and 85 % of the case studies had an aspect block ratio lower than 2. Based on the calculation, the average block area is 0.04 km2. Urban blocks range between 0.00052- 0.3204, where CCCM Cluster Naivasha IDP, Domiz2 Camp, Tunaydbah Settlement, and Gawilan Camp are outliers. On the other hand, 81% of cases have a block area below 0.036 km2.

Equation 13

$$Urban\ block\ aspect\ Ratio = \frac{Block\ L}{Block\ W}$$

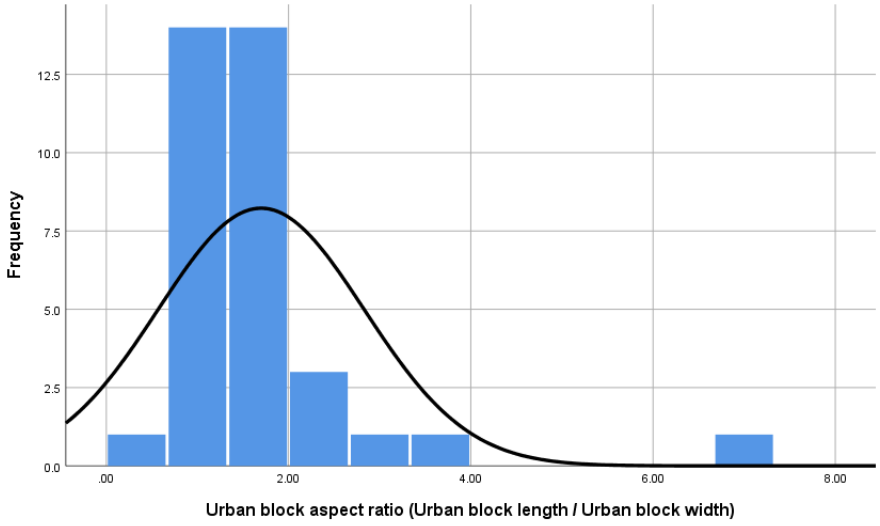


Figure 54 Histogram of urban block aspect ratio

6.2.7 Discussion

The forced displacement settlement crisis is a global situation with increasing risk. Since 1982 humanitarian organisations and many NGOs have played a crucial role in standardising the design process, parameters, and indicators of emergency settlements by providing design guidelines and a planning handbook. However, it was conspicuous that the standards and guidelines were not followed through the implementation and planning of emergency settlements. The research shows that 43% of the cases do not align with the minimum requirement of covered living space. The minimum camp per person directly affects the emergency settlements' quality of space and

livelihood. In addition, it can disable the development of displaced communities and risk their safety, dignity, and health in their living environments.

As categorised in this section, the set of dependent and independent parameters could be studied further and in-depth to evaluate and develop future livelihood indicators and design standards for emergency settlement and refugee camps. In addition, numerical parameters of emergency settlements could be extended to enhance the speed of design and the quality of living within displaced populations living in refugee camps and have evidence related to social discrimination, crime, equal access, and humanitarian aid efficiency.

The chapter shows discrepancies between design guidelines and realised emergency settlements. This observation requires further investigation into the reasons and consequences of these differences and a deep evaluation of the applicability of existing design standards and planning guidelines. In addition, the study suggests that further research can be carried out on public spaces, open spaces, community facilities, and urban services. For example, evaluate refugee camps' available space ratio, private space usage, and urban block pen space adaptation.

Quantifying design parameters is an essential step toward optimising emergency settlement design, planning, and developing the modular structure of the urban pattern. Therefore, this research can be considered a reliable scientific approach to quantifying emergency settlement planning and design parameters, improving the quality of living in emergency settlements and enhancing emergency response timeframe and design outcomes.

THESIS III: NUMERICAL CORRELATION

While there is a significant number of new design standards and guidelines related to refugee camp designs and planning, the design constraints and built environment desired characteristics are in many standards ambiguous and cause high risk on design outcomes, this problem can be seen in many practices in refugee camp cases especially camps in the Middle East. Quantified built-environment characteristics can help establish new numerical guidelines and indicators that could support new design tools and methods, such as establishing a numerical guideline for plot and block area, form, and ratio.

SUB THESES: Refugee camps design parameters

- This section continues to analyse different global design standards and guidelines, extract numerical measures, and compared them.
- In addition, it generates comprehensive numerical standards that include all numerical measures in various guidelines and assure their coherence.

SUB THESES: Refugee camps design parameters, correlations, and constraints

- The created database is analysed to defined new parameters and examined 198 significant numerical unpresidential correlations between established parameters. For example, the research found a strong negative correlation between urban density (Ud) and urban plot length (PL), which can be expressed mathematically.
- With the use of existing numerical standards and urban design theories, the correlation analysis establishes mathematical ranges for design element and correlations by defining design constraints.

7 NUMERICAL CORRELATION

7.1 PEARSON CORRELATION ANALYSIS:

According to David Nettleton, the Pearson correlation method is "the most common method for numerical values". It evaluates the magnitude (strength) and nature (direction)of a linear relationship between two variables. (Nettleton, 2014). The research uses SPSS to detect a correlation between all numerical variables of the case studies. The method used uses the bivariate Pearson correlation. The analysis yields a correlation coefficient for the variables, abbreviated as (*r*). the Pearson coefficient is considered a parametrical measure that supports the statistical correlation between variables. The Pearson correlation can provide three main indications: a significant statistical linear relationship between variables, the strength of the linear association, and the direction of the linear relationship.

7.1.1 Data Requirements

To apply the Pearson correlation analysis, data must comply with seven main requirements', first there must be at least two continuous variables; second, the cases should have no missing values; third, the tested relationship is linear fourth, the cases are independent of each other's, meaning that there is no association between the across cases variables, the change in any variable cannot influence the values in any other cases. Fifth, each tested pair are bivariate and normally distributed; sixth, the data must be a random sample; seventh, there must be no outliers.

7.1.2 Hypotheses

The null hypothesis (H0) and alternative hypothesis (H1) of the significance test for correlation can be given in one of the following ways, depending on whether a one-tailed or two-tailed test is preferred:

Test of significance with two tails:

H_o: ρ = o ("the population correlation coefficient is 0; there is no association")

H_1: ρ ≠ o ("the population correlation coefficient is not 0; a nonzero correlation could exist")

One-tailed significance test:

Ho: ρ = o ("the case correlation coefficient is 0; there is no association")

H1: ρ > o ("the population correlation coefficient is greater than 0; a positive correlation could exist")

OR

H1: ρ < o ("the case correlation coefficient is less than 0; a negative correlation could exist")

where ρ is the case correlation coefficient.

7.1.3 Test Statistic

The case study Pearson correlation coefficient can be calculated as follows:

Equation 14

$$r_{xy} = \frac{cov(x,y)}{\sqrt{var(x)}.\sqrt{var(y)}}$$

Where:

cov (x,y): case covariance of x and y

var (x): the case variance of x

var (y): the case variance of y

The correlation can range between [-1,1]; the positive sign of the coefficient indicates a positive linear relationship. In contrast, the negative indicates a

negative linear relationship. the strength of the relationship is correlated with its closeness to the maximum and minimum values of the coefficient range [+1], shows a perfect positive correlation and the closer the coefficient to this value, the more substantial the magnitude. The relationship and vice versa for the minimum value for [-1], illustrated in Figure 55 Scatterplots showing an example of correlations, ranging in strength and direction.

The following guidelines can rule the strength of the linear association of the variables:

a. $.1 < | r | < .3$ ... small / weak correlation

b. $.3 < | r | < .5$ ... medium / moderate correlation

c. $.5 < | r |$ ..... large / strong correlation

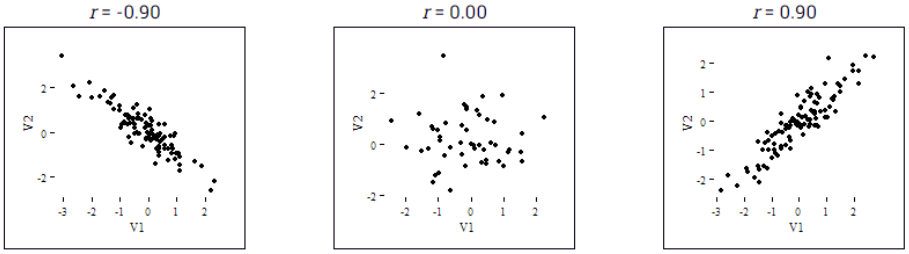


Figure 55 Scatterplots showing an example of correlations, ranging in strength and direction (Kent State University, 2022)

Applying the Bivariate Pearson correlation test

The database was set according to the test requirement, where the numerical variables listed in Table 14 were selected to be analysed using SPSS software; the result of the test are displayed in Table 18. As shown in Table 18, the test identifies 165 statistically significant correlations. The orange cells indicate a significant correlation at the 0.01 level (2-tailed), while the blue cells indicate a significant correlation at the 0.01 level (2-tailed).

7.1.4 Results

The results are expressed by scatterplot graphs annotating the expression of the linear equation. These correlations provide insight into the mathematical guidelines and rules of parametric refugee camp design and planning, and the description explains the correlation direction's significance and strength. Table 18 represents the result of the correlation analysis where the highlighted cells express a significant linear correlation relationship between the parameters of the design; this table can also be summarised in Figure 56

