Article

A Human-Centered Shelter Design for People on the Move in the Al-Sahel Region

Hind Al-Shoubaki [1,*], Dimitris Psychogyios [2], Matthias Drilling [1], Yioryos Chatziefthymiou [2], Tatiani Fragkou [2], André Marinho Costa [3] and Aris Tsangrassoulis [2,*]

[1] Institute Social Planning, Organizational Change, and Urban Development ISOS, University of Applied Sciences and Arts of Northwestern Switzerland (FHNW), 4132 Muttenz, Switzerland
[2] Department of Architecture, The University of Thessaly, 38221 Volos, Greece; dps@uth.gr (D.P.); gchatz@uth.gr (Y.C.)
[3] Department of Social Studies, The University of Basel, 4001 Basel, Switzerland; andre.marinhocosta@stud.unibas.ch
[*] Correspondence: hind.alshoubaki@fhnw.ch (H.A.-S.); atsagras@uth.gr (A.T.)

Abstract: This article addresses the development of a human-centered shelter design tailored to meet the specific needs of refugees in the Al-Sahel Region. It focuses on five essential aspects of humanitarian-centered design. The goal is to create a livable unit that accommodates the three distinct phases of an emergency, transitional, and durable situation. We have adopted a non-linear design approach to develop the refugee shelter unit. We engage in discussions with team experts following each data collection phase. The conceptual design of the shelter unit is intended to align with the refugee settlement's natural growth while maintaining a degree of control over its evolution. We have outlined a spatial configuration for a residential unit designed for three to six individuals and various patio options. Additionally, we have devised plans for an education and healthcare facility, all designed with the same structure to bring a more organized approach to the organic growth of the camp. The design proposal adopts a process-oriented approach, incorporating refugees indirectly in the design and construction of their shelters. While we do not assert that the framework of a 'refugee camp' can be sustainable, our goal is to show that its planning, in the absence of alternatives, should adhere to sustainability criteria.

Keywords: refugee camps; human-centered design (HCD); shelter; sustainability

1. Introduction

The Sahel region faces a multitude of complex challenges, including armed conflicts, climate change, food insecurity, and a widespread lack of socioeconomic opportunities. With the population in the region growing and the rising number of forcibly displaced people, these issues are becoming increasingly intricate [1]. Currently, 4.1 million people are affected, including 1.1 million refugees and asylum-seekers, as well as 3.0 million internally displaced people (IDPs). These numbers have grown by over 200% in the last two years and are expected to continue to rise [2].

To mitigate the humanitarian crisis in Al-Sahel, the United Nations High Commissioner for Refugees (UNHCR) follows a protection-oriented emergency response that includes temporary and semi-permanent shelters and the distribution of essential relief items. Despite their temporary nature, these structures often span years. However, the assumption of the camps as temporary structures has been criticized by critical camp studies for their constitutive absence and subversive presence [3]. The camps have been figured as the exceptional [4], the non-place, the extra-national [5], the abnormal, the extra-legal [6,7], un-urban [8], the ghetto, and the gated community [9], and the absolute, pure, impassable biopolitical space [10].

The configuration of refugee camps presents a nuanced and intricate challenge that has undergone substantial development over time. It involves navigation of two distinct scales: the individual unit (shelter) and the entirety of the camp layout. The latter (the refugee camps) are initially conceived as temporary solutions, designed with a top-down approach, emphasizing standardization and efficiency, often resulting in grid-based layouts that prioritize logistical considerations over the needs of residents [11]. However, they have increasingly become long-term settlements, necessitating a shift in design approaches to better accommodate the diverse needs of their inhabitants and acknowledge the sociocultural dynamics and the evolving needs of refugee populations. For instance, the Al-Zaatari camp in Jordan illustrates how refugees adapt standardized layouts to reflect their cultural norms and social structures, leading to organic transformations of space [12]. In the Baqa'a camp, a comprehensive approach to camp design highlights the importance of addressing humanistic needs such as belonging, community integration, and cultural adequacy. This approach promotes urban planning that facilitates the socio-spatial development of camps. In Palestinian refugee camps, incorporating cultural memory into camp design underscores the significance of traditional urban models in shaping street networks and community interactions, thereby preserving cultural identity [13]. The Sahrawi refugee camps near Tindouf, Algeria, exemplify how cultural practices influence camp design. These camps incorporate nomadic spatial practices, which are integral to the Sahrawi people's identity. The design reflects a repertoire of gestures and movements that preserve cultural heritage and resist colonial narratives [14]. The establishment of the Minawao refugee camp in Cameroon in response to the Boko Haram crisis has brought about significant environmental and socio-economic impacts on its surroundings. The camp's presence has resulted in environmental degradation, depletion of resources, and challenges in sustainable management. Although efforts to address these impacts have been set in motion, they are encountering various obstacles [15]. To tackle these issues, the green refugee camp project was launched, focusing on creating a sustainable living environment for refugees and host communities through three main elements: 1. Environmentally sustainable shelters: transitioning to locally produced bricks for shelters to reduce the carbon footprint and provide sustainable housing for refugees. 2. Sustainable cooking alternatives: providing eco-friendly cooking stoves and training on briquette production to eliminate the need for refugees to forage for wood fuel. 3. Protection of the environment through reforestation and education: planting 40,000 trees using innovative technology, resulting in impressive tree survival rates and contributing to environmental protection [16]. Another example can be seen in the layout of refugee camps near the Chad-Sudan border, which incorporates an Emergency Energy Module (EEM) to address the fundamental energy requirements of refugees. This module makes use of a mixture of polycrystalline solar PV panels, micro wind turbines, biogas polyethylene digesters, and diesel generators to tap into local energy sources. Using HOMER software for optimization and techno-economic analysis ensures that the energy system is both effective and sustainable [17].

At the shelter scale, recent research highlights innovative approaches to shelter design, emphasizing sustainability, adaptability, and integration with local contexts. These studies propose various methodologies and technologies to improve the living conditions of refugees while addressing logistical and environmental challenges. For instance, by utilizing biomimicry principles, shelters can be designed to emulate nature's efficiency and resilience. This approach involves using computational tools to apply biological strategies to shelter design, addressing structural integrity and insulation issues. This method not only meets immediate needs but also contributes to climate mitigation by creating environmentally conscious and resource-efficient structures [18]. An emerging technology in the construction industry is 3D printing, which utilizes local materials such as quartz sand and solar energy to provide sustainable solutions for building shelters in challenging environments like deserts. This innovative approach reduces logistics and energy costs and delivers durable and scalable shelter complexes [19].

Furthermore, 3D concrete printing technologies, like contour crafting, have been acknowledged as effective for constructing long-lasting shelters that meet cultural and environmental requirements [20]. In some cases, using energy-efficient materials, such as basalt fiber panels in shelter construction, has shown promising results in maintaining indoor thermal comfort and significantly reducing energy consumption. This approach is particularly practical in regions with extreme temperature variations, ensuring a more comfortable living environment for refugees [21]. Employing incremental design strategies and using vernacular materials with high thermal mass can accommodate extreme weather fluctuations. This method provides flexibility to meet social needs and enhances the sustainability of shelters. From a sociocultural perspective, Designing shelters that respect and integrate the socio-cultural norms of refugees is crucial. Studies have shown that camps often evolve from temporary shelters to permanent homes, necessitating designs that accommodate cultural practices and community integration [22,23]. Herscher [24]; and Dalal [25] provided practical criticism of the UNHCR model when constructing refugee camps, as demonstrated by using calculations that the available planning standards are inadequate and become complicated once refugees start to expand beyond the space given to them at the beginning. A multidimensional approach to shelter design considers humanistic needs such as social adequacy, belonging, and community integration. This approach supports the evolution of shelters from temporary solutions to more permanent, culturally appropriate homes.

1.1. Towards a Human-Centered Planning Approach in Refugee Settlements

Humanitarian urbanism is a concept that delves into the intersection of humanitarian action and urban development. Dense populations and complex socio-economic dynamics characterize the intricate nature of urban settings. This complicates the process of identifying and prioritizing vulnerable populations within these dense contexts, especially during crises [26]. Considering forced migration and camps from such an understanding explains the current challenges formulated by humanitarian urbanism: While the camps function under an increasingly permanent form of humanitarian governance, their structures have not adapted to the needs of those refugees who have lived there for over a few months. Out of the human need for dignified living conditions, the literature showed that refugees inside camps start to organize their own methods of self-governance, thus creating opportunities to maintain their lives and livelihoods within these environments. In the long term, refugee camps worldwide have created a form of city-like settlements, leading to the misconception of current standardized camps as livable urban areas [27]. The recent 'urban turn', as criticized within critical urban studies, highlights how scholarly attention has shifted away from emergency-focused perspectives and humanitarian discourses towards acknowledging a 'normalization of the geography of the camp' [28]. This normalization encompasses the settling of people, their active involvement in economic activities, and the reconstitution of a political community. Fundamental criticism of camps is rarely addressed [29].

