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Designing Sustainable Housing Using a User-Centred Approach: Paipe Case Study

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Abstract: This paper presents a user-centred design method for developing prototype housing designs in the Paipe community of Abuja, Nigeria, addressing the challenges posed by rapid urbanisation in low- and middle-income countries (LMICs). UCD is a qualitative methodology that prioritises end users in the design process. This study employs qualitative methods to collect data through interviews, field surveys, and site analysis using a single case study. The UCD approach was used to develop a profile of residents and identify their needs and preferences. Thematic analysis of the data led to the creation of design specifications and prototype designs. Two design options were developed: a cluster design based on field survey observations and an enclosed modern design based on residents' preferences. This study contends that user-centred design (UCD) is essential for sustainable housing provision in LMICs, aligning with the United Nations' adequate-housing programme.

Keywords: bottle house; user-centred design; adequate housing; prototype design; informal settlement; participatory design; sustainable housing

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1. Introduction

Rapid urbanisation in low- and middle-income countries (LMICs) has resulted in significant population expansion in cities. The United Nations estimates that over the next three decades, more than 66 percent of the world's population will live in cities; urbanisation is set to be one of the twenty-first century's most transformative trends [1]. At present, rapid urbanisation occurs mainly in Africa, Asia, and Latin America, leading to a shortage of housing in cities, consequently resulting in the formation of informal settlements by the urban poor. Such settlements are characterised by makeshift shelters, overcrowding, poor sanitation, unemployment, and insecurity [2]. Sub-Saharan Africa has the highest proportion of slum residents, accounting for 62 percent of the urban population, compared with 35 percent in Southern Asia, 24 percent in Latin America and the Caribbean, and 13 percent in North Africa [3]. This poses many challenges in relation to the organisation and provision of infrastructure, basic services, food, health, education, and employment. In addition, this phenomenon is inefficient and unsustainable, placing tremendous pressure on natural resources [1,4].

Housing is more than just buildings, dwellings, or places of abode; it includes utilities; infrastructure; recreational, educational, and commercial services; as well as economic and cultural arrangements to promote comfortable living in the built environment [5]. Housing facilitates social, psychological, political, economic, and cultural norms and behaviours, which in turn shape lifestyles and the surrounding natural environment [6]. The provision of adequate housing can contribute significantly to an individual's wider

social, environmental, and economic context [7]. Furthermore, housing has implications for the natural environment and the wider regionally built ecosystems. Poor housing results in inadequate sanitation, which has repercussions for healthcare, mental well-being, education, employability, capital investment, governance, and development. Therefore, the provision of adequate housing is a key requirement, especially for low-income households that are sensitive to the vulnerabilities of poor health and lack the education or political voice needed to find solutions to the problems they encounter. According to estimates by the World Health Organization, poor housing in LMICs leads to approximately two million deaths annually [8]. The development of housing structures was primarily motivated by the desire to meet man's fundamental needs: shelter, safety, and comfort [9]. However, suitable provisions vary from person to person, and house design and materials should naturally reflect users' lifestyles and local building practices. In addition to being a physical requirement, housing also has cultural, economic, and social significance. The psychological well-being of a community's people is significantly affected by the housing and architecture surrounding them [10].

This paper is part of the Bottle House Project, a transdisciplinary, international research collaboration between academia, industry, and end users in rural Nigeria. The project explored designing and building an affordable, sustainable home using a user-centred design (UCD) process [11]. Nigeria is situated in West Africa, a sub-region of sub-Saharan Africa, with a total land area of 923,768 km^2. Rapid population expansion over the past 50 years has transformed Nigeria from a primarily rural nation to one in which 53 percent of its population resides in urban centres [12,13]. Nigeria is the most populous and one of the most urbanising countries in Africa, with a population of over 213 million [13] made up of over 500 ethnic groups [14]. With a projected yearly growth rate of 2.4 percent, more than 70 percent of the population is projected to reside in urban areas by 2050 [13,15]. The current housing shortage is 28 million units [16]. Annual formal housing production is roughly 100,000 units, which is extremely inadequate given that at least 1,000,000 units are required to meet demand [17].