Table 18 Results of the Bivariate Pearson Correlation test

				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1	Year of establishment	Pearson Correlation																																						
		Sig. (2-tailed)																																						
		N																																						
2	Area of the refugee camp (km2)	Pearson Correlation		-0.040																																				
		Sig. (2-tailed)		0.815																																				
		N		37																																				
3	Population (person)	Pearson Correlation	1	0.027	.821**																																			
		Sig. (2-tailed)		0.875	0.000																																			
		N		37	37																																			
4	The urban density	Pearson Correlation	1	-.325*	-0.298	-0.171																																		
		Sig. (2-tailed)		0.050	0.074	0.311																																		
		N		37	37	37																																		
5	Average camp area per person (m2)	Pearson Correlation	2	-0.020	.338*	-0.036	-.472**																																	
		Sig. (2-tailed)		0.909	0.041	0.832	0.003																																	
		N		37	37	37	37																																	
6	Urban block width (m)	Pearson Correlation	0	0.178	-0.099	-0.116	-0.238	0.151																																
		Sig. (2-tailed)		0.307	0.570	0.507	0.169	0.386																																
		N		35	35	35	35	35																																
7	Urban block length (m)	Pearson Correlation	2	0.194	0.100	-0.019	-0.309	.454**	.742**																																
		Sig. (2-tailed)		0.264	0.567	0.914	0.071	0.006	0.000																																
		N		35	35	35	35	35	35																																
8	Urban block aspect ratio	Pearson Correlation	0	0.110	0.243	0.153	-0.102	0.186	-0.242	0.146																															
		Sig. (2-tailed)		0.531	0.160	0.380	0.561	0.284	0.161	0.402																															
		N		35	35	35	35	35	35	35																															
9	Urban block area (m2)	Pearson Correlation	3	0.172	-0.054	-0.137	-0.188	.341*	.844**	.922**	-0.037																														
		Sig. (2-tailed)		0.308	0.751	0.417	0.264	0.039	0.000	0.000	0.835																														
		N		37	37	37	37	37	35	35	35																														
10	Number of clusters per urban block	Pearson Correlation	4	0.249	-0.055	-0.077	-0.120	.366*	.566**	.866**	0.030	.832**																														
		Sig. (2-tailed)		0.149	0.752	0.661	0.494	0.031	0.000	0.000	0.864	0.000																														
		N		35	35	35	35	35	35	35	35	35																														
11	Number of units per cluster	Pearson Correlation	1	-0.298	.384*	0.277	-0.100	0.059	-0.075	0.034	0.138	-0.073	-0.164																													
		Sig. (2-tailed)		0.082	0.023	0.108	0.567	0.737	0.670	0.848	0.428	0.676	0.347																													
		N		35	35	35	35	35	35	35	35	35	35																													
12	Number of camp zones	Pearson Correlation	4	-0.182	.551**	.602**	-0.159	0.079	-0.159	0.047	.513**	-0.098	-0.166	.665**																												
		Sig. (2-tailed)		0.282	0.000	0.000	0.346	0.640	0.362	0.789	0.002	0.566	0.342	0.000																												
		N		37	37	37	37	37	35	35	35	37	35	35																												
13	Number of camp sectors	Pearson Correlation	0	0.189	-0.054	0.135	0.052	-0.160	-0.256	-0.196	0.323	-0.153	-0.140	-0.017	0.261																												
		Sig. (2-tailed)		0.263	0.752	0.427	0.759	0.344	0.138	0.258	0.059	0.366	0.422	0.923	0.119																												
		N		37	37	37	37	37	35	35	35	37	35	35	37																												
14	Urban block built-up area (m2)	Pearson Correlation	5	0.181	0.019	-0.060	-0.153	.425**	.607**	.916**	0.064	.906**	.963**	-0.042	-0.045	-0.118																												
		Sig. (2-tailed)		0.283	0.909	0.725	0.367	0.009	0.000	0.000	0.713	0.000	0.000	0.812	0.791	0.488																												
		N		37	37	37	37	37	35	35	35	37	35	35	37	37																												
15	Urban block built-up area ratio	Pearson Correlation	3	-0.002	0.116	0.256	.470**	-0.252	-.469**	-0.333	0.007	-0.245	-0.027	0.014	-0.012	.393*	-0.043																											
		Sig. (2-tailed)		0.993	0.494	0.126	0.003	0.133	0.004	0.051	0.970	0.144	0.876	0.934	0.943	0.016	0.800																											
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37																											
16	Urban block void area (m2)	Pearson Correlation	5	0.168	-0.066	-0.148	-0.191	0.319	.869**	.905**	-0.053	.997**	.793**	-0.077	-0.105	-0.156	.872**	-0.276																										
		Sig. (2-tailed)		0.322	0.699	0.381	0.257	0.054	0.000	0.000	0.760	0.000	0.000	0.659	0.537	0.356	0.000	0.099																										
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37																										
17	Urban block void area ratio	Pearson Correlation	4	0.002	-0.116	-0.256	-.470**	0.252	.469**	0.333	-0.007	0.245	0.027	-0.014	0.012	-.393*	0.043	-1.000**	0.276																								
		Sig. (2-tailed)		0.993	0.494	0.126	0.003	0.133	0.004	0.051	0.970	0.144	0.876	0.934	0.943	0.016	0.800	0.000	0.099																								
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37																								
18	Urban block public space area (m2)	Pearson Correlation	6	0.146	-0.121	-0.205	-0.147	0.301	.865**	.850**	-0.058	.981**	.753**	-0.115	-0.137	-0.121	.838**	-0.245	.987**	0.245																							
		Sig. (2-tailed)		0.389	0.476	0.223	0.386	0.070	0.000	0.000	0.739	0.000	0.000	0.511	0.419	0.475	0.000	0.144	0.000	0.144																							
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37																							
19	Urban block public space area ratio	Pearson Correlation	7	-0.105	-.517**	-.588**	0.006	0.086	.366*	0.264	0.019	0.311	0.179	-0.125	-0.127	0.014	0.190	-.482**	.326*	.482**	.397*																						
		Sig. (2-tailed)		0.538	0.001	0.000	0.971	0.612	0.031	0.125	0.912	0.061	0.304	0.475	0.453	0.936	0.260	0.003	0.049	0.003	0.015																						
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37																						
20	Refugee camp public space area (m2)	Pearson Correlation	5	-0.099	.908**	.624**	-0.294	.427**	-0.081	0.151	0.324	-0.027	-0.050	.414*	.579**	-0.038	0.033	-0.035	-0.037	0.035	-0.072	-0.169																						
		Sig. (2-tailed)		0.561	0.000	0.000	0.077	0.008	0.644	0.386	0.058	0.872	0.774	0.013	0.000	0.821	0.848	0.837	0.826	0.837	0.671	0.316																						
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37																						
21	Refugee camp public space ratio	Pearson Correlation	1	-0.251	0.029	-0.217	-0.113	0.319	-0.282	-0.130	0.234	-0.203	-0.111	0.087	0.137	0.071	-0.071	-0.104	-0.222	0.104	-0.163	.422**	0.268																			
		Sig. (2-tailed)		0.134	0.864	0.196	0.506	0.055	0.101	0.456	0.175	0.229	0.524	0.618	0.420	0.674	0.676	0.542	0.187	0.542	0.335	0.009	0.108																			
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37																			

22	Local street width (m)	Pearson Correlation	0	0.249	0.203	0.191	-0.248	0.221	0.045	0.039	0.018	0.039	0.023	-0.236	-0.023	0.300	0.002	-0.115	0.045	0.115	0.046	0.102	0.204	0.025																
		Sig. (2-tailed)		0.138	0.228	0.259	0.138	0.188	0.799	0.823	0.918	0.820	0.894	0.173	0.891	0.071	0.992	0.498	0.794	0.498	0.787	0.548	0.226	0.884																
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37																
23	Minor collector street width (m)	Pearson Correlation	8	0.296	0.073	0.094	-0.199	.465**	0.256	.560**	0.055	.539**	.727**	-0.208	0.012	0.228	.714**	0.080	.499**	-0.080	.479**	0.061	0.052	0.070	.325*																
		Sig. (2-tailed)		0.075	0.670	0.582	0.237	0.004	0.137	0.000	0.752	0.001	0.000	0.230	0.942	0.175	0.000	0.636	0.002	0.636	0.003	0.722	0.760	0.681	0.050																
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37																
24	Refugee shelter's width (m)	Pearson Correlation	7	-0.128	0.149	0.119	-0.164	.398*	0.244	.456**	.341*	.404*	0.320	0.039	0.288	0.118	.427**	-0.045	.392*	0.045	.390*	0.100	0.160	0.041	-0.107	0.302															
		Sig. (2-tailed)		0.451	0.380	0.481	0.331	0.015	0.158	0.006	0.045	0.013	0.061	0.825	0.084	0.488	0.008	0.792	0.016	0.792	0.017	0.554	0.345	0.812	0.527	0.069															
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37															
25	Refugee shelters length (m)	Pearson Correlation	8	0.197	0.245	0.243	-.361*	0.324	.355*	.434**	-0.032	.405*	0.298	-0.171	-0.001	-0.027	.351*	-0.084	.407*	0.084	.396*	0.033	0.226	-0.260	0.196	0.252	.521**														
		Sig. (2-tailed)		0.243	0.144	0.147	0.028	0.051	0.036	0.009	0.857	0.013	0.082	0.326	0.995	0.873	0.033	0.622	0.012	0.622	0.015	0.846	0.178	0.120	0.244	0.132	0.001														
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37	37														
26	Refugee shelter area (m2)	Pearson Correlation	10	-0.056	0.177	0.143	-0.302	.430**	.383*	.512**	0.074	.491**	.365*	-0.106	0.083	-0.002	.455**	-0.117	.488**	0.117	.484**	0.122	0.177	-0.112	0.035	0.313	.870**	.842**												
		Sig. (2-tailed)		0.744	0.295	0.397	0.070	0.008	0.023	0.002	0.674	0.002	0.031	0.544	0.625	0.991	0.005	0.492	0.002	0.492	0.002	0.472	0.294	0.510	0.838	0.059	0.000	0.000												
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37	37	37												
27	Shelter aspect ratio	Pearson Correlation	4	.381*	0.135	0.175	-0.239	-0.014	0.083	0.029	-0.177	0.001	0.009	-0.226	-0.178	-0.071	-0.045	-0.044	0.009	0.044	0.000	-0.049	0.115	-0.272	.340*	-0.015	-.347*	.592**	0.080										
		Sig. (2-tailed)		0.020	0.425	0.301	0.154	0.935	0.635	0.868	0.308	0.997	0.959	0.192	0.291	0.676	0.792	0.795	0.960	0.795	1.000	0.773	0.496	0.104	0.040	0.928	0.035	0.000	0.637										
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37										
28	Average urban plot width (m)	Pearson Correlation	7	0.079	0.216	0.207	-.430*	0.223	.402*	0.242	-0.110	0.188	-0.016	0.066	0.228	-0.187	0.042	-.547**	0.210	.547**	0.136	-0.108	0.173	-0.312	0.061	0.001	.387*	.382*	.440**	0.020									
		Sig. (2-tailed)		0.658	0.220	0.239	0.011	0.205	0.023	0.182	0.547	0.288	0.931	0.722	0.194	0.289	0.815	0.001	0.233	0.001	0.444	0.542	0.327	0.073	0.730	0.998	0.024	0.026	0.009	0.912									
		N		34	34	34	34	34	32	32	32	34	32	32	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34									
29	Average urban plot length (m)	Pearson Correlation	9	0.043	0.050	-0.027	-.519**	.397*	.478**	0.339	-0.074	0.264	0.067	-0.157	-0.063	-0.237	0.092	-.693**	0.290	.693**	0.252	0.141	0.060	-0.258	0.271	0.033	.433*	.552**	.606**	0.179	.690**								
		Sig. (2-tailed)		0.810	0.780	0.878	0.002	0.020	0.006	0.058	0.688	0.131	0.714	0.391	0.723	0.177	0.606	0.000	0.096	0.000	0.150	0.425	0.734	0.141	0.121	0.852	0.011	0.001	0.000	0.310	0.000								
		N		34	34	34	34	34	32	32	32	34	32	32	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34								
30	Average plot area (m2)	Pearson Correlation	8	-0.052	0.158	0.126	-.421**	0.308	0.323	0.254	-0.120	0.194	0.005	-0.083	0.075	-0.219	0.043	-.541**	0.216	.541**	0.145	-0.086	0.097	-.332*	0.147	-0.030	.456**	.468**	.568**	0.045	.905**	.891**							
		Sig. (2-tailed)		0.760	0.349	0.458	0.010	0.064	0.058	0.141	0.491	0.251	0.979	0.635	0.659	0.193	0.799	0.001	0.199	0.001	0.393	0.614	0.570	0.045	0.385	0.858	0.005	0.004	0.000	0.790	0.000	0.000							
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	34	34							
31	Urban plot aspect ratio	Pearson Correlation	2	0.188	-0.013	-0.058	-0.241	0.213	0.099	0.132	0.043	0.068	0.154	-0.302	-.354*	-0.120	0.066	-0.134	0.067	0.134	0.081	0.030	-0.054	-0.098	0.318	0.052	0.003	0.265	0.175	0.314	-0.286	.415*	0.062						
		Sig. (2-tailed)		0.288	0.942	0.744	0.170	0.225	0.589	0.473	0.817	0.702	0.399	0.093	0.040	0.500	0.711	0.449	0.705	0.449	0.648	0.865	0.761	0.581	0.067	0.771	0.988	0.130	0.321	0.071	0.102	0.015	0.729						
		N		34	34	34	34	34	32	32	32	34	32	32	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34						
32	Urban plot built-up area (m2)	Pearson Correlation	7	-0.050	-0.216	-0.120	.484**	-0.187	-0.187	-0.100	0.042	0.039	0.185	-0.093	-0.096	.421**	0.187	.756**	0.013	-.756**	0.099	0.175	-0.159	0.214	-0.041	0.219	0.067	-0.025	0.001	-0.067	-.665**	-.658**	-.668**	-0.121					
		Sig. (2-tailed)		0.770	0.199	0.478	0.002	0.268	0.282	0.568	0.810	0.818	0.288	0.594	0.570	0.010	0.269	0.000	0.941	0.000	0.561	0.299	0.347	0.204	0.812	0.193	0.696	0.883	0.995	0.694	0.000	0.000	0.000	0.495					
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	34	34	37	34					
33	Average floor area per person (m2)	Pearson Correlation	12	0.107	0.100	-0.019	-0.255	.646**	.347*	.664**	0.060	.683**	.717**	-0.035	-0.036	-0.018	.790**	0.122	.651**	-0.122	.635**	-0.038	0.045	-0.121	0.051	.656**	.550**	.454**	.584**	-0.039	0.128	0.267	0.177	0.193	0.174					
		Sig. (2-tailed)		0.527	0.557	0.912	0.128	0.000	0.041	0.000	0.733	0.000	0.000	0.840	0.833	0.917	0.000	0.471	0.000	0.471	0.000	0.825	0.793	0.477	0.765	0.000	0.000	0.005	0.000	0.817	0.470	0.127	0.295	0.273	0.303					
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	34	34	37	34	37					
34	Number of urban Blocks per Camp	Pearson Correlation	8	0.243	.431**	.523**	-0.118	-0.024	-.358*	-0.303	0.095	-0.249	-0.221	0.045	0.212	.595**	-0.178	.525**	-0.257	-.525**	-0.252	-.555**	0.239	-0.204	.390*	0.251	0.004	0.130	0.021	0.141	-0.022	-0.161	-0.101	-0.004	0.184	0.139				
		Sig. (2-tailed)		0.146	0.008	0.001	0.485	0.886	0.034	0.077	0.585	0.137	0.202	0.795	0.208	0.000	0.293	0.001	0.124	0.001	0.132	0.000	0.154	0.226	0.017	0.134	0.979	0.444	0.901	0.406	0.900	0.362	0.554	0.982	0.275	0.411				
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	34	34	37	34	37	37				
35	Number of households in the camp	Pearson Correlation	8	0.075	.735**	.859**	-0.139	0.023	-0.122	-0.047	0.049	-0.099	-0.009	0.302	.385*	0.089	-0.002	.428**	-0.114	-.428**	-0.169	-.808**	.421**	-.377**	0.152	0.116	0.027	0.138	0.046	0.127	0.077	-0.096	0.054	0.079	-0.069	0.151	.635**			
		Sig. (2-tailed)		0.660	0.000	0.000	0.412	0.892	0.484	0.790	0.779	0.560	0.960	0.078	0.019	0.600	0.989	0.008	0.502	0.008	0.317	0.000	0.009	0.021	0.368	0.493	0.875	0.415	0.786	0.454	0.666	0.588	0.750	0.658	0.685	0.373	0.000			
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	34	34	37	34	37	37	37			
36	Number of units in an urban block	Pearson Correlation	10	0.224	-0.003	-0.045	-0.143	.329*	.661**	.895**	0.011	.857**	.954**	0.031	-0.067	-0.178	.948**	-0.062	.824**	0.062	.787**	0.198	0.008	-0.100	-0.035	.632**	0.272	0.230	0.298	-0.029	-0.033	0.025	-0.050	0.110	0.168	.662**	-0.252	0.030		
		Sig. (2-tailed)		0.182	0.988	0.790	0.398	0.047	0.000	0.000	0.949	0.000	0.000	0.860	0.692	0.292	0.000	0.717	0.000	0.717	0.000	0.240	0.961	0.558	0.838	0.000	0.104	0.171	0.074	0.863	0.853	0.888	0.768	0.538	0.321	0.000	0.133	0.860		
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	34	34	37	34	37	37	37	37		
37	Average household size	Pearson Correlation	3	0.021	0.007	0.103	-0.002	-0.314	-0.049	-0.086	0.190	-0.188	-0.207	-0.168	0.135	0.006	-0.229	-.350*	-0.177	.350*	-0.173	0.251	0.115	0.294	-0.032	-0.200	0.107	0.006	0.054	-0.060	0.095	0.102	0.098	-0.033	-0.218	-.516**	-0.274	-0.253	-0.238	
		Sig. (2-tailed)		0.901	0.968	0.543	0.991	0.058	0.780	0.624	0.275	0.266	0.233	0.336	0.426	0.972	0.172	0.034	0.295	0.034	0.307	0.134	0.497	0.077	0.851	0.236	0.527	0.973	0.750	0.724	0.594	0.568	0.562	0.854	0.195	0.001	0.101	0.130	0.156	
		N		37	37	37	37	37	35	35	35	37	35	35	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	34	34	37	34	37	37	37	37	37	