According to the authors of [30], it is important to understand that camps do not exist in isolation. Instead, they are part of a larger national, sub-national, and local development context. The refugee camp thus represents one of the purest forms of 'makeshift architecture, last-ditch living, and emergency urbanism' [31] (p. 1). Hujale [32] conceptualize the camp as a city by drawing on three features that he believes define urban life (p. 324): (1) the camp's ability to produce and reproduce spatial symbolism; (2) its ability to generate social stratification; and (3) its ability to allow for the construction and negotiation of both ethnic and non-ethnic identity and the strengthening of particularisms, anti-ethnic behaviors, and inter-ethnic exchanges. Despite this debate, the current humanitarian response to displacement is driven by political factors, which means that 'camps are established with the intention of being demolished. They are meant to have no history and no future' [33] (p. 1), resulting in temporary solutions that do not meet needs.

The idea of humanitarian urbanism starts here, showing through examples how camps can fundamentally be understood as extraterritorial zones but simultaneously offer

options for ensuring a 'low-range quality of life' by processes of negotiations between the international humanitarian authorities, the local governments, the local communities, and the refugee communities. In the town of Gulu in Northern Uganda, for instance, prolonged humanitarian interventions have influenced urban development such that responsibility is shared with local aid organizations, transitioning from a humanitarian role to a more development-oriented role [34]. Similarly, humanitarian urbanism is evident in refugee camps like Kakuma in Kenya. Here, social and spatial interactions between refugees and humanitarian authorities become visible, leading to an urban environment that challenges traditional notions of temporary refugee settlements [35]. The increasing urbanization of humanitarian aid, especially in border areas near Syria, underscores the importance of understanding that camps always represent a spatial transition state, here between urban and rural [36].

Thus, from the perspective of humanitarian urbanism, it is crucial that humanitarian actors, local authorities, urban infrastructure, and community-based networks are incorporated into camp processes to enhance their understanding and response to the complex realities of urban crises. This comprehensive approach, rooted in critical urban theory and practical experiences, can help develop more effective and just humanitarian interventions in humanitarian crises.

1.2. Human-Centered Approach

In this research, we adopt a Human-Centered Design (HCD) approach focused on refugee shelters. This comprehensive method prioritizes displaced populations' needs, preferences, and cultural backgrounds. Our primary goal is to develop living spaces that provide basic shelter and promote the well-being and dignity of refugees. The core principle of HCD in this context is to ensure that shelter design and implementation are flexible, culturally considerate, and sustainable, addressing both the immediate and long-term needs of refugee communities. Detailed insights into the key aspects of HCD in refugee shelter design, drawn from the previous research, are provided in the following subsections.

1.2.1. Flexibility and Adaptability

Refugee shelters must possess flexibility to accommodate varying family sizes and needs. The modular and incremental design allows shelters to be adapted over time, providing a sense of permanence and belonging [37]. Using flexible cluster units in camps can cater to different family dynamics and cultural practices, ensuring that the physical space can evolve with the community's needs [38].

1.2.2. Cultural Sensitivity and Community Involvement

Like those applied in Syrian camps in Jordan, participatory design processes underscore the importance of involving refugees in the design process. This approach ensures that shelters reflect the cultural and social needs of the occupants, fostering a sense of ownership and identity. The integration of local cultural contexts in the design of shelters, as seen in Middle Eastern prototypes, enhances the socio-cultural compatibility of living spaces, making them more acceptable and comfortable for refugees [39].

1.2.3. Sustainability and Environmental Considerations

Sustainable design practices are imperative in refugee shelters to ensure energy efficiency and environmental compatibility. The use of locally available materials and techniques not only reduces costs but also minimizes the environmental impact [40]. Incremental improvement strategies in shelter design can lead to significant energy savings and improved indoor environmental quality, essential for the long-term sustainability of refugee camps.

1.2.4. Addressing Psychological and Social Needs

Refugee shelters should not only provide physical protection but also address the psychological and social needs of the occupants. This includes creating spaces that promote community interaction and support mental health [41]. The design of shelters should consider the humanistic needs of refugees, such as social and cultural adequacy, belonging, and community integration, to improve their overall quality of life.

1.2.5. Compliance with International Standards

Designing shelters that meet international eligibility standards is essential for ensuring the safety and well-being of refugees. This involves a comprehensive understanding of both architectural and non-architectural aspects, such as basic needs and evacuation activities [42].

While we do not claim that a 'refugee camp' can be inherently sustainable, we stress the importance of incorporating sustainability criteria into its planning, especially when better alternatives are unavailable. We aim to highlight the significance of thoughtful planning and design in creating refugee camps that can effectively support development. In essence, we advocate for a human-centered approach that places the needs of refugees at the forefront.

2. Methods and Materials

Human-centered design, coined by Irish engineer Mike Cooley in his 1987 publication "Human-Centred Systems," is an approach that focuses on identifying people's needs and solving the right problem with simple interventions [43]. This creative approach to problem-solving is tailored around the extensively researched needs of the end user. Designers heavily rely on data to establish a foundation for their design strategy, conducting thorough research and using the data to inform their design approach. This data is gathered from multiple sources and scales, providing insights that guide design decisions. Methods such as participatory data analysis and co-design workshops are utilized to integrate this data into the design process [44]. By embracing architectural design with this mindset, a more holistic approach can be ensured, resulting in a deeper understanding of the user's experience from the outset and allowing human behavior to significantly impact the design process [45].

As a result, we have embraced a non-linear design approach to meticulously develop the refugee shelter unit, ensuring that the design is adaptable to the specific needs of the refugee community. We engage in ongoing discussions with team experts following each data collection phase, focusing on the five key aspects of Human-Centered Design (HCD). Please refer to Figure 1 for further details.
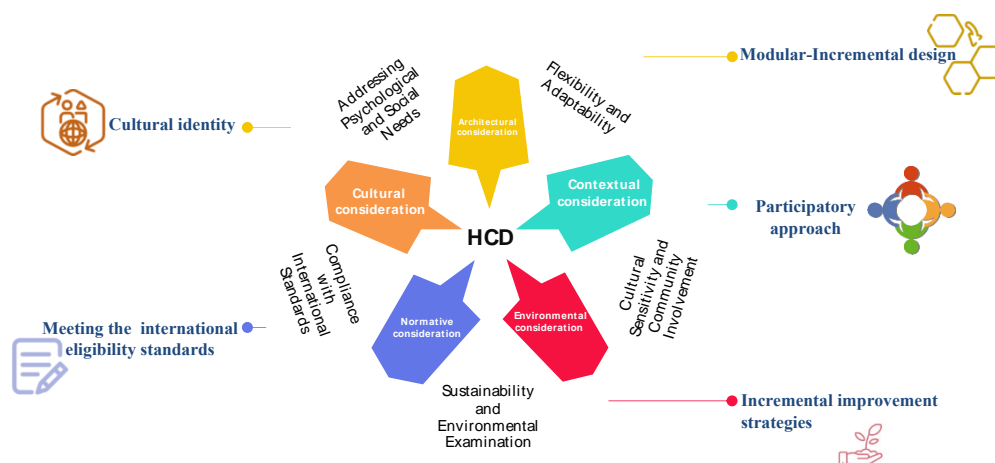

**Figure 1.** Key aspects of HCD. By the authors, 2024.

2.1. Prototyping a Sustainable Shelter: Influencing Variables

To better understand the Al-Sahel region, it is essential to analyze the climate conditions and natural resources in the area, as well as how the local residents use them. People seek shelter in the camps for various reasons, and the migratory patterns of the region's population impact the growth of the camps and the traditional practices of the residents, including their cultural beliefs and customs.

2.1.1. Migration Flows

Migration patterns in the Al-Sahel region have primarily emerged due to conflicts and natural disasters that have compelled the Sahelians to relocate to safer areas. These movements have profoundly impacted the region's economic, social, and cultural fabric and have presented significant challenges for policymakers, researchers, and humanitarian actors. The causes of these migrations are multifaceted and have often been exacerbated by a range of factors, including climate change, political instability, and economic stressors.