Nigeria is a multicultural nation comprising six geopolitical zones; the customs and activities of the ethnographic regions are influenced by three prominent language groups. Each region reflects the accompanying cultural and political variations of its people and, as a result, exhibits housing styles that are influenced by its climate, traditions, and religion [18]. Much of the current literature highlights the multiplicity of socio-political and economic realities that impact the provision of housing in various LMIC contexts worldwide, although there is a paucity of analysis around user-driven dwelling design [19]. This is a pertinent gap in the literature on housing provision in low-income countries, where the discourse on independence, decolonisation, and the preservation of traditional customs is significant. The aim of this paper is to develop a housing design that meets the sociocultural needs of the Paipe community. It employs a user-centred design (UCD) approach to collect relevant information that leads to the development of the prototype designs.

The rest of the paper will present some background literature relating to sustainable and adequate housing; the Section 3 will discuss the method employed with a background on UCD. The Section 4 will describe the results and discussion including the design outcomes of the UCD.

2. Background

2.1. Sustainable Housing

Housing addresses the fundamental requirement for shelter, significantly impacting quality of life, health, safety, and welfare [8]. Often ranked second in the hierarchy of human needs after food, this highlights its importance to modern society. Housing inherently reflects a society's cultural, social, and economic values while providing tangible evidence of a nation's civilisation [20]. Factors such as location, materials, and construction aesthetics influence individuals' experiences concerning security, health, and well-being, affecting both current and future generations [21,22], leading to adverse intergenerational health

and well-being consequences, weakened educational systems, and persistent poverty cycles [23].

Housing is integral to sustainable development [24] due to its reliance on natural resources, which have been significantly depleted by the housing boom. Chiu [24] defines sustainable housing development as meeting the present generation's needs without compromising future generations' ability to fulfil their needs. The social dimension of sustainability, as defined by Woodcraft et al. [25], focuses on creating successful, sustainable places that promote well-being by understanding people's needs in their living and working environments. Despite its importance, social sustainability has been largely overlooked in mainstream debates [25], with integrated policies addressing the social, cultural, environmental, and economic aspects of housing being particularly scarce in low- and middle-income countries.

Low-cost housing projects frequently offer substandard accommodation with little regard for residents' lifestyles, thereby exacerbating cultural, social, religious, and geopolitical tensions in vulnerable communities [21]. For instance, in Nigeria, cultural and religious beliefs shape community activities and influence residential architecture [26]. Ignoring these preferences may limit women's access to education and commercial opportunities, contributing to wider geopolitical ramifications such as the Boko Haram insurgency [27]. Local participation in planning and implementation can better address users' needs and foster a sense of responsibility and ownership. Culturally appropriate built environments are thus integral to sustainable housing [22]. The New Urban Agenda, adopted at the United Nations Conference on Housing and Sustainable Urban Development (2016), sets global standards for sustainable urban development by collaborating with partners at all levels of government [1].

2.2. Need for Sustainable Housing

Civilisations build homes with varying styles, reflecting the evolution of cultural values. The organisation and utilisation of space are closely linked to cultural traditions, best comprehended by local populations. The lack of consideration for socio-cultural factors, such as family values, size, religion, and ethnocentric practices, poses a significant obstacle to housing satisfaction [20]. Cultural adequacy is emphasised as a crucial criterion for adequate housing in the International Right to Adequate Housing [22]. Sustainable housing can substantially mitigate issues related to population growth, urbanisation, poverty, and climate change. By introducing a planning component, it encourages governments and stakeholders to contemplate provision creatively, reorienting the focus towards the complex nature of housing and the experiences of the urban poor. Sustainable housing necessitates the integration of various sustainability aspects; however, its implementation is rare in LMICs. Studies indicate that neglecting one aspect of sustainability leads to multiple housing vulnerabilities [21].

2.3. Adequate Housing

Goal 11 of the United Nations' Sustainable Development Goals aims to ensure that everyone has access to adequate, safe, and affordable housing by 2030 [12]. However, the concept of "adequacy" varies from country to country due to cultural, social, environmental, and economic factors. Since the adoption of the Universal Declaration of Human Rights in 1948, the right to adequate housing has been recognised as an essential component of the right to an adequate standard of living [28,29]. The Habitat II global plan of action document highlights the commitment of all levels of government, the community, and the private sector to achieve the principal goal of adequate shelter for all through an enabling process in which individuals, families, and their communities play a central role [28]. However, studies have shown that the problem of housing is universal, as virtually all countries face the problem of providing adequate housing for their citizens. The assumption that a dwelling's physical and structural adequacy alone is a good indicator of its suitability

for providing satisfactory housing to its occupants has frequently contributed to the failure of housing delivery programmes for low-income earners [20].