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

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

The following section shows an example of how the results of correlation analysis can be represented using mathematical expressions. As shown in Figure 56 and Table 18, The correlation analysis can identify 198 correlations, each could be studied individually to establish a deeper understanding of the correlation relation, but from the initial analysis, it can be noticed that the dimensions of the urban block have the most correlation of all design parameters with 17 correlations, making it a crucial design decision.

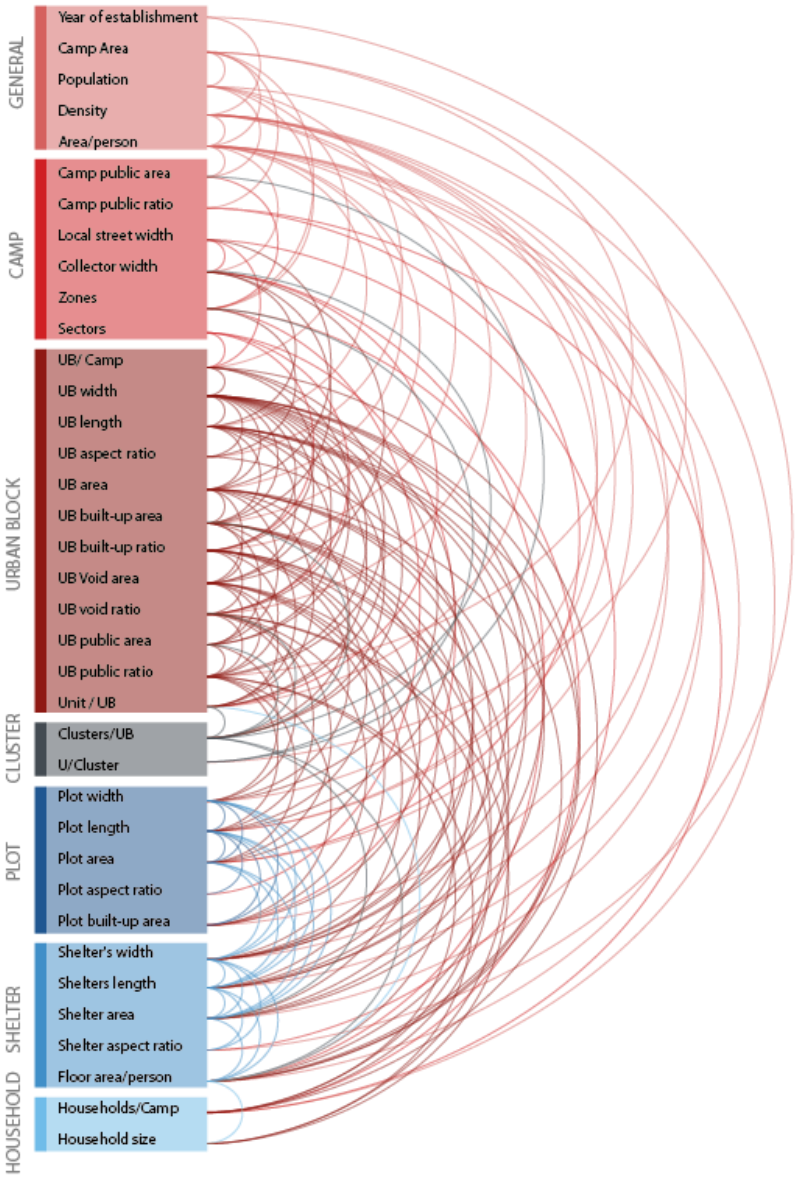


Figure 56: The Bivariate Pearson correlation analysis summary

7.1.4.1 Year of establishment

The analysis shows a correlation between two variables, urban density and the ratio of shelter units, as shown in Figure 57 and Figure 58.

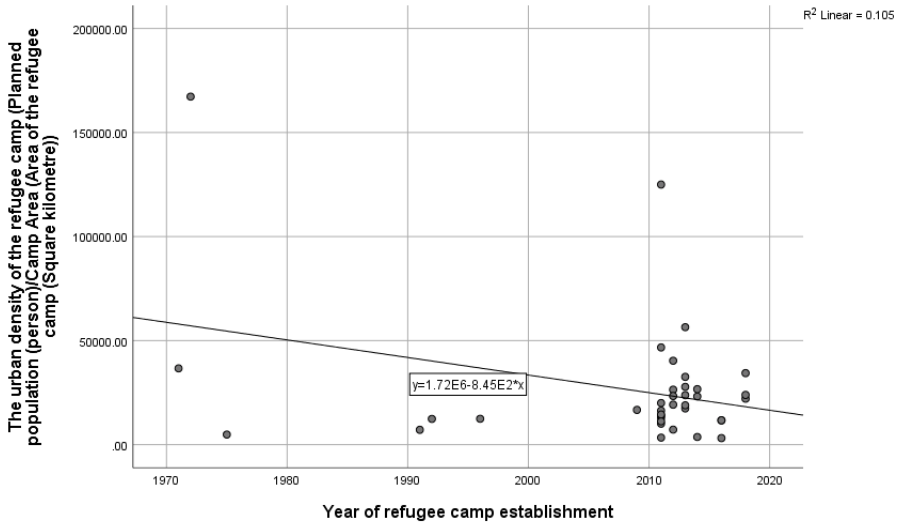


Figure 57 Scatterplot representing the correlation between urban density and the year of cam establishment

A Pearson correlation coefficient was calculated to assess the relationship between the year of refugee camp establishment and the urban density of the camp (Cd). There was a moderate, negative correlation between the two variables, r = -.325, N = 37; the relationship is significant (p = .050). The year of establishment is associated with urban density. The linear correlation equation could be expressed as per Equation 15 :

Equation 15

$$Urban\ density\ (Ud) = \ 1.72E6 - 8.45E2 * (year\ of\ establishment)$$

Shelter aspect ratio

A Pearson correlation coefficient was calculated to assess the relationship between the year of refugee camp establishment and the shelter aspect ratio (ShAR). There was a moderate, positive correlation between the two variables, r =.381, N = 37; the relationship is significant (p = .020). Therefore,

the year of establishment is associated with the shelter aspect ratio (ShAR). The linear correlation equation could be expressed as Equation 16:

Equation 16

$$Year\ of\ establishment = 1.99E3 + 9.71 * \text{ShAR}$$

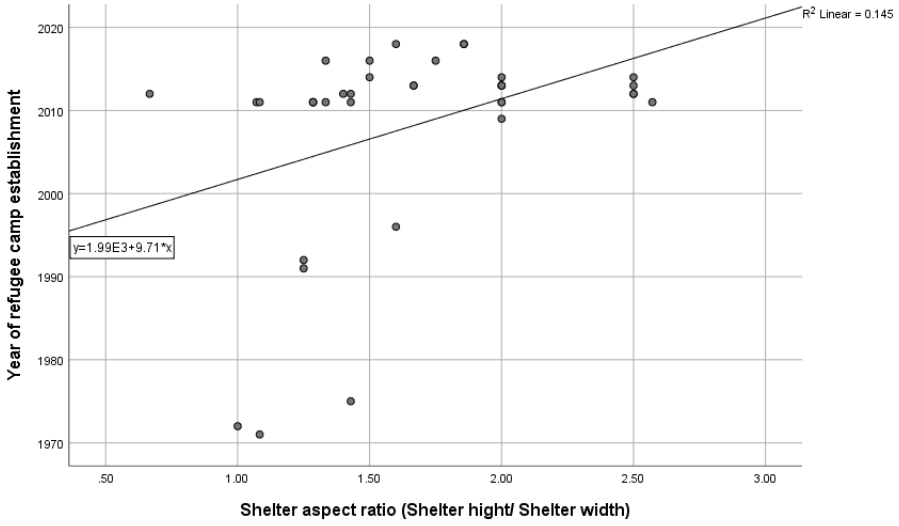


Figure 58 Scatterplot representing the correlation between shelter aspect ratio and the year of cam establishment

Area of the refugee camp (CA)

The analysis expresses a correlation between the area of refugee camps (CA) and camp population (CPop), average camp area per person (CAPP), number of units per cluster (UPC), number of camp zones (CZ), Block open space area (BOSA), camp open space area (COSA), number of urban blocks (BPC), number of households in the camp (HHPC).