In 2022, the central Sahel faced a troubling increase in forced displacement, resulting in over 2.9 million refugees and internally displaced persons scattered throughout Burkina Faso, Mali, and Niger. Additionally, a concerning pattern arose with Burkinabe citizens seeking asylum in both southern and northern regions, including North Africa and Europe. The violence and conflict even spread to coastal nations such as Benin, Cote d'Ivoire, Ghana, and Togo, bringing thousands of new individuals [46]. The deteriorating security situation has resulted in reduced humanitarian access throughout the region. Local communities and national authorities, who already had limited resources, further stretched, causing more Sahelians to join mixed movements towards coastal countries, North Africa, and Europe. Burkina Faso had two coups in 2022, and the number of internally displaced persons (IDPs) reached almost 1.9 million, representing a 300,000 increase. In parallel, non-state armed groups (NSAGs) imposed a blockade on urban centers by severing roads and supply lines, resulting in the displacement of rural inhabitants across international borders. In 2022, the number of people who fled Burkina Faso reached 22,000, seeking refuge in neighboring countries such as Benin, Côte d'Ivoire, Ghana, and Togo (see Figure 2).
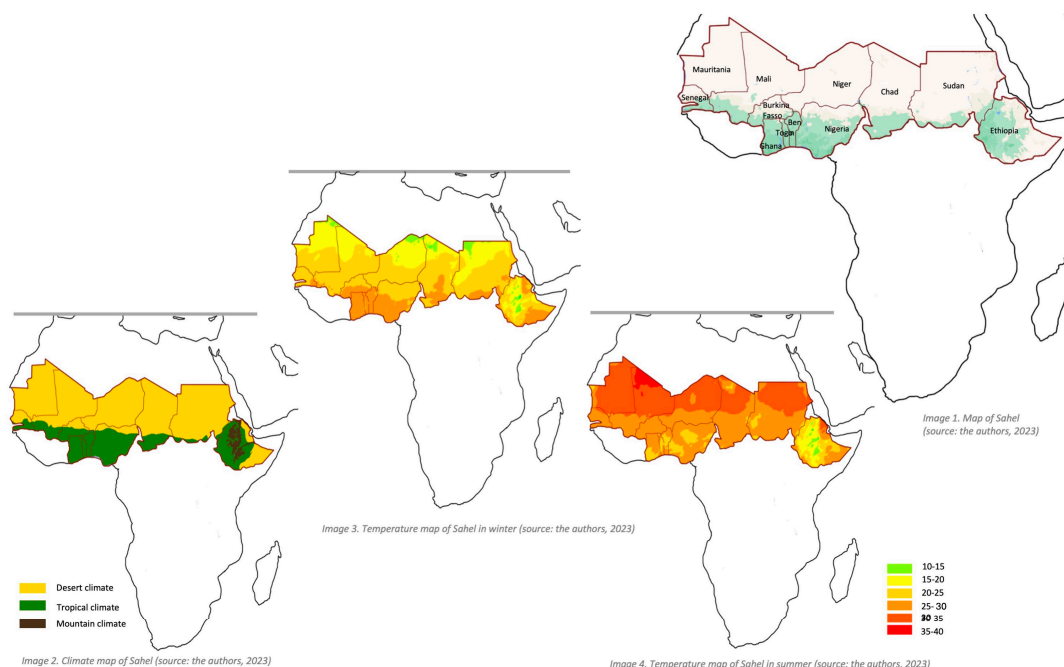

Source: UNHCR, Governments, IOM, UNCS
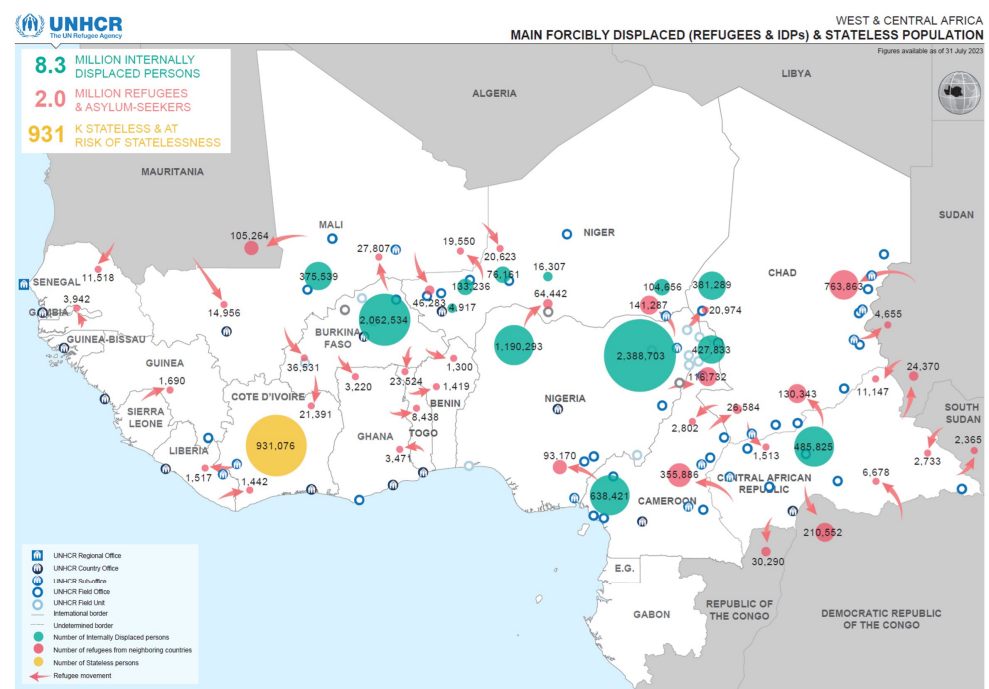
Figure 2. Migration flows in Al-Sahel region. By the authors from UNHCR, 2022.

Additionally, 50,800 people sought asylum in Mali and Niger, with women and children comprising the majority of refugees. Over 700 officials and community members in Burkina Faso, Chad, Mali, and Niger were trained on referral mechanisms for mixed movements. Over 32,000 people were identified on the move, and over 2500 were referred to protection services.

2.1.2. Local Climate

The Sahel, a transitional region between the Sahara Desert and the savannas of West Africa, is known for its tropical semi-arid climate that varies considerably across the region. The climate is characterized by high temperatures, ranging from 30 to 45 °C, and low humidity levels, which, together with abundant sunshine, create a hot and dry environment for most of the year (see Figure 3). The annual precipitation is low and erratic, usually between 200 and 600 mm, and falls mainly during the wet season, which lasts from June to September. The Sahel's precipitation is often in the form of heavy, brief thunderstorms. The region also experiences moderate to strong Harmattan winds, which blow from the Sahara Desert and contribute to the dryness of the air. The Sahel's climate resembles the Sahara Desert, but the conditions are not as extreme [47].

Adapting shelter materiality and design to conform to the tropical semi-arid climate of the Al-Sahel region is a critical consideration in addressing local climatic conditions. The Sahel region is characterized by high temperatures, low rainfall, and frequent dust storms, which pose significant challenges to the design and construction of shelters. In this regard, employing appropriate materiality and design practices tailored to the region's specific climatic conditions is essential. Such practices may include using locally sourced and sustainable materials, incorporating passive cooling and ventilation strategies, and integrating appropriate shading and insulation systems. By adopting these measures, it is possible to create shelters that are not only resilient to the harsh climatic conditions of the Sahel region but also contribute to the sustainable development of local communities.

Image 1. Map of Sahel (source: the authors, 2023)

Image 3. Temperature map of Sahel in winter (source: the authors, 2023)

Desert climate
Tropical climate
Mountain climate

Image 2. Climate map of Sahel (source: the authors, 2023)

10-15
15-20
20-25
25-30
30-35
35-40

Image 4. Temperature map of Sahel in summer (source: the authors, 2023)

Figure 3. Climate Analysis for Al-Sahel. By the authors, 2023 from Nicholson, S. E. (2018).

2.1.3. Local Neighborhood Typologies

We analyzed the traditional neighborhood typologies in two selected locations: Bomo and Maradi's traditional settlement patterns and residential compounds in Nigeria. The analysis focused on both neighborhoods' structural and functional features, including

their planning, layout, and design. Through a thorough analysis of the community's social structure, we aim to identify the factors that have contributed to the evolution of these planning typologies. Through this approach, we aim to acquire crucial insights that can facilitate the creation of sustainable and culturally relevant housing solutions. In the subsequent section, we will explore the influence of local architectural practices on social cohesion within the context of Bomo.

The climate in Bomo presents a significant challenge for housing design, given its composite nature. The demands of the hot and humid Damina and the hot and dry Bazara are at odds with the requirements of the cold and dry Hunturu and those of Bazara [48]. Therefore, achieving year-round comfort in a building without relying on mechanical aids can be challenging. Housing design needs to consider the specific climatic conditions of each location to ensure that the building is comfortable throughout the year.

To achieve optimal comfort, a careful balance of factors is required, including passive design techniques, insulation, and materials suitable for the local environment. Traditional compounds often fail to take full advantage of their varying thermal properties, resulting in discomfort. For example, mud rooms with domed roofs and small windows are used year-round despite being best suited for cold nights and hot afternoons. Similarly, sheds made of posts and thatch, which are comfortable during hot and humid periods, are frequently designated for animals or utilized as cooking areas. Meanwhile, the corrugated iron roof with a hard-board ceiling and relatively large window is considered a status symbol and serves as the main dwelling for the household head throughout the year [49].

The analysis of Bomo reveals several areas of climate adaptation, along with a strong preference for traditional and cultural practices influencing anticlimactic solutions. Key observations include:

(a)   Buildings are typically oriented North–South with south-facing windows to meet climatic requirements. However, windows are scarce.

(b)   Shade is of paramount importance to the inhabitants of a given locality, as it significantly enhances their thermal comfort. In this regard, it is common practice to plant leafy trees in the courtyards of most compounds and in open spaces designated for communal gatherings, such as the Dandali.

(c)   The utilization of a courtyard serves a dual purpose: to provide privacy to residents while also serving as an effective thermal comfort solution. The courtyard's effectiveness in regulating the temperature within the living space is attributed to its ability to protect the interior from external environmental factors. It provides a natural source of ventilation, enabling air circulation throughout the space and maintaining a comfortable living environment by keeping the interior cool in hot weather and warm in cooler weather. Thus, using a courtyard preserves privacy and contributes to a sustainable and comfortable living environment (see Figures 4 and 5).

(d)   Traditional architecture often featured small, high-level window slits that measured approximately 25 cm × 40 cm. These apertures were primarily intended to provide illumination rather than ventilation. Conversely, modern vernacular architecture generally incorporates windows; however, they may remain closed as a symbolic gesture.

(e)   Historic structures frequently incorporate thick walls, which offer insulation and protection during the Kaka and Hunturu seasons; however, such walls can create negative consequences in hot and humid weather.