3. Methodology

This paper describes how a user-centred design (UCD) method was used to develop prototype housing designs that meet the socio-cultural needs of the Paipe community. A single case study was conducted to gather data through interviews, field surveys, and site analysis. The UCD approach was used to develop a profile of respondents and identify their needs and desires. Thematic analysis led to design specifications and prototype designs.

This article is a component of the Bottle House Project, an international, transdisciplinary collaboration between academia, industry, and end users in a low-income community in Nigeria [11]. The project aimed to produce a low-cost, self-sufficient dwelling that can be easily replicated by locals using upcycled materials sourced locally. A transdisciplinary team accomplished the project's objectives through collaboration. The team comprised researchers and professionals with expertise in numerous fields, including:

- A user-centred designer with expertise in designing for low-income communities;
- Architects with expertise in passive/low-energy design;
- Material science engineers;
- Solid mechanics engineers;
- Structural engineers;
- Environmental engineers with expertise in water and energy management;
- Community members;
- Local entrepreneurs [11,30].

3.1. User-Centred Design

Prat and Nunes [31] define user-centred design (UCD) as "a design philosophy that puts the user of a product, application, or experience at the centre of the design process. In UCD, a designer strives for a detailed understanding of the needs, wants, and limitations of the people who will use the end product and then makes design choices that incorporate this understanding" (p. 12). In the 1980s, Donald Norman's research laboratory at the University of California, San Diego gave birth to the concept of "user-centered design" (UCD), which rose to prominence following the publication of *User-Centred System Design: New Perspectives on Human-Computer Interaction* (1986). In his influential book *The Psychology of Everyday Things*, Norman later elaborated on the UCD concept (1988). This strategy prioritises the needs and interests of users and emphasises design usability. By placing the user at the centre of design considerations, it is the designer's responsibility to facilitate user tasks and ensure minimal effort is required to effectively use the product [32]. Numerous disciplines have used UCD to support person-centred approaches. Agee et al. [33], Moore Haines and Lilley [34] and Wilson, Bhamra, and Lilley [35] have demonstrated the utility of UCD in the housing sector, particularly as a result of the dominance of cultural and socio-political needs.

A user-centred design process can therefore contribute to social sustainability by bringing people together, establishing social ties and networks, and empowering individuals. The UCD process engages with design alternatives openly and sincerely. It considers potential future visions that incorporate a wide variety of perspectives, needs, and advocates [36].

A user-centred design prioritises an individual in community development. This aligns with Sustainable Development Goal 11 of the United Nations, which states, "People must be at the centre of human development, both as beneficiaries and as drivers, as individuals and as groups. People must be given the tools and knowledge to construct their own communities, states, and nations" [37]. The United Nations' New Urban Agenda emphasises a commitment to urban and rural development, prioritising people-centred approaches, environmental protection, and age and gender sensitivity. This commitment encompasses the realisation of human rights and fundamental freedoms, fostering coexistence, eradicating discrimination and violence, and empowering individuals and communities

through full and effective participation. Moreover, the promotion of culture, respect for diversity, and equality are deemed essential components of humanising cities and human settlements [1].

According to Palich and Edmonds [36], the key to empowering a community is involving community members in the design process. Allowing the process to dictate the outcome is one method of promoting a user-centred design process. A design-led process translates, interprets, and communicates design options often with the assistance of an architect. As depicted in Figure 1, this procedure may include research, evaluation of case studies, development of an investigative brief, and design testing. The purpose of the research is to identify the issues at stake and to change the parameters. Evaluation of case studies involves stakeholders in discussions of alternative design approaches and eventual solutions. The design team prepares the investigative brief, which is used to explore and evaluate potential future scenarios based on design alternatives that highlight contextualised values and performance outcomes. These potential features can then be presented to stakeholders in the form of design testing. According to Palich and Edmonds [36], the objective is for all participants to feel ownership of the design and resolve any potential conflicts through the process.