Population

A Pearson correlation coefficient was calculated to examine the relationship between the refugee camp (CA) area and the camp population (CPop)Figure 59. The analysis showed a strong, positive correlation between the two

variables, r =.821, N = 37; the relationship is significant (p = .000). The linear correlation equation could be expressed as per Equation 17:

Equation 17

$$CA = 1.28E4 + 8.96E3 * CPop$$

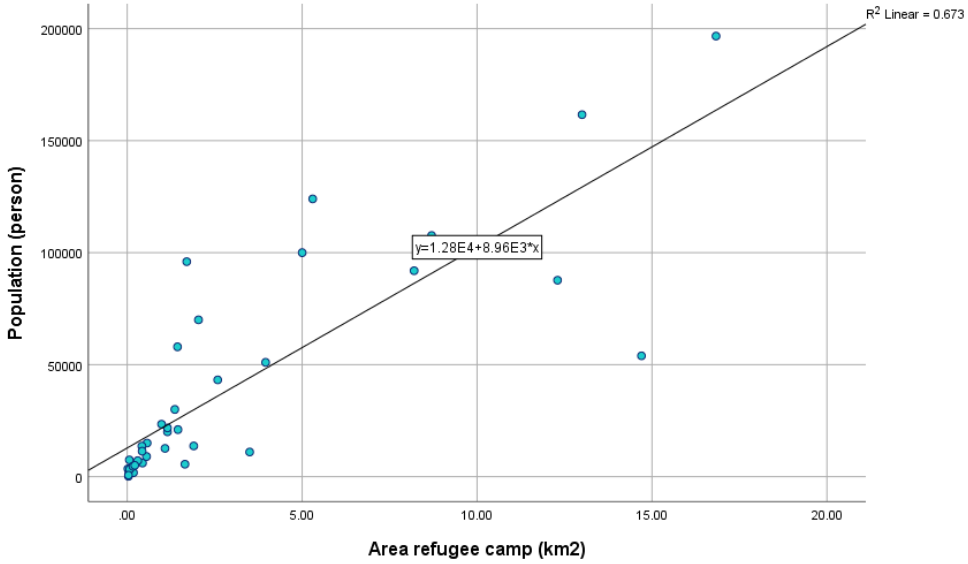


Figure 59 Scatterplot representing the correlation between the area of the refugee camp and the camp population

On the other hand, standards have expressed a clear relationship between the refugee camp area and population, which is a constant linear equation dependent on the average area per person. For example, The value of CAPP is considered constant value according to the standards of the UNHCR (United Nations High Commissioner for Refugees, 2007) and the Sphere Handbook (Sphere Association, 2018), "the minimum usable surface area is 45 square metres per person (CAPP) in camp-type settlements" which indicates that the graph can be represented per the following equation:

Equation 18

$$CA = 45 * CPop$$

For example, camps of over 20,000 people should generally be avoided. The size of a site for 20,000 people should be calculated as follows, assuming space for vegetable gardens is included:

20,000 people x 45 m2 = 900,000 m2 = 90 hectares.

Camp area per person

A Pearson correlation coefficient was calculated to assess the relationship between the refugee camp area (CA) and the average camp area per person (CAPP) Figure 60. There was a moderate, positive correlation between the two variables, r =.338, N = 37; the relationship is significant (p = .041). Therefore, the linear correlation equation could be expressed as per Equation 19:

Equation 19

$$CA = 1.49 + 0.02 * CAPP$$

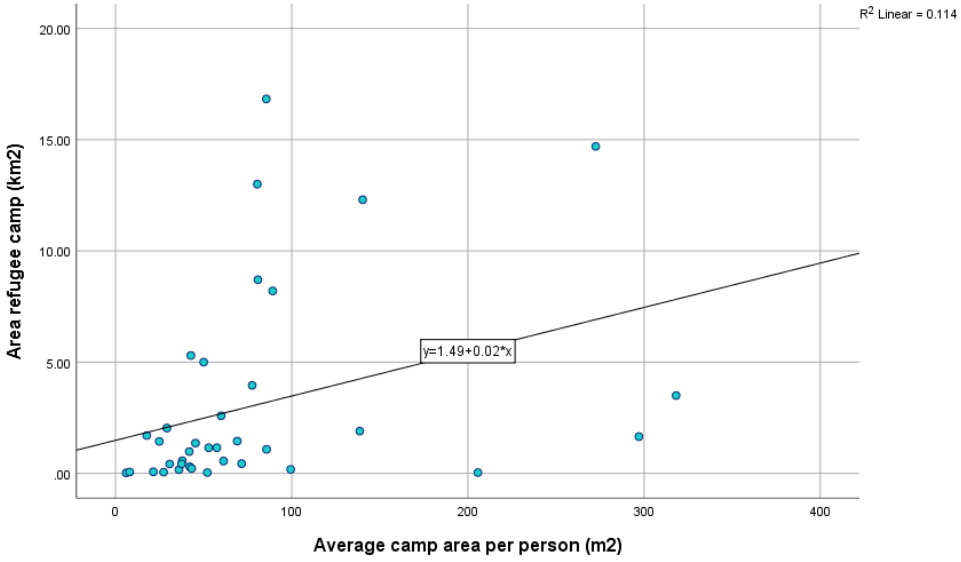


Figure 60 Scatterplot representing the correlation between the area of the refugee camp and the average camp area per person

Camp Public space area (CPSA)

A Pearson correlation coefficient was calculated to assess the relationship between the refugee camp area (CA) and the open space area (COSA). The analysis showed a strong, positive correlation between the two variables, r

=.908, N = 37; the relationship is significant (p = .000). The linear correlation equation could be expressed as per Equation 20:

Equation 20

$$CPSA = 1.21E4 + 6.48E5 * (CA)$$

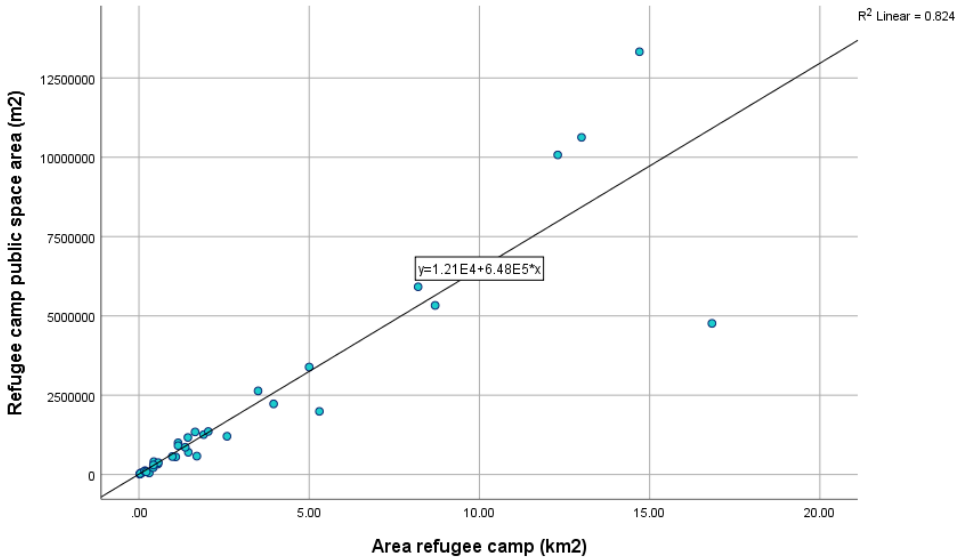


Figure 61 Scatterplot representing the correlation between the area of the refugee camp and the camp's public space

Number of urban blocks per camp (BPC)

A Pearson correlation coefficient was calculated to assess the relationship between the refugee camp area (CA) and the number of blocks per camp (BPC)Figure 62. The analysis shows a strong, positive correlation between the two variables, r =.431, N = 37; the relationship is significant (p = .008). Therefore, the linear correlation equation could be expressed as per *Equation 21*:

Equation 21

$$BPC = 51.38 + 16.34 * (CA)$$

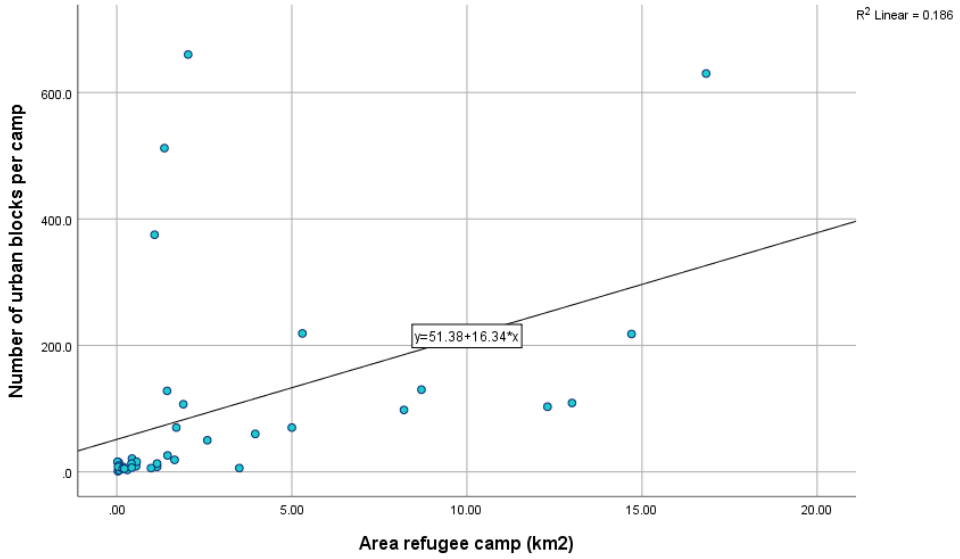


Figure 62 Scatterplot representing the correlation between the area of the refugee camp and the number of urban blocks per camp

Number of households in the camp (HHPC)

A Pearson correlation coefficient was calculated to evaluate the relationship between the refugee camp area (CA) and the number of households per camp (HHPC). The analysis shows a strong, positive correlation between the two variables, r =.735, N = 37; the relationship is significant (p = .000). The linear correlation equation could be expressed as per Equation 22:

Equation 22

$$HHPC = 0.94 + 2.52E - 4 * (CA)$$

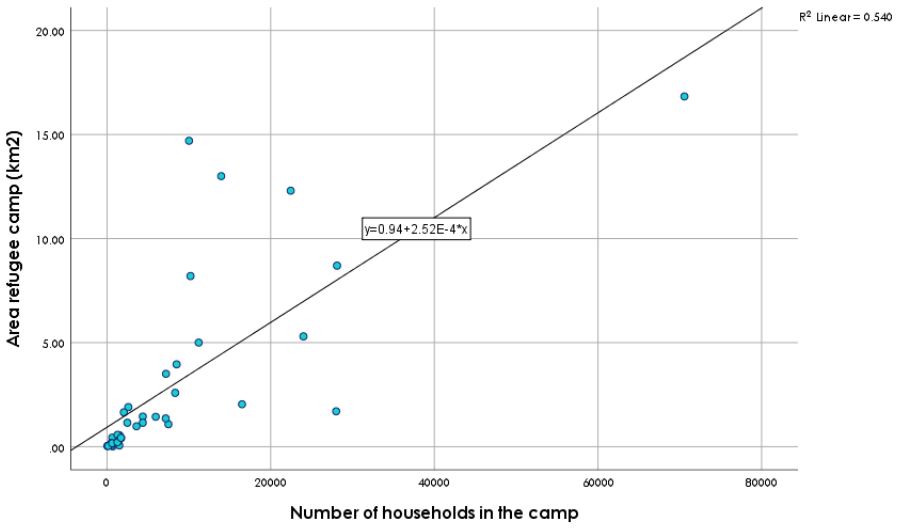


Figure 63 Scatterplot representing the correlation between the area of the refugee camp and the number of households per camp

In the case of the correlation between camp area and camp zones, even though it shows a strong correlation, the number of camp zones is generally perceived as one; therefore, this parameter does not indicate a relationship that could be used. Moreover, in the case of correlation between the number of units per cluster, the reference for the number of units per cluster can be found in the standards of (United Nations High Commissioner for Refugees, 2007) and (Sphere Association, 2018) guidelines optimised the number of units per cluster with 16, therefore. The correlation, in this case, is not relevant because it shows the defect in the implementation. The correlation between the camp area and the urban block ratio can be considered a complex relationship that could be studied in the future.