(f)   Ceilings are often installed for decorative purposes rather than thermal comfort. However, it is common knowledge among builders and homeowners that ceilings made of corrugated iron roofing materials can improve the indoor climate and provide better thermal insulation.
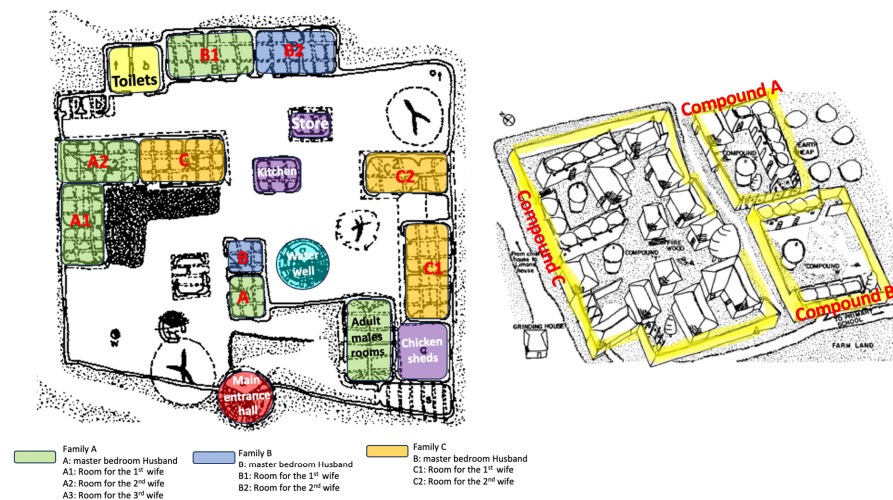
Figure 4. Residential Compound details in Bomo. By the authors, 2023.

Our in-depth analysis of neighborhood urban planning typologies that have emerged in Sahelian communities has yielded valuable insights into how these practices can be adapted and applied to design a humanitarian habitat that aligns with the local building culture and social features. The analysis of Sahelian urban planning typologies revealed that using locally available building materials, such as mud bricks, and incorporating passive cooling principles, such as courtyards and wind towers, are central to the success of traditional Sahelian architecture. It is essential to incorporate these features into the design of a humanitarian habitat that meets the needs of the local population.

Furthermore, the utilization of communal spaces, such as courtyards, and the inclusion of green areas and facilities for social engagement can cultivate a sense of community and bolster social harmony. To create a sustainable and culturally relevant living environment, it is essential to carefully consider the unique requirements of Sahelian communities.
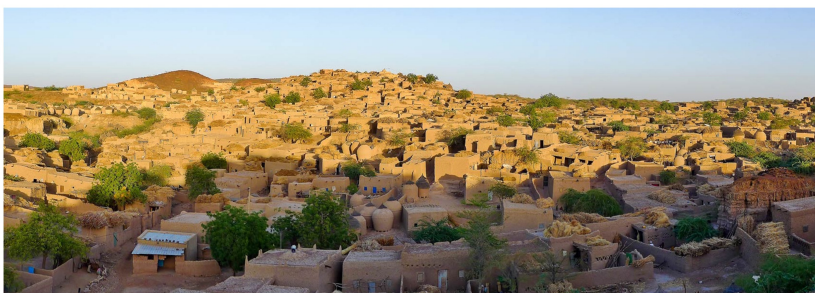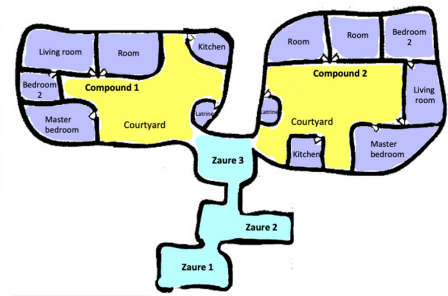
Figure 5. Vernacular architecture in Hausa. Edited by the authors, 2023.

2.1.4. Local Housing Typologies

Climate consideration is a crucial aspect of traditional architecture worldwide. As per [50], traditional builders cannot overlook climate in their designs due to the lack of technology. Traditional builders in Northern Nigeria exhibit their expertise in materials by erecting structures capable of withstanding rain and winds. The direction of winds and rain may sometimes influence the orientation of these buildings, while window openings and sizes are appropriate for wind direction. Sa'ad [51] discussed categorizing the traditional household into three distinct areas: the private inner core, the semi-private central core, and the public outer core (see Figure 5). The inner core, also called the women's area, encompasses the ward, guest/servant quarters, and a backyard designated for animal husbandry and waste disposal. Conventional architecture often includes a spacious dwelling that can house a man and his up to four wives, along with their offspring. Typically, this housing unit is situated within a grand walled city that boasts a towering, multi-story building with a gate [52]. These architectural principles can be traced back to Egyptian domestic architecture from around 500 CE and have influenced Hausa villages and towns' morphology and housing arrangements [53].

The courtyard, predominantly located in the central core, serves as a space for household and social activities and is an indispensable source of ventilation and natural light.

The Hausa architectural style is renowned for its distinct separation between exterior and interior spaces. The influence of Islamic culture is notable in the concept of "Purdah," which emphasizes the social and religious practice of female seclusion. As a result, the design of living spaces is divided into two areas: the Haremlik, which is accessible to women, and the Selemlik, which is not. The courtyard functions as the central hub for household and social activities, whereas the kitchen and dining areas are usually situated in separate spaces. The kitchens are typically located away from the main living areas, and dining areas may be found either individually or collectively in a parlor or open area [54]. To maintain privacy, hygiene, and other fundamental aspects, the restrooms or toilets are placed at the end of the compound, away from the living quarters. Throughout Nigeria's diverse geographical zones, traditional buildings have evolved to respond comprehensively to the climate, local technology, and socio-economic environment in which they were created. The roots of these varied building styles can be traced back to the natural materials available to local builders, as well as religious beliefs, cultural practices, and taboos. The majority of dwellings in Northern Nigeria today are what may be called "vernacular architecture" rather than "traditional architecture" since quite a number of modern elements have been incorporated into their design and construction (see Figure 6). These include corrugated iron roofs, asbestos or concrete ceilings, windows with glazed, wooden or metal sheet shutters, cement-screed floors, plastered and white-washed walls, and so on.
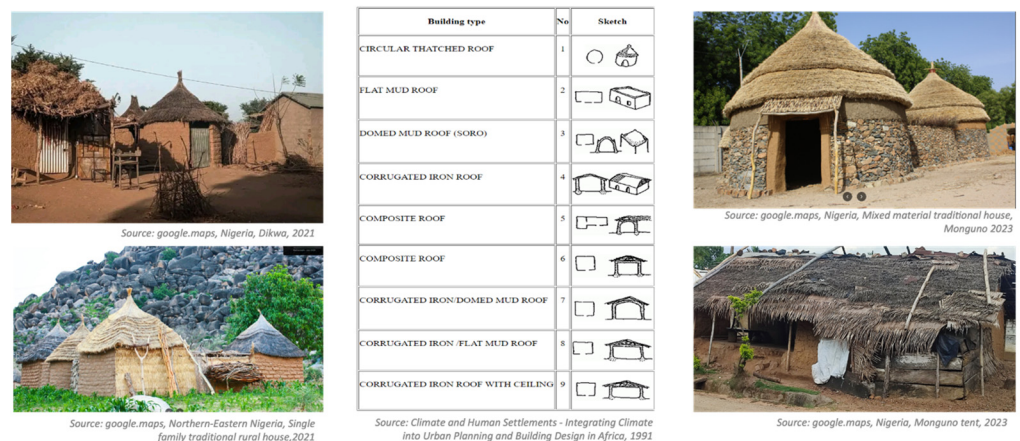

Figure 6. The vernacular architecture of Al-Sahel. By the authors, 2023.

2.1.5. Local Construction Methods and Materials

After evaluating various construction methods and materials available in the local area (see Table 1), we have determined that a combination of prefabricated materials and adobe bricks would be the most optimal solution. This approach offers several advantages over other construction methods, such as prefabricated materials. They can be manufactured quickly, which allows for faster implementation and reduced labor costs.

Additionally, they can be designed to meet specific requirements, ensuring high quality and consistency in the final product. Combining prefabricated materials with adobe bricks offers further benefits. Adobe bricks are made of natural materials and are highly durable, making them an excellent choice for building structures that need to withstand harsh weather conditions. They are also energy efficient, which can help to reduce the overall environmental impact.

Moreover, this approach allows for a smooth transition from temporary to permanent structures. The prefabricated materials can be used to construct temporary structures, which can later be replaced with adobe bricks as the project progresses. This saves time and money and ensures that the structures are built to last and conform to the Sahelians' local building culture.

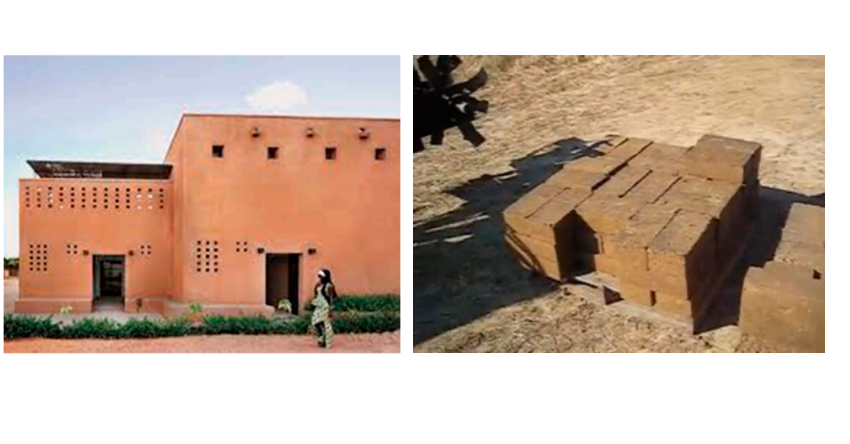**Table 1.** Construction material analysis. Source: the authors, 2023.