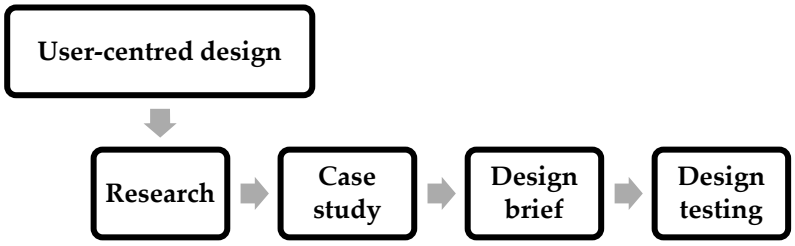


Figure 1. User-centred design process. Adapted from Palich and Edmonds (2013) [36].

Considering the ideas, beliefs, and traditions of specific cultural groups facilitates the provision of housing that satisfies the needs of people, is appropriate in the context, and thus ensures the optimal use of housing and promotes a sense of belonging and well-being of its occupants. Different cultures have different traditions regarding settlement patterns, construction materials, design, shape, form, and size of buildings, all of which must be considered when designing housing, alongside local skills, techniques, and building technology. Many researchers have recommended a participatory approach to this nature, including Choguill [38], Nix et al. [9] and Valladares [39]. User-centred design and participatory design are two separate approaches used in the design industry [40]. While both methodologies attempt to place the user at the centre of the design process, their techniques and levels of user interaction differ, as shown in Table 1.

Table 1. Differences between User-centred design and Participatory design.

	User-Centred Design	**Participatory Design**
Definition	An approach to designing products or services that involves conducting research on the user's needs and preferences	Actively involving users in the design process
Level of user involvement	Passive, through research methods	Active collaboration throughout the entire design process
User feedback	Gathered through research methods	Gathered throughout the design process through active collaboration
Example	Conducting interviews and surveys to gather information on how people use their homes	Active collaboration between users and designers in the design of housing initiatives

Source: [40–42].

Similarly, there is much to be gained from the traditional building techniques and processes. Therefore, it is beneficial to begin projects with a focus on local needs, allowing community-driven strategies [22]. Since the Habitat I Conference in Vancouver, it has been acknowledged that informal, small-scale, community-based housing initiatives are an essential element of any successful, sustainable low-income housing. More than half of the existing housing stock in most cities in low-income countries is constructed by the owner-occupants themselves [43].

3.2. Research Design

The research plan is governed by "fitness for purpose" rather than a single blueprint [44]. The design process for this paper was guided by the procedure illustrated in Figure 1. In addition, the design team considered the geoclimatic, social, economic, and political agencies of the residents as well as the sustainability, cost, and availability of modern housing features. This paper aims to design socially and culturally sustainable housing for Paipe residents. This influenced the research design, which in turn determined the methodology. As the primary objective of this project was to research and work with people, as opposed to objects, interpretivism was deemed suitable [45]. This methodological perspective affected the research framework used for data collection and analysis. Interpretivism asserts that it is crucial for researchers to acknowledge human differences in their roles as social actors [45]. Qualitative methods, such as semi-structured interviews, observations, and focus groups, were used because they describe and interact with people in real-world settings and natural environments [46]. Through participants' experiences and voices, they also provided an in-depth understanding and description of the issues under consideration. By fostering appreciation for the community's culture and way of life, these techniques increase user acceptance of the prototype [11].

3.3. Case Study

Among the different research methods, the case study approach was deemed appropriate for implementing a user-centred design (UCD). A case study is an in-depth investigation and analysis of a specific research topic, about which little is known, but extensive knowledge is desired [47–49]. Case studies recognise that there are numerous variables operating within a single case; capturing the implications of these variables typically requires more than one data collection instrument and multiple sources of evidence [44]. For this research, a case study of the Paipe community was conducted to understand their socio-cultural needs. Paipe is a rapidly growing community located 17 km outside Nigeria's Federal Capital Territory. The region is populated by rural residents who relocated to the city. Most residences in the community are temporary, resulting in substandard living conditions. Paipe was chosen as the study location because of its excellent representation of low-income communities in Nigeria's semi-urban areas [11].