7.1.4.2 Population (Pop)

The analysis shows a correlation between the camp population and refugee camp area, which is explained in the previous section, the number of camp zones. It also correlates with the urban block public space ratio and camp public space area, the number of blocks per camp and the number of households per camp. It is vital to notice the dependency of the variables, where all variables are dependent on population variables and only public space block ratio and camp public area are dependent,

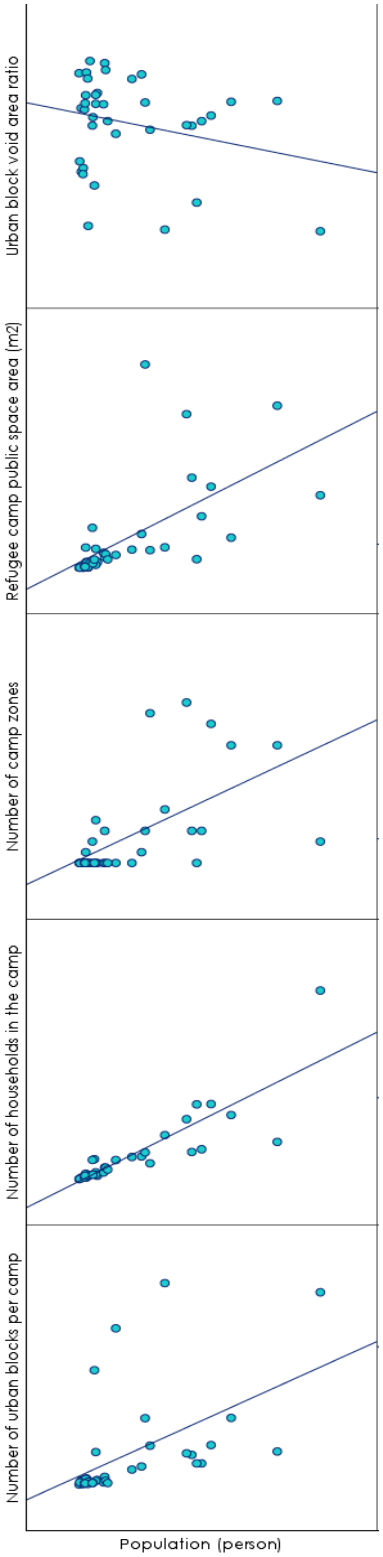


Figure 64 Correlation of population with a: urban block void ratio. b: camp public space area. c: number of camp zones. d: number of households. e: number of urban blocks

Strong negative correlation between the refugee camp population (CPop) and the block void area ratio (BVoidR), r =-.588, N = 37; the relationship is significant (p = .000). The linear correlation is expressed as Equation 23:

Equation 23

$$BVoidR = 84.89 - 5.73E - 5 * (CPop)$$

a. Strong negative correlation between the refugee camp population (CPop) and camp open space area (COSA), r =.624, N = 37; the relationship is significant (p = .000). The linear correlation is expressed as Equation 24:

Equation 24

$$COSA = 3.55E5 + 40.77 * (CPop)$$

b. Strong negative correlation between the refugee camp population (CPop) and the number of camp zones (CZ), r =.602, N = 37; the relationship is significant (p = .000). The linear correlation is expressed as Equation 25:

Equation 25

$$CZ = 1.29 + 5.39E - 5 * (CPop)$$

c. Strong negative correlation between the refugee camp population (CPop) and the number of households per camp (HHPC), r =.523, N = 37; the relationship is significant (p = .001). The linear correlation is expressed as Equation 26:

Equation 26

$$HHPC = -7.95E2 + 0.23 * (CPop)$$

d. Strong negative correlation between the refugee camp population (CPop) and the number of blocks per camp (BPC), r =.523, N = 37; the relationship is significant (p = .001). The linear correlation is expressed as

e. Equation 27:

Equation 27

$$BPC = 28.36 + 1.81E - 3 * (CPop)$$

7.1.4.3 Urban Density:

The analysis shows a correlation between urban density (Ud) and the following parameters, camp area per person (CAPP). However, this relationship would be excluded from the analysis because CAPP depends on Ud. On the other hand, other linear correlations include the following

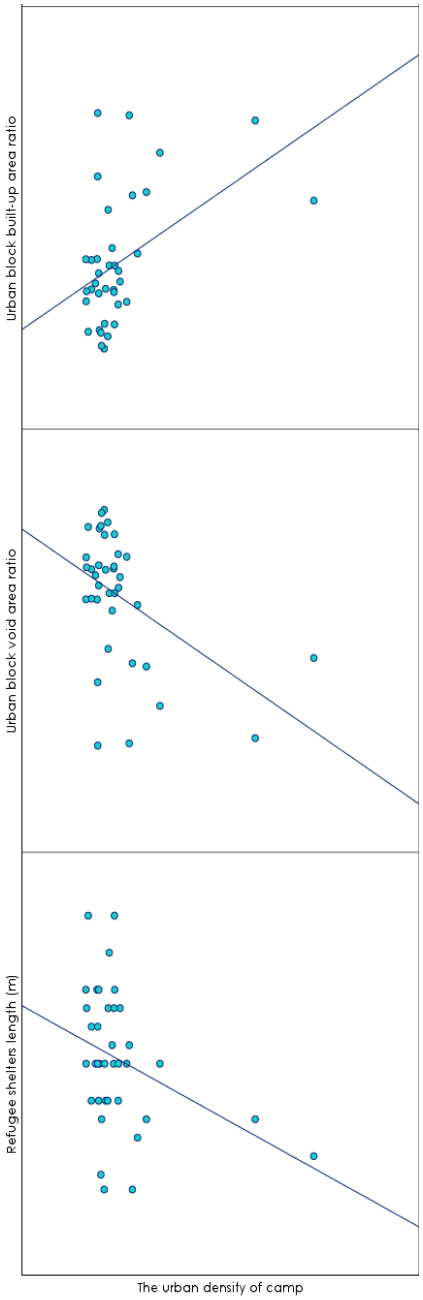


Figure 65: Correlation of urban density with a: Urban block built-up area ratio. b: Urban block void area ratio. c: Refugee shelter length.

a. The diagram shows a strong positive correlation between urban density (Ud) and urban block built-up area ratio (BBUR), r =.470, N = 37; the relationship is significant (p = .003). The linear correlation is expressed as Equation 28:

Equation 28

$$BBUR = 13.09 + 1.62E - 4 * (Ud)$$

b. The diagram shows a strong negative correlation between urban density (Ud) and urban block void area ratio (BVoidR), r =-.470, N = 37; the relationship is significant (p = .003). The linear correlation is expressed as per Equation 29:

Equation 29

$$BVoidR = 86.91 - 1.62E - 4 * (Ud)$$

c. The diagram shows a moderate negative correlation between urban density (Ud) and refugee shelter length (ShL), r =-.361, N = 37; the relationship is significant (p = .028). The linear correlation is expressed as per

d. Equation 30:

Equation 30

$$ShL = 6.67 - 2.09E - 5 * (Ud)$$

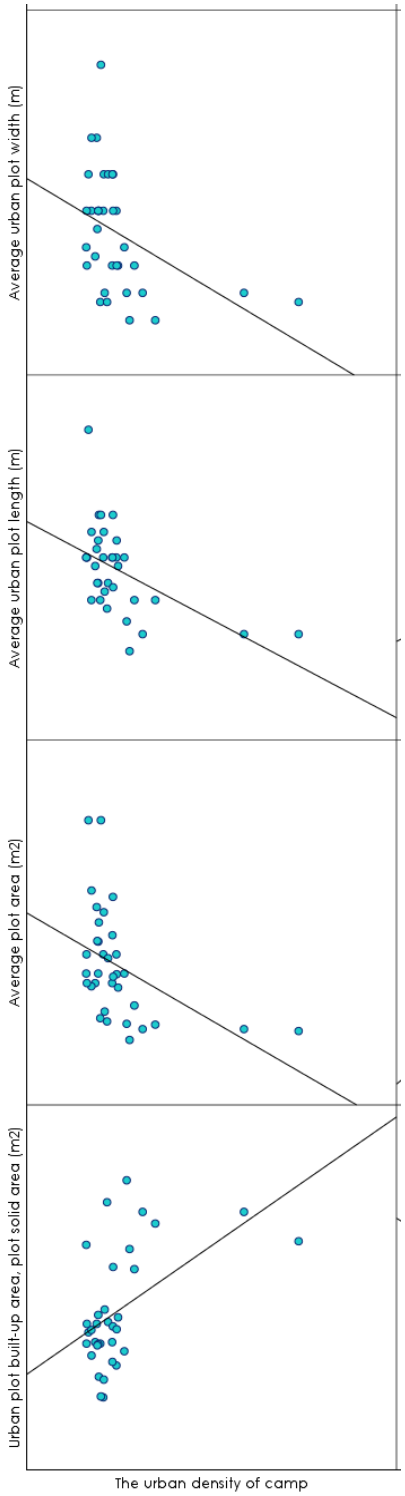


Figure 66 Correlation of urban density with a: Plot width. b: Plot length. c: Plot area. d: Plot build-up area.

- The diagram shows a moderate negative correlation between urban density (Ud) and urban plot width (PW), r =-.430, N = 37; the relationship is significant (p = .011). The linear correlation is expressed as per Equation 31:

Equation 31

$$PW = 9.95 - 4.26E - 5 * (Ud)$$

- The diagram shows a strong negative correlation between urban density (Ud) and urban plot length (PL), r =-.519, N = 37; the relationship is significant (p = .002). The linear correlation is expressed as per Equation 32:

Equation 32

$$PL = 15.77 - 8.07E - 5 * (Ud)$$

- The diagram shows a strong negative correlation between urban density (Ud) and urban plot area (PA), r =-.421, N = 37; the relationship is significant (p = .010). The linear correlation is expressed as per Equation 33

Equation 33

$$PA = 1.56E2 - 1.12E - 3 * (Ud)$$

- The diagram shows a strong positive correlation between urban density (Ud) and urban plot length (PBUA), r =.484, N = 37; the relationship is significant (p = .002). The linear correlation is expressed as per Equation 34

Equation 34

$$PBUA = 19.57 + 2.04E - 4 * (Ud)$$

7.2 SUMMARY

The Pearson correlation analysis results are examples of section 10.4 of this chapter. However, the complete analysis results, including correlation relationships and their mathematical representation, are added as an appendix, and can be found in appendix 01 at the end of the research. The examples showcase refugee camps as a system of elements and subsystems interacting, forming correlations that can be expressed mathematically.

This conclusion proves that refugee camp urban settlement can be considered a system modelled parametrically.

THESIS IV: FRAMEWORK DESIGN

Design approaches and tools applied to refugee camp designs and planning are traditional. Although there are many design standards, the start and end of the design process are structured in the standards and design guidelines. As a result, the design process can easily vary, causing significant shifts in the practice. A parametric framework focused on the structural hierarchy of refugee camp layout can offer a new design approach that helps establish a systematic method and tools for refugee camp design, allowing the design to be flexible and adaptable to different design stages and goals; the framework applies design standards, improves the design process, eliminates design errors, and improves the quality of living conditions for users.

SUB THESES: Identity refugee camps built environment as a system

- The established numerical relations between built environment elements, enabling the researcher to model refugee camps as a system.

SUB THESES: Top-down design framework

- The following section proposed a design framework that focuses on receiving the design of a refugee camp as a system from a top-down design approach—focusing on the layering of different systems to achieve the final camp layout.

8 FRAMEWORK DESIGN

8.1 DEFINE A PARAMETRIC FRAMEWORK FOR REFUGEE CAMP DESIGN

In the short timeframe of developing refugee camp layouts, the design process and tools are crucial for the quality of the refugee camp and the quality of life it provides. Similar to many urbanisation processes, urban planners and designers create an urban brief consisting of a set of rules that define the physical form and composition of the urban settlement; in famous cities like the Cerdà blocks in Barcelona and Manhattan, New York, a rigid urban block form can be easily identified, which was initially developed with a focus for hygiene and ease of mobility and transportation two advantages of grid-like layout and urban structures. In contrast, Boston and London have an organic block form, developed by the rabid population movement toward the city and the long span of chronological development.

The planning guidelines define the form, urban density, hierarchy, functional layout and space configuration of the urban block and, later, the complete urban fabric. In addition, they also determine other layers of the urban fabric, including land use, utilities, communal facilities networks and capacities.

The parametric framework of refugee camps aims to develop a generic system representation for refugee camp planners and design officers to generate new prototypes and design alternatives for refugee camp planning and re-imagining the refugee camp-built environment with customised layouts and block forms.

8.2 MODELLING THE REFUGEE CAMP SYSTEM

The model to be created foremost identifies the refugee camp as a system by deconstructing it into its primary elements and then recreating a study model of the system's elements that is abstracted, pragmatic, and expedient to study.

Furthermore, the refugee camp model that will be established represents the urban system and the relationship of its elements mathematically, for that is essential to introduce the system modelling theory before examining the framework to model the system. Therefore, the following section focuses on establishing a framework to design a refugee camp by considering it a system composed of different units/ parts.

8.2.1 Identifying refugee camps as a system

A system can be defined in a Cambridge dictionary as "a set of connected things or devices that operate together". While the definition of Ludwig von Bertalanffy is the most cited where he defines in his book the general system theory the system as a "set of elements standing in interrelationship" (Bertalanffy, 1968). When dealing with refugee camps as a set of elements, it is essential first to reidentify the camp elements, second to their relations, and third, the boundaries of elements' relationships to model the system.