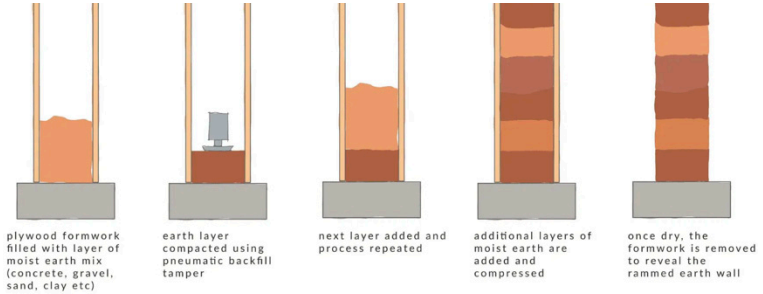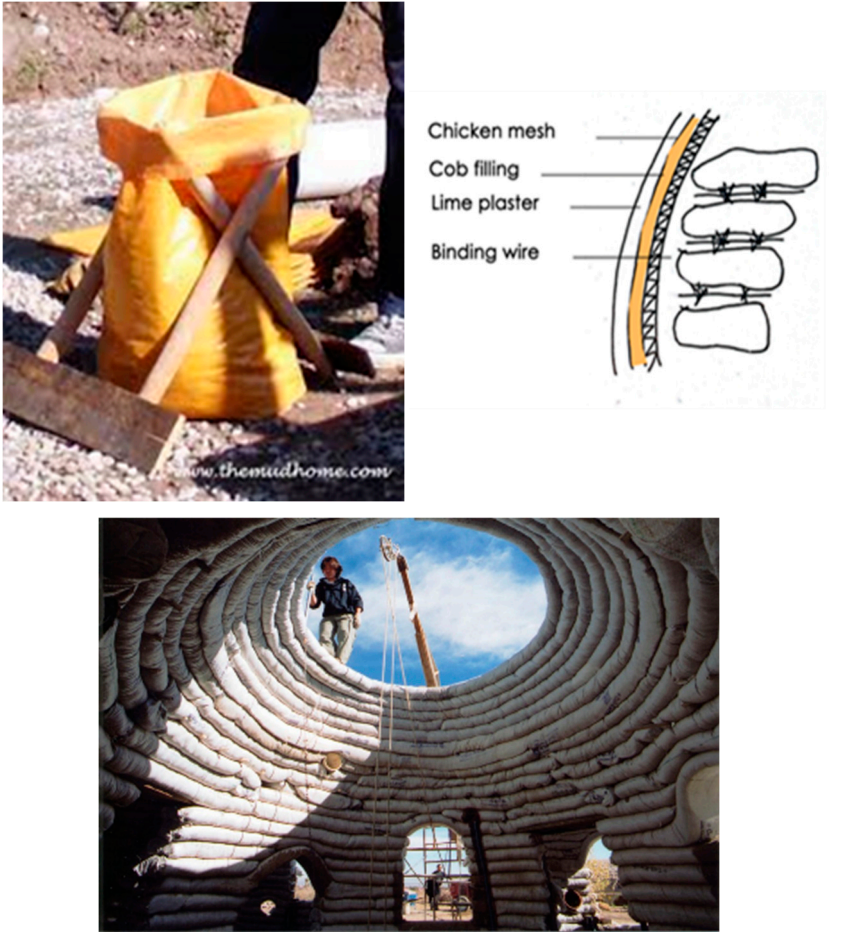| Material Name	Description	Pros.	Cons	Examples
Adobe (Sun-Dried Mud Bricks)	A traditional building material made by mixing earth, sand, straw, or other organic materials, and water. The mixture is placed in molds and compressed; the bricks are then left to dry in the sun.	-Locally available soil. -Cost-effective. -Good thermal properties providing insulation against the region's hot daytime. -Temperatures and cool nights. -Durable when properly maintained.	-Susceptible to erosion and water damage. -Regular maintenance and reapplication of mud plaster. -Not withstand strong earthquakes. -The drying process can take time.	
CEB (Compressed Earth Block)	Manufactured with a mechanical press, these blocks are denser and more uniform than adobe bricks. Unlike traditional adobe, Compressed Earth Blocks (CEBs) have superior resistance to erosion and water damage.	-Ensuring the longevity of materials available in the local area. -The thermal mass aids in regulating indoor temperatures, resulting in reduced heating and cooling expenses. -The material exhibits good thermal properties, providing insulation against the hot daytime temperatures and cool nights prevalent in the region. -Creates durable buildings with a prolonged lifespan, capable of withstanding severe weather conditions. -Aesthetically appealing.	-Susceptible to moisture -Limited Structural Strength -To enhance the stability of Compressed Earth Blocks. (CEBs), it might be necessary to include stabilizers such as cement. -Buildings may need maintained more often as compared to structures made of other construction materials.	

| Material Name	Description	Pros.	Cons	Examples
Rammed Earth	The method consists compacting earth (soil, clay, gravel along with small amounts of cement and water) into wooden molds. It requires specialized techniques and equipment.	-Excellent thermal mass properties, regulating indoor temperatures. -Durable. -Fire-resistant. -Unique aesthetic.	-Wood is needed for the molds. -Require specialized equipment. -The quality of the soil mix and proper stabilization are critical for durability.	
Laterite Bricks	It is made from a natural sedimentary rock called laterite. These bricks are commonly used in tropical and subtropical regions, including parts of Nigeria, due to their availability and suitability for construction. Laterite bricks have unique properties that make them suitable for specific applications.	-Locally Sourced: This can reduce transportation costs, and the environmental impact associated with the procurement of construction materials. -Natural Insulation: Good thermal properties, this can help maintain comfortable indoor temperatures in hot climates. -Durability: They can withstand weathering, particularly in regions with a tropical climate. -Low Carbon Footprint: High-temperature furnaces are not required, such as for the manufacture of fired bricks. -Fire Resistance: The dense earth-filled bags offer thermal mass, regulating indoor temperatures.	-Low structural strength compared to concrete or fired clay bricks -Inconsistent Quality: the quality of laterite bricks can vary significantly depending on the specific composition of the manufacturing process. -Maintenance Requirements -Construction might be limited during rainy seasons due to soil moisture. -Aesthetics: walls may not suit everyone's aesthetic preferences.	

Table 1. *Cont.*

Material Name	Description	Pros.	Cons	Examples
Earthbag Construction	They are special bags which are made of local soil and are placed horizontally on top of each other up to the structure. It is a very easy and quick construction process.	-Low Cost: inexpensive and use minimal additional materials. Soil is abundant and often free. -Sustainability: it minimizes the use of non-renewable resources and reduces waste. -Ease of Construction: simple to fill and stack, making them suitable for unskilled labor and community involvement -Resilience: earthbag walls can be resistant to weather, fire, and pests when properly finished and maintained. -Thermal Mass: the dense earth-filled bags offer thermal mass, regulating indoor temperatures. -Adaptability: Earthbag construction can be adapted to various shapes and sizes.	-Stabilization: depending on the soil type, stabilizers like cement may be needed to ensure durability. -Require engineering expertise to ensure stability for large structures. -Weather Dependency: construction might be limited during rainy seasons due to soil moisture. -Aesthetics: walls may not suit everyone's aesthetic preferences.	

2.1.6. Existing Shelter Types and Projects by UNHCR

We have examined various shelter designs that fall into three categories: emergency shelters, designed for immediate response to natural disasters or other crises; transitional shelters, intended for use in intermediate stages of recovery and reconstruction; and durable shelters, built to withstand long-term use and provide sustainable housing solutions.

UNHCR emergency shelters are specifically designed for immediate and short-term use following a crisis or displacement. These shelters are quickly deployable and are intended to offer basic protection and comfort to refugees or internally displaced persons (IDPs) during the initial phases of a humanitarian emergency [55]. The initial shelter solutions typically consist of tents or simple structures that can be rapidly set up to provide immediate protection. They are designed to be temporary, with the expectation of being removed or replaced as the situation stabilizes. (see Figure 7).
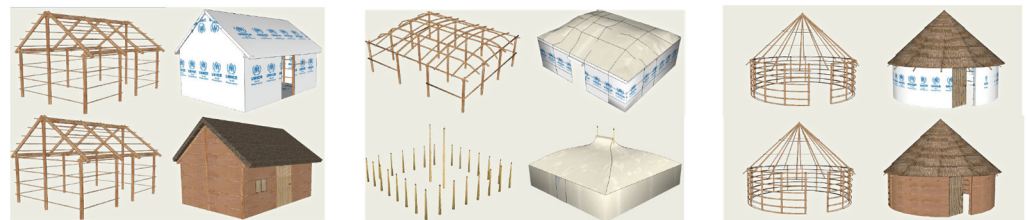

Figure 7. Types of emergency shelters. Source: [55].