The user-centred design (UCD) method was used to create a profile of the local community and identify their innate needs and wants [11]. This process was launched by conducting semi-structured interviews with the residents [50]. The interview is a versatile instrument for data collection because it allows the use of multiple sensory channels. The purpose of this project's interviews was to collect data to support the research objectives [44], which in this case were to understand the family structure, number of people living in a typical house, primary use of houses, challenges with current homes, and hopes for future homes. Thirteen households (approximately 5% of the population) were each interviewed for 30–50 min. The participants were purposefully selected from residents who volunteered to participate in the interviews. The interviews were recorded and transcribed. As Paipe is a multicultural community whose residents speak a variety of Nigerian languages, translators were hired to assist the researcher and ensure that the residents' responses were accurately recorded and translated into English. The conversational tone of the translation enabled flexibility and follow-up questions during interviews. This method also considers the cultural and spiritual needs of the participants and their symbolic significance [11,20].

The community visit allowed researchers to conduct a field survey to observe and document the settlement pattern while taking photographs and sketching the housing layout. In addition, information was collected from local meteorological stations to determine the regional weather patterns and variations in the cycle. A Nigerian SME, Awonto Konsolts Limited (Abuja, Nigeria), supported the data collection.

3.4. Data Analysis

The responses to this data collection were subjected to thematic analysis, which consisted of identifying codes and grouping them into themes, which served as the basis for interpretation [51]. The results of this analysis were incorporated into the creation of a design specification that was used to create the prototype designs. The transcripts of the interviews were analysed by a researcher who is fluent in the local language. The researcher compared the written transcripts with the audio recordings to ensure data accuracy. Information was compiled using a template to facilitate analysis. The template was analysed to identify common factors which resulted in design concepts that satisfied the socio-cultural needs of residents. Manual thematic analysis was used to examine the frequency of factors occurring in the sample. The analysis of the field survey data, interviews, and site analysis led to the development of a design specification, which was then used to create a design brief for the prototype designs, as shown in Figure 2. The outcome resulted in two design options: option one was based on their needs, whereas option two was based on their preferences. Section 4.1 discusses the design specification and development procedure.

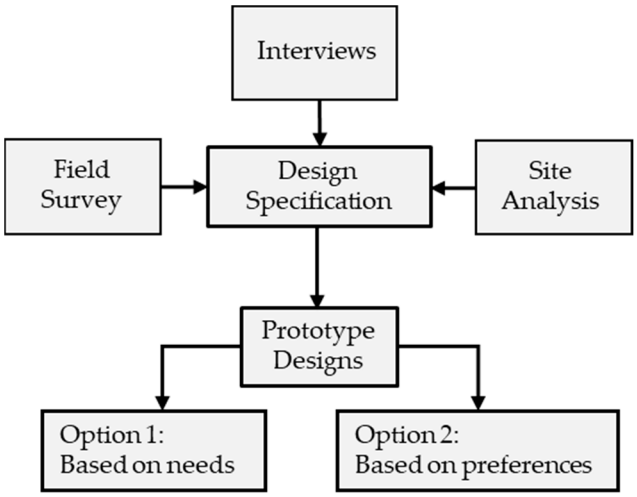


Figure 2. Flowchart of the design process.

4. Results and Discussion

4.1. Design Specification Development

4.1.1. Interviews

Thirteen residents were interviewed and asked about the following:

- Family profile, such as family size, occupation, and ownership status (renting or owned).
- The construction method, material, and thermal comfort.
- Details of the house, such as the number of rooms and the absence of kitchens and/or toilets.
- Usage profile of house for daily activities/business.
- Their preferences in terms of housing layouts and utilities.
- The existence of utilities (water and electricity) and alternate coping mechanisms.

The family profiles are listed in Table 2. In total, 77 percent of the respondents indicated that their household consisted of two parents and more than four dependents (children and relatives). Families with more than six children are prevalent in rural Nigeria, where extended families often live together. Therefore, the design must accommodate a high footfall. The extended family system consists of parents, numerous children, and other relatives residing in a single residence [52,53]. Almost all the respondents (92 percent) were property owners, while only one respondent was a tenant. A total of 46 percent of the respondents had small farms where they cultivated food for personal consumption. Rarely do they sell surplus produce. Meanwhile, 39 percent of the farmers were employed in other fields. The majority of the farmland is a few minutes' walk away and was inherited; the men spend most of the day working on the land, and the women run their small businesses at home while caring for their children and performing housework.

Table 2. Family Profile.