The abstract definition of the system can be represented graphically in Figure 67, where the parts are represented in circles, and the arrows represent different connections and correlations, or relationships between the parts, the direction of the arrow can indicate the direction of interaction between the parts.

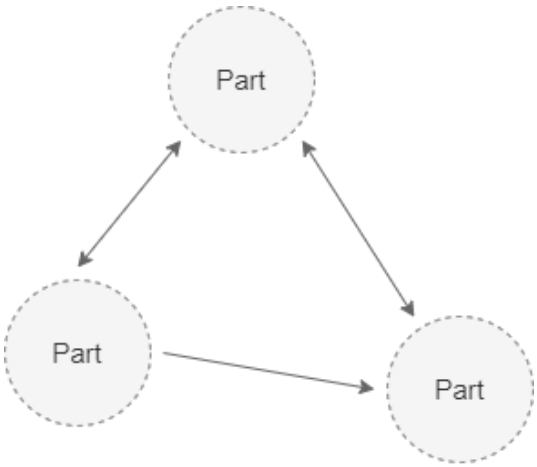


Figure 67 Abstract definition of a system

As important as it is to define the parts and their relationships, it is crucial to identify the limits and boundaries of the system, the confines of the system and entities which can be managed and modelled. Therefore, the system is modelled and isolated from its environment to help simplify the system to analyse and understand the system's behaviour or parts. A similar methodology is used in the case of studying natural sciences phenomenon in that the system is isolated from its environment and studied independently Figure 69. Still, the exclusion of the system context must not take down essential elements of the design, including all necessary system entities that the system owners or managers control is essential.

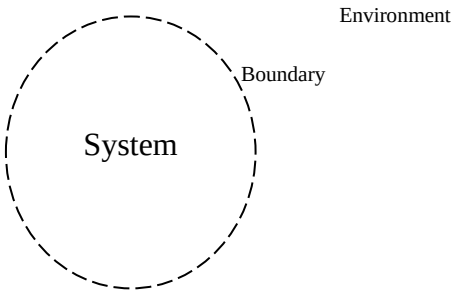


Figure 68 System boundary

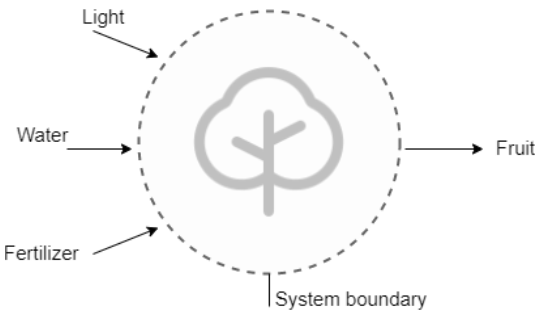


Figure 69 An example of a system isolated from the environment

The systems can be part of a more complex subsystem; in that case, it is called a subsystem. A group of subsystems form a system, and this hierarchy allows researchers to study subsystems independently and then integrate them into a complete relationship within the main system.

8.3 THE DESIGN FRAMEWORK OF THE REFUGEE CAMP SYSTEM MODEL

The process of designing a complex system such as a refugee camp which is comprehensive and integrated usually consists of a vast amount of data that needs to be processed, integrated, and correlated to form helpful information that can be fed into a process that results in a solution proposal that is accurate and efficient. In contrast with the current process of modelling refugee camps, the modelling strategy used is mainly related to the nature of the design program and its components as a set of elements disregarding the element relations. Moreover, this can be translated into the existing standards and design guidelines of refugee camp planning and design. Nevertheless, chapter 4 provides proof supporting the camp system modelling of a refugee camp, where its elements are significantly affected by each other and can be dealt with as a system rather than a set of elements.

As observed in the case studies studied in chapter 4, the refugee camp design is a process based on a modular system. When referring to the modular system, we refer to the parts (family plot, cluster, block, open space) and the whole resulting from arranging the parts. Furthermore, as mentioned in the second chapter, the humanitarian organisation involved in the design and planning of refugee camps uses design standards based on a modular system.

After identifying refugee camps as a system, the modelling process of the system will be led by two system modelling methodologies used by engineers in many design fields top-down and bottom-up design methods, which will be discussed in the following section.

Essential questions to be decided before building the design framework is to answer the following question,

- Purpose of the models to be created:
  The model is created to establish a baseline design of the street network and block size, plot for assessment and initial decision-

making, and predict any design flaws in an earlier design phase to cut down costs and achieve the best strategy in a timely manner.

- The elements that shall be presented
  - Site boundary
  - Street network
  - Block boundary
  - Plot sizes and boundary

- Limitations of the model by (time, money, information, team)
  - **Time:** there is not enough time to develop all design considerations on all elements to create a comprehensive and fully integrated model that is the closest to reality.
  - **Information**: lack of a numerical database to make and evaluate design decisions and the lack of systematic and comprehensive documentation of previous cases makes the model based on design guidelines and eliminates many cases that could improve the modelling outcome.
  - **Team:** such comprehensive modelling needs a team of expert engineers to include all aspects, imitations, and regulations of systems and components to provide an integrated model, which is hard to find due to the lack of interest in the topic.

THESIS V: THE TOP-DOWN SYSTEM PROCESS

The parametric design framework has various design options which achieve the minimum standards and guidelines. In addition, parametric optimization of system modelling tools can be adapted to improve and upgrade different design scenarios helping designers and planners achieve the best design with the available time, resources, and design information.

SUB THESES: Applying a top-down system modelling framework

- The research identifies system modelling purposes, elements, relationships, and design constraints and identify tools and modelling environment that can facilitate system modelling using a graphical representation of numerical standards.

SUB THESES: Optimisation of a top-down based system using parametric tools

- The following section applies system modelling framework to optimise urban block dimensions. The system model showcases the process of using the top-down-based framework and the optimization process using parametric tools.

9 THE TOP-DOWN SYSTEM PROCESS

In the top-down method, the design is perceived as an integrated combination of components, where each component of the system has its own global reference within the system. Therefore, each component can be analysed, modelled, and optimised as a centralised system.

The design method is based on developing an abstraction layout of a refugee camp which starts by defining the site boundary and primary roads and then generating the secondary road network and the boundary of the settlement sectors or blocks,

The block generative form includes (6) division patterns mentioned in chapter 4 based on the existing planning and cluster unit layouts developed by the UNHCR planning handbook.

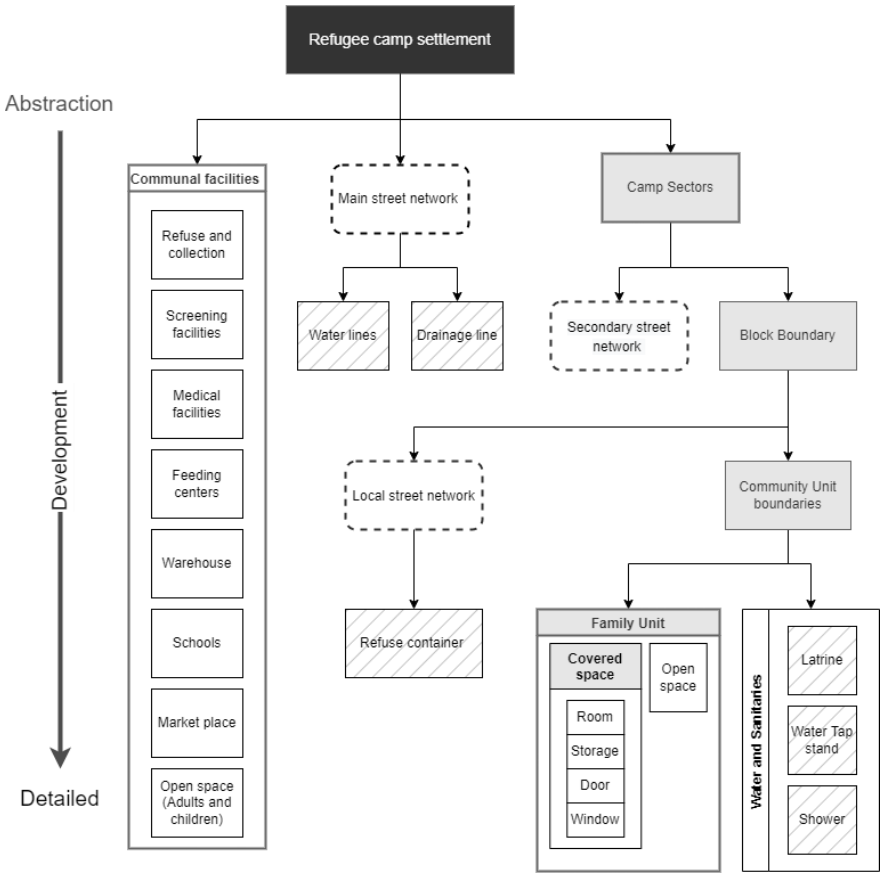


Figure 70 Top-down refugee camp design method

The design framework proposes an automated workflow of refugee camp planning, therefor parameters included in the design workflow are categorised into two types. The first type of parameters are external dependent parameters, which can drive an assessment of the case; parameters can include design needs or program, such as population, location of the primary roads, and site boundaries. The second type of parameters are internally impeded parameters in the workflow, established based on the standards and correlation analysis of previous case studies, such as plot size, block size, and street width.

The design workflow of a refugee camp based on a top-down design process; can be described in steps as the following:

1. Define site boundary
2. Constrain site in a rectangle (define rectangular dimensions)
3. Select block dimension
4. Divide the site into a grid layout
5. Offset centre of grid lines to establish streets (firebreaks)
6. Optimize block dimension based on communal facility block location
7. Divide urban blocks into clusters using decoding space extension
8. Divide clusters into family plots(parcels)

Before explaining the workflow, it is essential to describe the design environment and its setup of the preparation prior to the design work frame design and

9.1 SOFTWARE ENVIRONMENT

The grasshopper graphical algorithm editor and Rhinoceros 3D environment held all the developed tools and design outcomes, visuals and scripting included in this chapter. In addition, adding extensions that include, Decoding space and using external expressions that were calculated based on parameters correlations in SPSS prior displaced and discussed in chapter 4.1.

9.1.1 Rhinoceros 3D

Rhinoceros 3D is a three-dimensional computer-aided design application software developed by Robert McNeel & Associates; Rhinoceros 3D is primarily famous for its ability to alter design parametrically. It utilises the NURBS mathematical model, which enables computer graphics software developers to transfer three-dimensional geometries between various applications with minimal errors. In addition to its ability to support scripting languages and applications such as Grasshopper 3D, which is considered one of the well-spread computational design tools.

9.1.2 Grasshopper 3D

"Grasshopper is a visual programming language that runs within the Rhinoceros 3D CAD application.". Grasshopper is characterised by its user-friendly interface; scripts are created by combining components from the tools bar and dropping them into the work canvas. Components have a start and an end thread used for inputs and outputs; in a script output, a component can be used as an input for the subsequent component.

9.2 PREPARATION FOR THE SYSTEM MODELLING FRAMEWORK

In order to design a refugee camp using Grasshopper or Rhino3D, it is essential to create a design flowchart. The design flowchart represents the algorithmic design process that is easy to comprehend and transform into a programme (script) and defines input data that will be included in the algorithm.

9.2.1 System input data:

The following data should be collected:

b) Site boundary

c) Site dimensions Step 1 Requires defining site boundaries and then finding out the dimensions of the rectangle surrounding the site boundary entirely.

d) The central location of communal facilities (choosing a single site within the site boundary) represents the centre of the community facility's geometry.

9.2.2 System process

The process follows four steps workflow focused on minimising external data input and maximizing standard dependent inputs. The first starts with optimizing urban block size based on the suggested location of communal facilities, calculating the number of clusters from the previous step outcome, and dividing the block into groups using standards and correlation of parameters.

9.2.3 System outputs: optimised urban block dimensions

The process of optimizing block size aims to determine the best urban block size, which consists of 2 parameters, block length (BL) and block width (BW); the parameters are optimized based on the location of the community facility. The camp planner assigns the input parameters, which are:

- Site boundary,
- Overall site width,
- Overall site length.
- In addition to the centre point of the community facility

Algorithm breakdown

Define the initial block width (BW), and block length (BL) represented in Figure 71. The block length and width are constrained by the firebreak standards mentioned in chapter 4, Table 7. Where every 300 m, there must be a firebreak of 30 meters, borders of firebreaks define the boundaries of the urban block. Although standards have not constrained the urban block length and width minim dimensions, the case study analysis in chapter 4 shows that the minimum urban block width after excluding outliners is 100 m. As a

result, we can define the values of urban block width as integer numbers in the range of 100-300 m.