Transitional shelters offer better living conditions than emergency shelters, providing a more comfortable and stable environment for displaced individuals and families. These shelters give displaced populations a sense of stability and security. They are more durable and comfortable than emergency shelters, often made of sturdier materials and better insulation, providing better protection against extreme weather conditions. Transitional shelters often provide better thermal regulation and air quality compared to emergency shelters, which are typically designed for rapid deployment rather than long-term habitation. Poor thermal regulation and air quality in emergency shelters can lead to health issues, making transitional shelters a healthier option for displaced populations [56]. These shelters can facilitate the organization of displaced communities, helping them establish social structures and access essential services more effectively (see Figure 8).

Figure 8. Types of transitional shelters. Source: [55].

Durable shelters are intended for long-term habitation, offering a stable and secure housing solution for displaced populations. They provide better living conditions, including improved sanitation, access to clean water, and more space for families, contributing to an enhanced quality of life [57]. Durable shelters support self-reliance by creating a stable environment for refugees and IDPs to rebuild their lives, pursue education, and engage in income-generating activities. In some cases, durable shelters may be integrated into host communities, fostering social cohesion and reducing the burden on host countries' infrastructure (see Figure 9).
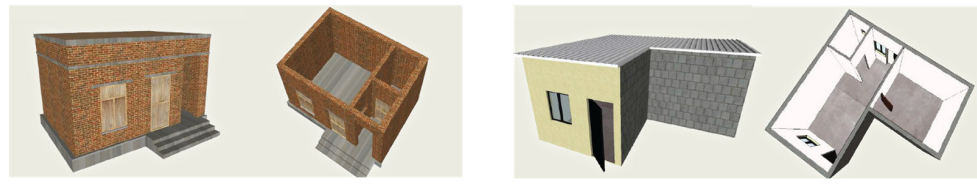
Figure 9. Types of durable shelters. Source: [55].

3. Results

Prototyping a Shelter in the Framework of Cultural and Climate Sustainability

According to the analysis above and the five key aspects of HOD defined in Section 1.2, the challenge is to create a habitable unit that can accommodate the three distinct phases of an emergency, transitional, and durable situation. This requires careful consideration of each phase's technical and logistical needs and the unique challenges that may arise during each period. During the emergency phase, the unit must be able to provide immediate shelter and essential resources to those in need. This requires a focus on rapid deployment and a design that can accommodate a variety of unforeseen situations [58]. The unit must be easy to assemble and disassemble, transportable, and able to withstand severe weather conditions. In the transitional phase, the focus shifts to creating a more permanent residence for the displaced individuals. At this stage, the unit must adapt to the community's changing needs and provide a comfortable living space that can accommodate the needs of households, neighborhoods, and settlements. This requires a design that can accommodate various living arrangements, such as individual homes, apartments, or communal living spaces. During the durable phase, the unit must provide a sustainable and functional living space supporting the community's long-term needs. This requires utilizing sustainable materials and energy-efficient technology and creating necessary infrastructure such as schools, hospitals, and community centers. Creating such a unit requires a deep understanding of the technical details involved in each phase and the ability to adapt to changing circumstances and requirements. By carefully considering these factors, we can design a habitable unit that can effectively fulfill the needs of communities during times of crisis and beyond.

The preliminary design of our prototype commenced with the architectural form commonly found in the Sahelian region. Specifically, the traditional Igbo houses, characterized by circular mud walls (ulo aja oto) and thatched roofs (aju or atani), provided the initial inspiration for the sketches (see Figure 10).
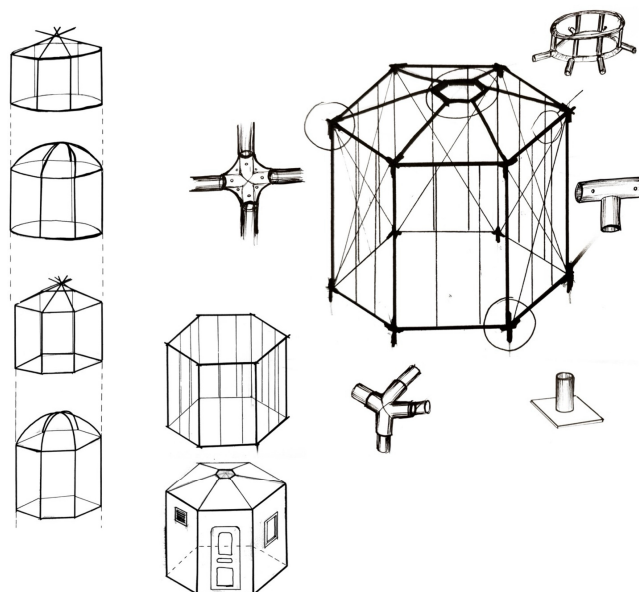

Figure 10. The preliminary sketches of the shelter design. The authors, 2023.

The transformation of the Igbo circular walls to the hexagonal form results from applying the five key aspects of the HOD, mainly flexibility and adaptability. Our approach aims to use flexible cluster units that cater to different family dynamics and cultural practices, ensuring that the physical space can evolve with the community's needs. The organic growth of this proposed shelter mirrors Christopher Alexander's vision of a living architecture that emerges naturally rather than being imposed by rigid planning frameworks [59]. This process allows for a more flexible and responsive urban environment that can adapt to changing circumstances.

Thus, the shelter prototype units are designed with a hexagonal shape, which offers a high degree of adaptability for campsite arrangements, circumventing the need for a standardized approach. This design presents a unique opportunity for customization and flexibility in placement and orientation. Following the sketches phase, the work was directed toward the architectural drawings, including the top view, the plan, the main elevation (see Figure 11), and the 3D rendering (see Figure 12). These drawings aimed to provide a comprehensive visualization of the proposed design and layout.
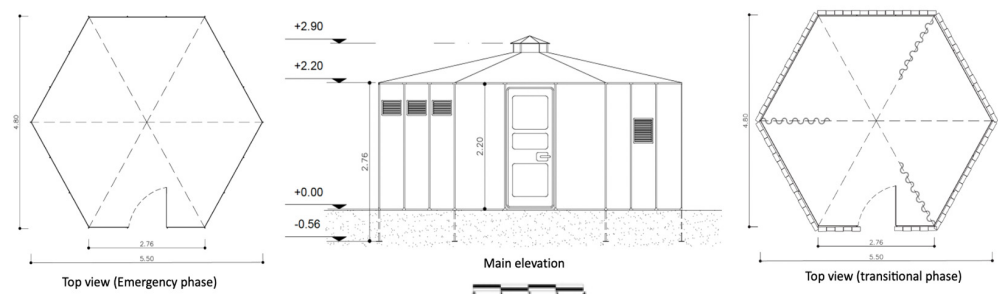

Figure 11. Architectural drawings. Source: The authors, 2023.

Figure 12. The shelter's exterior and interior shots. The authors, 2023.

The shelter design is highly flexible, allowing for the combination of multiple units to cater to the specific functional needs of the building. This means that if the initial shelter is insufficient, multiple units can be seamlessly combined horizontally to create a larger living space. At the same time, for better possible flexibility and the ability to adapt to environmental conditions, the unit-scale design has foreseen the change of the openings by dividing the masonry into three parts. In other words, the panels of the infill walls snap together (three equal parts) to create openings according to condition (avoiding one size fits all). Therefore, this design also implicitly affects the larger scale as there are numerous possibilities for configuring the space between shelters to form a communal patio, providing a comfortable and relaxing outdoor area for residents to enjoy (see Figure 13). This approach to architecture reflects the Sahelian customs of constructing and safeguarding individual privacy while simultaneously offering a leisure area within their residential compounds. Overall, the design is highly adaptable and can be tailored to meet each community's unique needs and preferences.
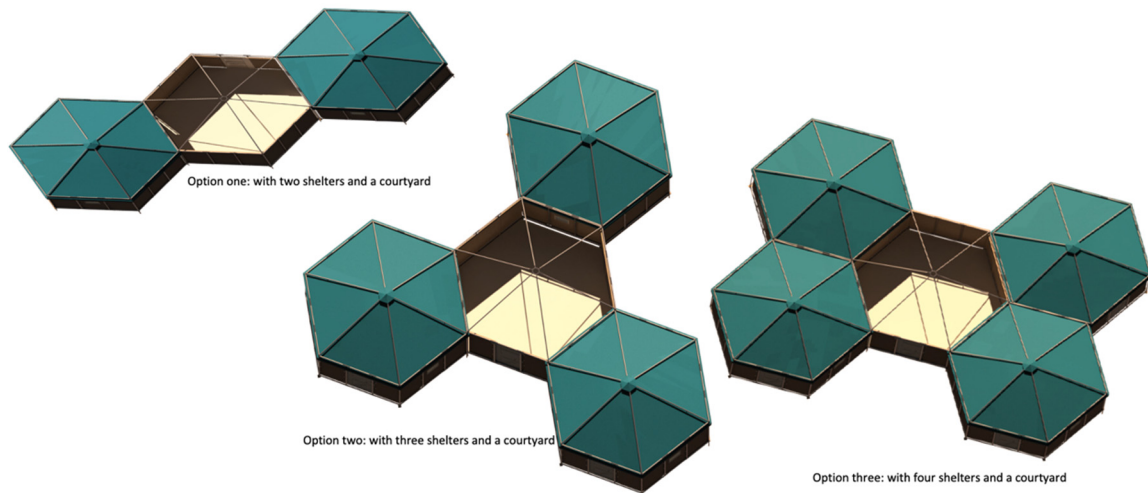
Figure 13. The potential of the shelter unit in creating different housing typologies. The authors, 2023.