		Responses	Percentage (%)
Family size	Up to six members	3	23
	More than six members	10	77
Total		13	100
Occupation	Farmers	6	46
	Non-farmers	2	15
	Both	5	39
Total		13	100
Home ownership	Own	12	92
	Rent	1	8
Total		13	100

The construction methods used are presented in Table 3. The data show that 85 percent of the respondents built their houses in stages according to the funds available, indicating that designs should accommodate expansion, as this is a common practice. In addition, 69 percent use mud blocks, which are significantly less expensive and can be made locally. However, they are not durable and deteriorate over time, necessitating constant replacement. The lack of structural integrity of mud bricks makes them susceptible to blasts from a nearby quarry factory. On average, they last seven years before cracking and falling apart. This necessitates the proposal of a sustainable alternative to mud bricks [11]. Overall, 39 percent of respondents said that their dwellings were comfortable. The remaining 61 percent reported that, during the dry season, indoor temperatures were so high that they were forced to sleep in the courtyard at night. The shade of the trees improved the conditions during the day. Participants did not appear to comprehend why their homes gained so much heat, despite the fact that the vast majority (89 percent) used materials with high thermal conductivity such as corrugated iron roofing sheets. In addition, inadequate ventilation could contribute to discomfort. A total of 62 percent of the dwellings had three or more windows, but they were small and poorly positioned to ensure adequate ventilation. The locals claimed that they could not afford to purchase large windows. The lack of consistent electricity for several days makes fans impractical. A few individuals have backup generators that operate for a few hours per day.

Table 3. Construction Method.

		Responses	Percentage (%)
House build	In stages	11	85
	At once	2	15
Total		13	100
Wall material	Locally sourced	9	69
	Externally sourced	4	31
Total		13	100
Windows	Three or more	8	62
	Less than two	5	38
Total		13	100
Roof material	Corrugated iron	11	85
	other	2	15
Total		13	100
Thermal comfort	Uncomfortable	8	62
	Comfortable	5	38
Total		13	100

The typical design of a community building is presented in Table 4. A total of 69 percent of the homes had four or more rooms, some of which were rented out (62 percent). As firewood is the primary source of cooking fuel (which cannot be used indoors), 62 percent of households have an outdoor kitchen, 31 percent have an indoor kitchen, and only 7 percent have both indoor and outdoor kitchens. Typically, kerosene stoves are used in kitchens indoors. Moreover, 62 percent had bathrooms outside the main building, and 23 percent of the population had both indoor and outdoor bathrooms.

Table 4. Building Design.

		Responses	Percentage (%)
No. of rooms	Up to three	4	31
	Four or more	9	69
Total		13	100
Have tenants	Yes	8	62
	No	5	38
Total		13	100
Kitchen location	Outdoor	8	62
	Indoor	4	31
	Both	1	7
Total		13	100
Bathroom location	Outdoor	8	62
	Indoor	2	15
	Both	3	23
Total		13	100

In terms of preferences, Table 5 indicates that 46 percent of the participants preferred to use sandcrete blocks (hollow cement-based blocks typically used in Nigeria) for wall

construction. They associated them with modern housing, but this was unaffordable. Most respondents (69 percent) who preferred outdoor kitchens and toilets cited a lack of a constant water supply as a reason for their preference. Water is usually purchased from vendors or drawn from boreholes or locally dug wells. However, during the six to eight months of the dry season, the wells dry up. Some find it more convenient to fulfil their needs in the nearby bush.

Table 5. Preferences.