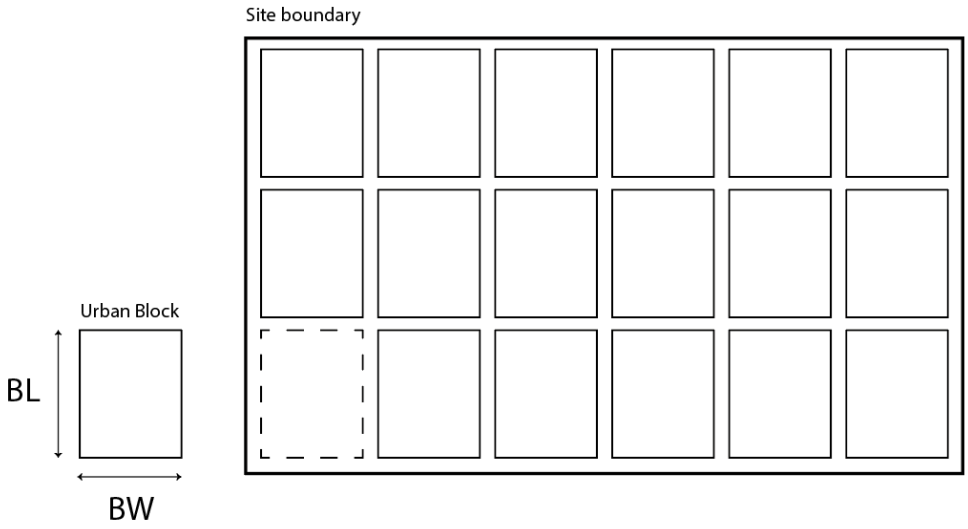


Figure 71 Site boundary and urban block parameters

After randomly defining block dimensions, it is essential to define rectangular grid cells that will form the base for the urban pattern of the refugee camp. In this case, the framework suggests using grid patterns to simplify the process. Still, different urban patterns and layouts can be used in the future or in other contexts. 4 main parameters identify the rectangular grid:

- Cell width
- Cell length
- Number of cells on the x-axis
- Number of cells y-axis

Table 19 refugee camp rectangular parameters and constraints

	Relation to predecessor parameter	**Constraints**
Cell width	Block width	300< Cell width >100
Cell length	Block length	300< Cell length >100

Number of cells x-axis	Site overall length/ Block length	Context-related based on the site boundary
Number of cells y-axis	Site overall width/ Block width	Context related based on the site boundary

The rectangular grid lines define the street network's centrelines; for creating the street network, the grid cells are offset by half the width of the urban block street, which is also the recommended firebreak of 30 m. there for offset value of the urban block is 15 m, shown in the second section of Figure 74Figure 74 Step-by-step implementation of algorithm framework for optimizing block dimensions.

Then the algorithm selects the blocks only located in the actual site boundary given by the planner; this step is essential when site boundaries are not regular and are further distorted from the geometry of a standardised rectangular shape. When analysing irregular site boundaries, the optimization of block size might include regions in the analysis that are not actually in the design outcomes, and this can be illustrated in Figure 72 and Figure 73.

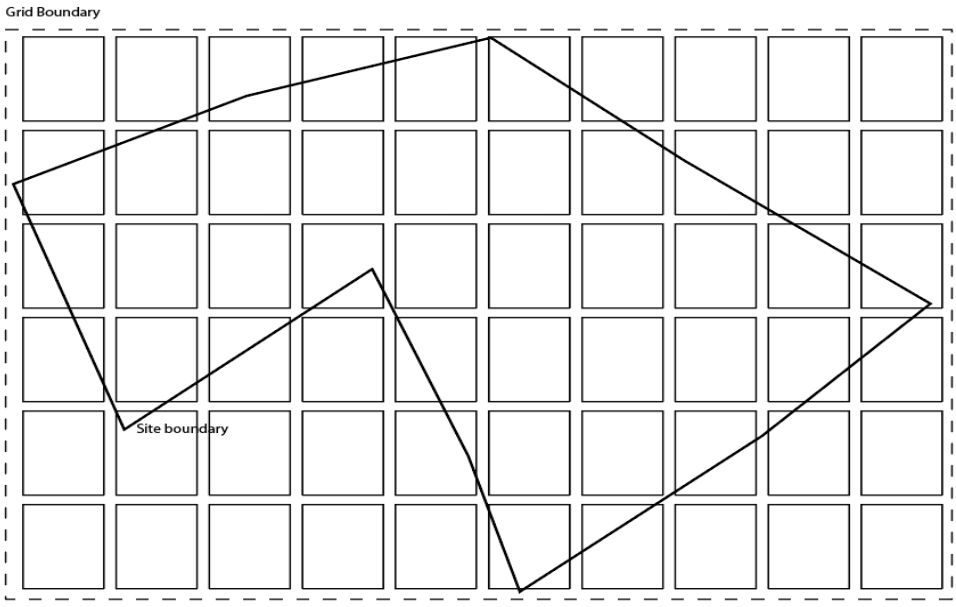


Figure 72 urban blocks in the overall grid

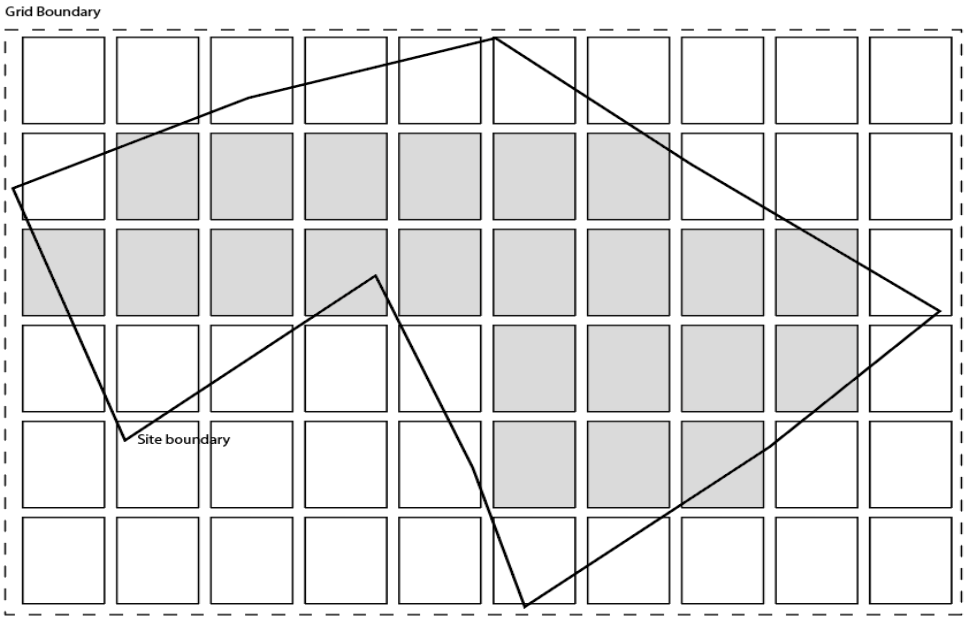


Figure 73:urban block within the site boundary

The following step identifies the blocks' centre points included in the site boundary. It measures the distances between the urban blocks' centre point and the community facility's potential centre, which is identified as an external input predefined by the camp planner. For example, in the illustration in Figure 74, the last section, where a line is constructed between each centre point of the refugee camp block that is within the site boundary and the centre point of the community facility, later, the length of all lines is summed in an amass addition component.

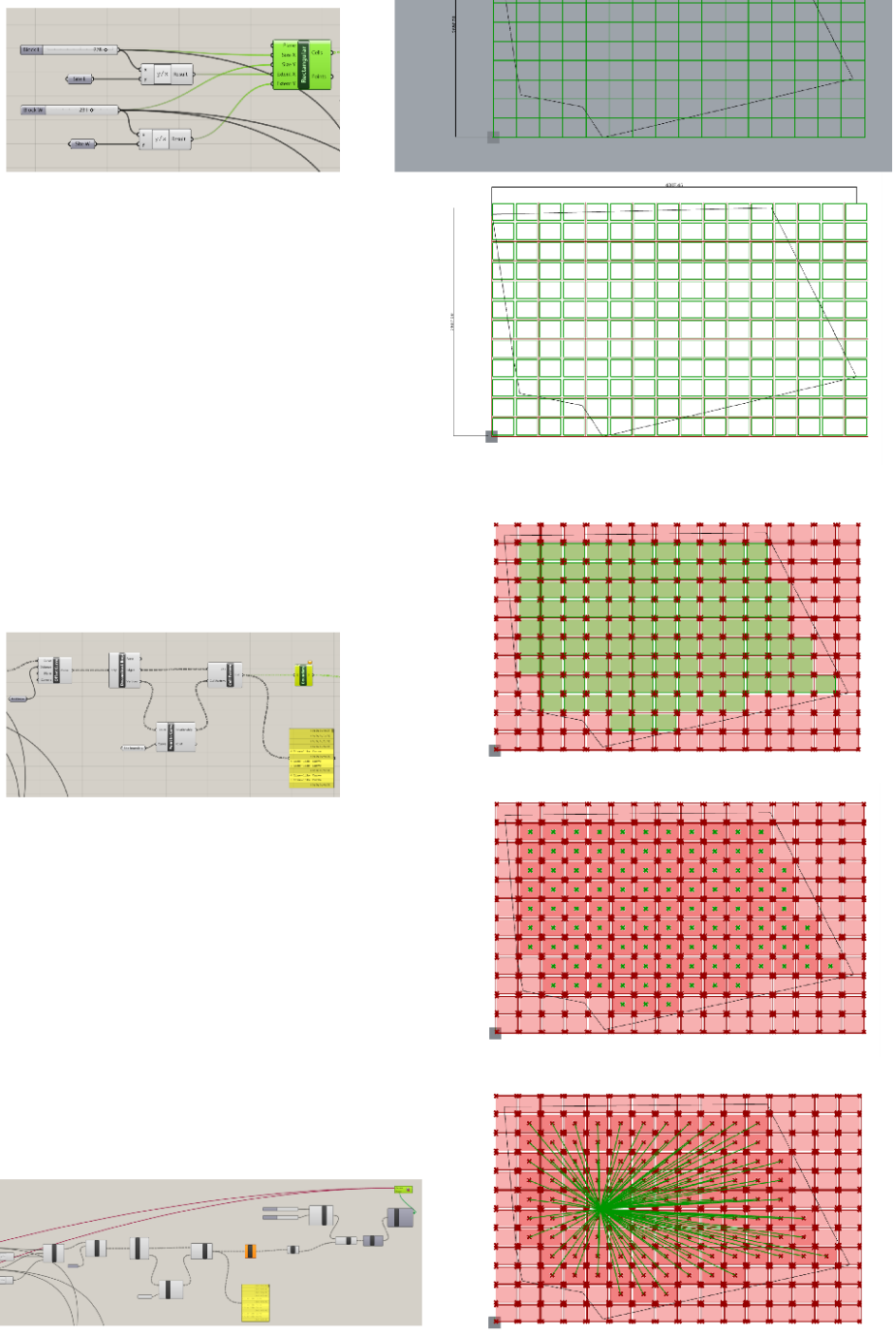


Figure 74 Step-by-step implementation of algorithm framework for optimizing block dimensions

The sum of the lines between the connects block centre, and the community facility centre is optimized using the Galapagos component; the Genome that we aim to optimize is the block width and length, while the value we want to optimize is the mass addition of lines created in the previous step.