Collaborating with the appropriate organization makes it feasible to vertically expand the structure by incorporating locally sourced materials. This method permits the construction of two-story units in public buildings and provides a solution to the issue of camp sprawl's rapid expansion. Although it may pose some challenges, this approach effectively achieves successful densification and ensures sustainable growth.

The above-mentioned standpoint accentuates the importance of procuring diverse materials and local know-how and emphasizing a philosophical participatory process grounded in cultural values. Indeed, to gather expertise and knowledge, it becomes imperative to delve deeper into the cultural ethos of the region. By fostering a participatory process, we can assimilate and benefit from the collective knowledge and experience of the community, which in turn leads to a more comprehensive and insightful understanding of the local environment. This approach fosters community development by facilitating job creation and economic growth while also nurturing small-scale enterprises. Its participatory nature acknowledges and respects the diversity and dignity of local residents. Additionally, it is designed to provide gender and age-friendly humanitarian habitats. This approach supports the local economy and promotes inclusivity and social equity in the community.

The shelter would follow transitional construction phases that initially deliver an easy-assembly and deployable solution with pre-fabricated components and a toolbox considering the possible urgency of building a shelter but are also devised for the long-haul by cladding the pre-fabricated primary structure with the use of local materials and vernacular techniques so to reinforce the shelter into a more permanent one while offering the possibility for residents to partake in the process and engage with their own home customization.

The shelter was designed to withstand the climate conditions of the Al-Sahel region. For this reason, a bioclimatic design analysis was conducted to investigate the thermal comfort conditions of a shelter under local conditions. The analysis demonstrated the effectiveness of the used materials in the transitional phase.

Consideration was given to construction materials and natural ventilation in order to assess environmental conditions and enhance thermal comfort. The latter is crucial in lowering temperatures (refer to Figure 14). Accordingly, the shelter's design is primarily focused on the existing conditions, acknowledging the need to address immediate requirements (emergency shelter) while also progressively mitigating high temperatures (transitional move towards a sustainable shelter).
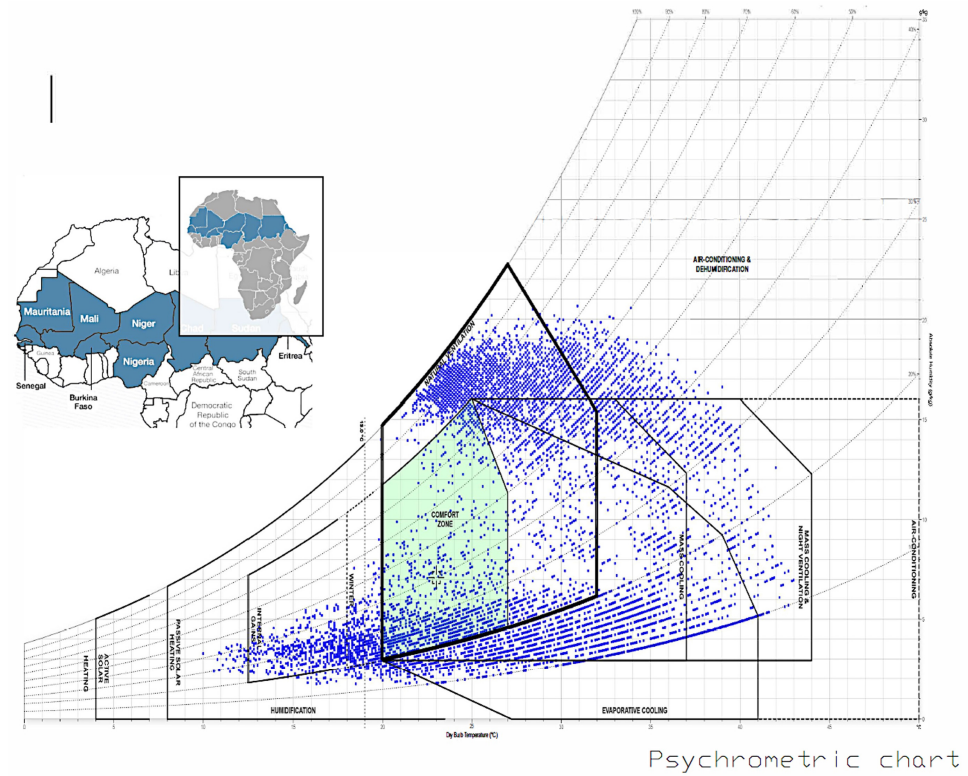
Figure 14. The bioclimatic analysis for the shelter unit. The authors, 2023.

The use of brick was found to enhance the shelter's thermal performance, while natural ventilation was identified as a dominant variable for dealing with heat in the absence of artificial means (see Figure 15). The design of the façade openings and roof was identified as an integral solution for improving thermal comfort. The analysis confirmed the shelter's sustainability and resiliency to adverse external environmental conditions.
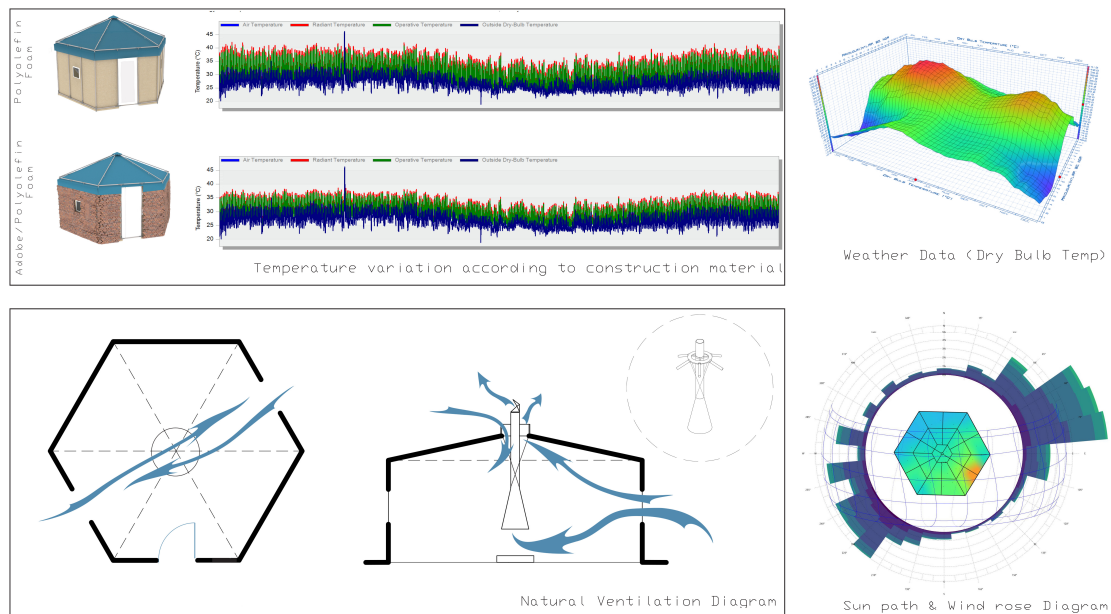
Figure 15. The bioclimatic analysis for the shelter unit. The authors, 2023.

The primary step is to assemble the main body of the construction with the help of the different connectors using a groove-and-tongue method. The secondary bearing body is

then placed to help connect the infill masonry panels and the roof panels. At the same time, the static adequacy of the load-bearing structure and the masonry is reinforced through the cross wires that tie on the one hand to the primary load-bearing body and on the other hand to the links on each side in the upper part. Then, the roof panels are snapped in, and a skylight is attached to the load-bearing body, which acts as an interior air re-circulator. The last stage is the construction implementation, which includes the elements of the door, windows, ventilation, and solar panel to cover basic electricity needs. As for the latter, these parts can be placed on any wall panel, making the overall construction flexible according to the needs of each user.

This proposal also offers the possibility of converting the temporary shelter into a permanent one. In other words, creating a permanent structure is possible by maintaining and utilizing the main supporting body and selected panels (to avoid one-size-fits-all). This permanent structure, built with local area materials (adobe bricks), offers the satisfaction of better living conditions both qualitatively and quantitatively. Qualitatively, the use of local materials provides, on the one hand, an ambiance with respect to each local characteristic and, on the other hand, better thermal comfort (optimization of insulation). Quantitatively, the possibility of conversion from a transitional shelter to a permanent one gives the possibility of enlarging both the family homes (small scale) and the respective camp in general (large scale), see Figure 16.
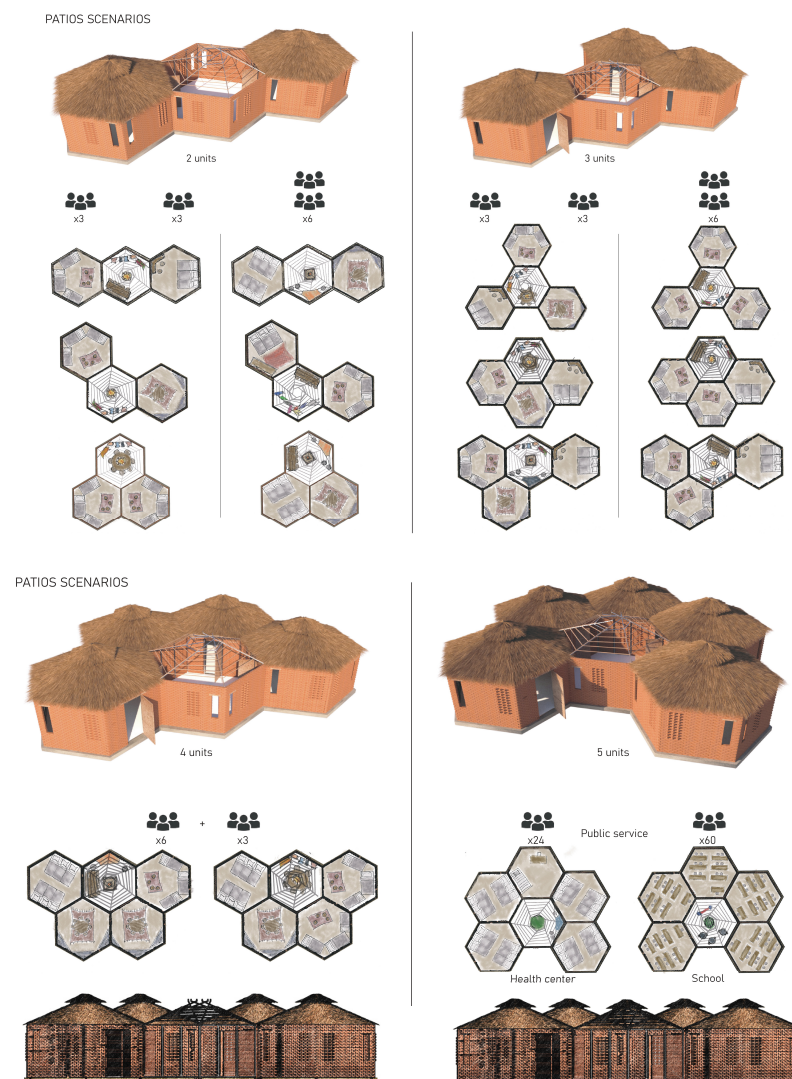

Figure 16. Patio scenarios. By the authors: 2024.

4. Discussion

The discourse on sustainable practices in refugee camps highlights the transition from short-term, emergency-centric strategies to lasting, human-centered solutions focused on enhancing the well-being of refugees and nurturing positive relationships within host communities. Prolonged displacement resulting from conflicts exacerbates resource scarcity, environmental degradation, and social tensions between refugees and host communities. Consequently, transient refugee camps often evolve into permanent settlements, mandating sustainable operational enhancements to improve living conditions.

The primary objectives of this contribution were twofold. Firstly, we sought to develop a shelter prototype that integrated the five key aspects of HOD to meet the essential requirements for environmentally responsible and resource-efficient living. Secondly, we endeavored to underscore the intrinsic limitations of even the most sustainable shelter in guaranteeing a dignified life for a displaced individual. This underscored that forced migration inevitably leads to non-sustainability, irrespective of the humanitarian response.

Analyzing housing typologies in different areas of the Al-Sahel region allowed us to gain valuable insights into the key architectural features and characteristics unique to that geographical location. We have discovered that the Sahelian homes in the region exhibit an apparent response to the climatic conditions, which should be a critical consideration when designing the shelter for the area. Our research has also revealed that the use of local materials and techniques is an integral part of the architectural style in the region. This information can help inform our decisions regarding the materials and techniques used when designing the shelter. Furthermore, we have observed that the use of courtyards and open spaces is a common feature in Sahelian homes, and this has significant implications for the overall design of the shelter. By incorporating such features in the design, we can ensure that the shelter is functional, aesthetically pleasing, and in harmony with the environment.

Refugee camps are often viewed as bleak and uninspiring places that lack the basic amenities required for a decent standard of living. The shelter prototype developed by the authors is viewed as a process rather than a product, which aligns with Alexanders' concept of "wholeness," which suggests that every part of a design should contribute to the overall harmony and life of the structure [60,61]. In refugee settlements, this can be seen in how communities organically develop, with each dwelling contributing to the social and spatial fabric of the settlement [62]. This, in turn, fosters a sense of empowerment and self-reliance, which can positively impact the mental health and well-being of refugees [63]. Its humanitarian approach to refugee shelter is a testament to the power of community-driven solutions in tackling complex humanitarian challenges. The hexagonal prototype for six family members was designed using locally sourced materials, carefully chosen to suit the refugees' cultural appropriateness and functional needs. The earlier research by Christopher Alexander concerning architectural patterns and their influence on "The Nature of Order" underscores the significance of repetitive design components that harmonize with human experiences [64]. This often manifests as inhabitants construct and adapt their dwellings using regionally available materials and time-honored techniques [65].

The hexagonal shape was chosen for its versatility, as it allows for easier assembly and transportation of the habitat. Moreover, the hexagonal design provides better ventilation, natural light, and privacy for each family unit. Furthermore, the hexagonal structure underwent a comprehensive bioclimatic analysis to evaluate its thermal comfort and has been proven to be a robust and resilient architectural design. This analysis included considering various environmental factors, such as wind patterns, solar radiation, and temperature fluctuations, to ensure the structure's ability to withstand harsh conditions. The result is a structure well suited for the challenging weather conditions common in the Al-Sahel region, where refugees often face extreme temperatures and harsh weather. In addition to its ability to withstand challenging weather conditions, the shelter's hexagonal structure design facilitates natural ventilation, promoting optimal air circulation and reducing the transmission of airborne illnesses. The hexagonal shape of the structure allows for the creation of a central courtyard, which serves as an open space for air to circulate freely. The

design also includes a series of openings that allow fresh air to enter the structure and stale air to exit, creating a natural flow of air.

The camp layout can be optimized using a modular arrangement of housing units, which allows for more efficient use of available space and resources. This arrangement not only improves living conditions for refugees but also enhances their social interaction. Informal housing encompasses not just physical structures but also the social networks and interactions that define these communities. Alexander's theory recognizes the importance of these social dimensions, suggesting that architecture should support and enhance human relationships [66]. In refugee settlements, spatial arrangements often reflect complex social orders, with private, parochial, and public spaces interwoven to facilitate community life. This aligns with Alexander's emphasis on creating spaces that foster connection and community [67]. The hexagonal shape structure offers diverse options for developing patios assigned to refugees, accommodating varying preferences and needs and providing a unique opportunity to create distinct and functional outdoor living spaces. This feature, along with the shelter's other design elements, facilitates the creation of aesthetically pleasing and practical patios. Overall, the shelter offers a versatile solution for developing outdoor spaces to benefit refugees. As a result, a locality is built by its inhabitants.

5. Conclusions

This article provides an in-depth exploration of the development of a human-centered shelter design specifically tailored to meet the unique needs of refugees in the Al-Sahel region. The primary objective is to create a habitable unit that can accommodate the three distinct phases of an emergency, transitional, and durable situation. Throughout the design process, we meticulously considered and incorporated five key aspects of humanitarian-centered design in our approach to developing a refugee camp in Al-Sahel: First, flexibility and adaptability: we ensured that the shelter design could easily adapt to changing needs and circumstances, providing practical solutions for various scenarios. Second, cultural sensitivity and community involvement: the design approach integrated the cultural context of the refugees and indirectly involved the community in the decision-making process to ensure the shelter design respected and reflected the cultural preferences and practices of the inhabitants (construct while living). Third, sustainability and environmental considerations: environmental impact and sustainability were integral to our design. We prioritized local materials, energy-efficient solutions, and sustainable construction practices to minimize the camp's environmental footprint. Fourth, addressing psychological and social needs: the proposed shelter design aimed to create a supportive and inclusive environment, addressing the psychological and social needs of the refugees. Where the shelter prototypes can create spaces (Patios) for community gatherings, counseling, and recreational activities to promote well-being and social cohesion. Fifth, compliance with international standards: the shelter design was meticulously developed to meet and exceed international humanitarian standards, ensuring the safety, security, and dignity of the refugees residing in the camp.

While the principles of HCD in refugee shelter design focus on adaptability, cultural sensitivity, sustainability, and community involvement, challenges remain in balancing these ideals with practical constraints such as cost, time, and logistical considerations. The integration of HCD principles requires a collaborative effort among designers, humanitarian organizations, and refugee communities to create shelters that truly meet the diverse needs of displaced populations.

In sum, to ensure a human-centered approach to designing refugee camps, it is necessary to adopt a multifaceted approach. This approach should include introducing innovative operational practices, aligning with the Sustainable Development Goals (SDGs) to address various facets of sustainable development, advocating for human rights, enabling access to quality education and healthcare facilities, implementing adaptable architectural designs, providing reliable energy sources, and ensuring access to clean water, sanitation, and hygiene services Every element plays a crucial role in establishing an environment

within refugee camps that seeks to integrate humanitarian considerations into a fundamentally unsustainable resolution. Incorporating human-centered practices within refugee camps necessitates a customized approach that considers each context and population's specific needs and conditions. In conclusion, establishing a camp is not a viable or sustainable solution. While we may be able to address some technical aspects of sustainability, the individuals in these camps remain uprooted, suffering from forced migration, and experiencing profound mental and physical health challenges. It is crucial that we approach this issue with the utmost criticality.

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