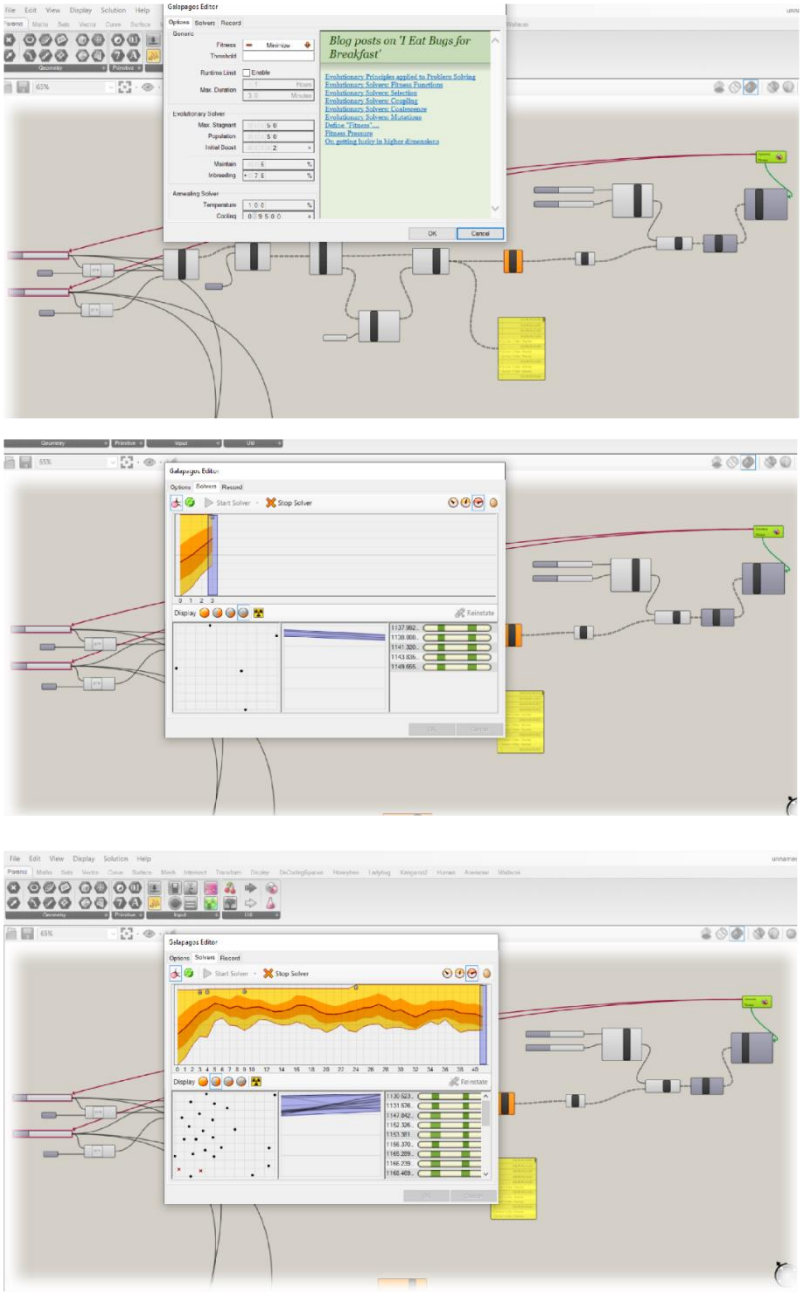


Figure 75 Optimization of refugee camp block dimensions based on the mass sum of line length between the centre point and utilities

The main algorithm can be shown in Figure 76.

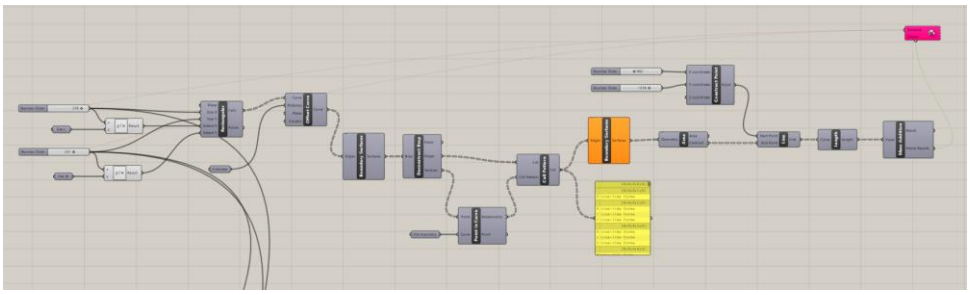


Figure 76 Optimising block dimensions

After optimizing the block dimensions, we divide urban block units into clusters. For this task, we use DeCodingSpace extensions and the Parcel component twice, the first to identify clusters and the second to divide clusters into family parcels or plots. Next, the plot width and length are determined based on the correlation relationship between the optimized building block and plot width and plot length, these parameters are then fed to the system, and the cluster layout is expressed in Figure 77.

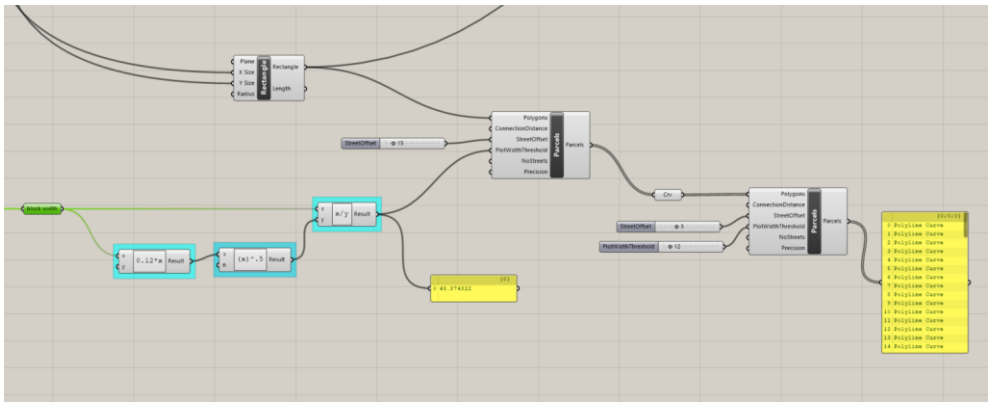


Figure 77 Divide blocks into clusters, and divide clusters into plots

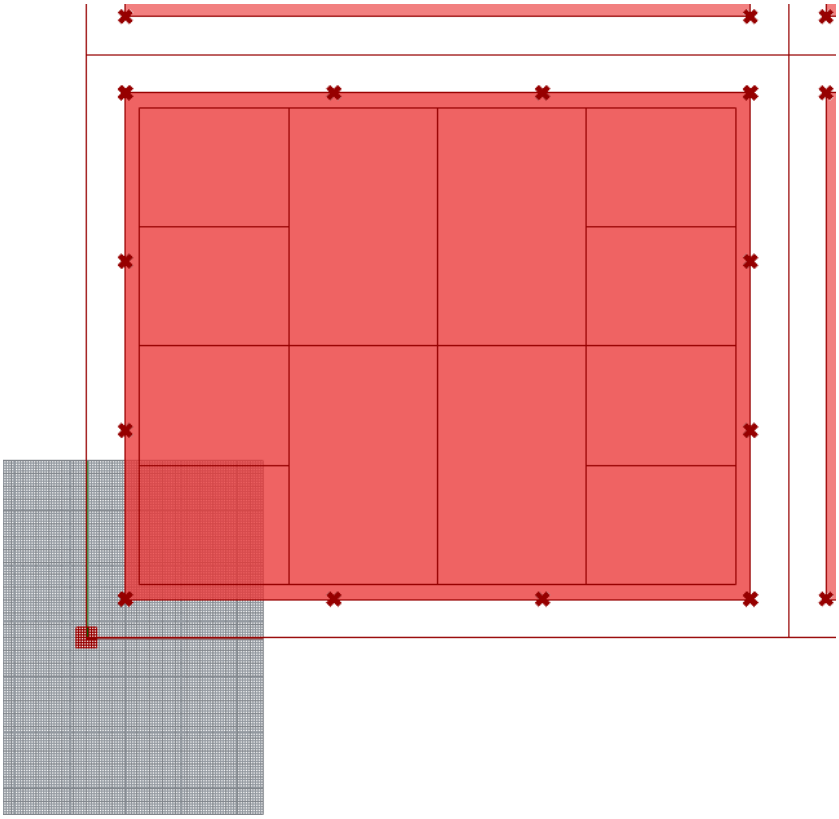


Figure 78 graphical representation of optimised cluster unit

Later the cluster layout can be filled with existing urban forms, community family's arrangement, and space configurations identified by global standards for refugee camp planning and design.

Summary

This chapter examines a refugee camp's Top-Down system modelling framework, which illustrates the workflow of using design parameters identified by numerical standards, ranges and constraints. Moreover, it suggests using new input parameters established using correlation analysis to achieve unpresidential optimisation of system outcomes that are significant to the system.

10 DISCUSSION AND CONCLUSION

10.1 REFUGEE CAMP REVISED

This research explores refugee camp design and suggests new tools and guidelines to make the best design decisions in a given situation. First, the research examines the development of refugee camps' design standards and planning guidelines and tracks their chronological development to understand the roots of standards and guidelines. Later it investigated different sets of standards developed by diverse humanitarian organisations to understand the inherited problems within the standards.

Second, the research analyses existing camps from different geographical locations established at different periods to understand current practices and assess the quality of cases; the research results indicate an inadequate implementation of design standards that can be found in generally 40% of refugee camp cases. Third, the research tested built environment parameters correlation and identified 198 correlations that are significant to the system modelling process. The correlation analysis shows that the urban block is one of the most significant design elements in the refugee camp design outcome since it is correlated with 17 design parameters.

10.2 CODING FOR REFUGEE CAMPS

The research suggests generating designs for routes, urban patterns, and layouts using modular design and a spatial hierarchy of refugee camps. Furthermore, the research proposes an approach to combine numerical case study analysis in addition to numerical refugee camp design standards to identify design parameters and draft parameters' potential relationships and constraints, which enable the use of parametric tools and parametric design methods to help solve the inherited design problems of refugee camps.

As expressed in this research, the focus was mainly on the physical elements of the refugee camps and quantifying the elements in a way to achieve computational relationships and focus on the existing standards but do not suggest developing new urban patterns or regulations. Nevertheless, this

system can be further extended to its fullest potential based on the following premises:

- Rather than using only physical elements to base the design on, additional parameters regarding social and economic, in addition to cost and sustainability, can be further studied and added to the design system.
- Opening the potential for using different urban patterns that can be created in a program or a code base still does not jeopardise the design's time, cost and quality since they are pre-settings of the system.
- The design framework creates a future for codding and programming new tools specific to refugee camps based on the elements and constraints of its design process and standards. It can be a newly established design tool tailored for camp designers and planners in the future.

The resulting design framework consists of grid network formation, allowable block dimensions and optimising street network. While the aforementioned is a conceivable system of general design principles and methodologies, it has not been feasible for this research to suggest specific alterations to particular design codes or to prescribe answers to specific design problems. The system would need to be developed entirely with a particular rule set, adapted to each specific context of geography or professional specialisation before it could be used in future applications. This eventually suggests diversity and divergence of potential ways, just as the most fundamental ideas, like shelter units, have been used (similarly, yet the designer can enter and escape the design process at any stage of the design

The research can be helpful for designers and planners that want to use traditional design methods and elements but incorporate new optimisation and analysis tools since the research focused on modifying inherited design

concepts of defining refugee camps as a system composed of related components rather than a set of selfstanding elements.

10.3 GUIDELINES CAN BE EASILY IMPLEMENTED AND MODIFIED AT ANY STAGE OF THE DESIGN

Generating numerical design guidelines is efficient and can significantly impact the design result. The numerical guidelines of refugee camps can be adapted for different organisations and locations. Moreover, the numerical standards can be developed in the future based on new design demands, paradigms, tools, policies and regulations required to design camps.

10.4 ANALYSIS IS FLEXIBLE

Because there is always a chance to add more analysis told and enhance the design based on the limitation of the design cases, analysis can be adapted based on the different design briefs and requirements, and in the future, give the possibility to adjust additional tools.

10.5 THE GOAL OF SYSTEM MODELLING IS TO OPTIMISE DESIGN RESULTS, NOT TO RECREATE THE SYSTEM

The refugee camp system modelling framework aims to create a simple model for assessment, and the design aims to create the best design regardless of the method used in the given design limitations. Therefore, subsystems and layers of the system can be studied in simplified and separate environments and later combined and optimised to achieve the best results. Moreover, it is always important to keep in mind that the model of the system, regardless of its accuracy, is still not absolute and must not be dealt with as a final result but rather as a design recommendation of the system itself.

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12 APPENDICES

12.1 APPENDIX 01

Pearson correlation analysis:

https://drive.google.com/drive/folders/1FUCGaIRTBsoWo9ETAo0T85Y_lbkiaYpc?usp=share_link