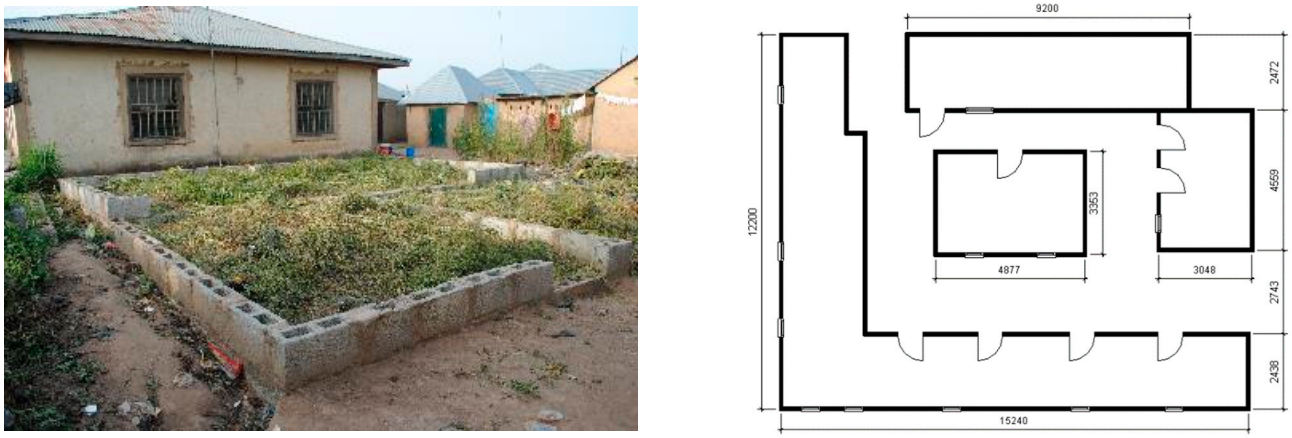
		Responses	Percentage (%)
Wall material	Sandcrete blocks	6	46
	Other	7	54
Total		13	100
Kitchen location	Indoor	4	31
	Outdoor	9	69
Total		13	100
Bathroom location	Indoor	4	31
	Outdoor	9	69
Total		13	100

4.1.2. Field Survey

As shown in Figure 3, a common observation from the field survey was the presence of courtyards in most homes. The courtyard is utilised for various purposes, including the processing and storage of farm produce, by most residents who practise subsistence agriculture. In addition, the courtyard is an architectural, religious, and socially significant relic of Northern Nigeria's socio-cultural heritage [52]. Courtyards are also used for cooking, sleeping, and socialising. Typically, courtyards are sufficiently large to accommodate all the activities. A more recent artefact is the presence of several large water storage containers owing to the lack of water supply.

Figure 3. Typical courtyards in Paipe.

The field survey also revealed the socio-cultural tradition of clustered buildings, an indication of communitarian living that accounts for shared housing among extended family members. Nonetheless, this architectural style has evolved to incorporate contemporary economic considerations. Additional rooms were constructed in stages as shown in Figure 4. For instance, when funds are available, more rooms are constructed to accommodate a growing family or more tenants. Families use the rent to supplement their income.



(**a**) (**b**)

Figure 4. (**a**) House built gradually and in stages. (**b**) Cluster layout.

Other domestic activities are influenced by cultural and economic factors. For instance, cooking outdoors with firewood is a common practice among residents, as shown in Figure 5. They can no longer obtain firewood in a sustainable manner, as the land is sold, and the trees are cut down to make way for construction. Owing to the cost and lack of modern infrastructure to supply cooking gas and reliable electricity, this is currently the most viable option. Figure 5a illustrates that even when an indoor kitchen is available, it is preferable to cook outside because of smoke. Occasionally, residents utilise any available convenient space.

(**a**) (**b**)

Figure 5. (**a**) Typical method of cooking outside the kitchen. (**b**) Outdoor cooking using any available space.

The toilets and bath spaces are located outdoors, mostly without a roof, as shown in Figure 6. This is due to the lack of pipe-borne water supply. The most typical type of toilet is a pit latrine that is enclosed within four walls with concrete floors for easy maintenance. As seen in the photographs, one of the walls in each bathroom had a drain at its base to allow water to drain. Visitors and tenants share these facilities.

(**a**) (**b**)

Figure 6. (**a**) Outdoor toilet and bathroom. (**b**) Outdoor bath area.

4.1.3. Site Analysis

The design team considered other vital factors linked to the socio-cultural realities of the participants as part of the strategy to examine the environmental and economic aspects of sustainability that may influence housing requirements [22]. The major features are examined as an amalgam of factors that shape the situational dynamics of living in the area: climatic conditions, geomorphology, everyday socio-political/economic realities, and the personal agency of the local people. The United Nations considers these essential sustainable design measures to contribute to successful low-cost housing programmes. A comprehensive site analysis was conducted to determine climatic and site features that could inform the design concept.

Climate

Several studies have shown that building designs that consider climate are the cheapest and most effective way to make buildings more comfortable. According to the Chartered Institute of Building Service Engineers [54], "an energy-efficient building provides the required internal environment and services with minimum energy use in a cost-effective and environmentally sensitive manner". Although this strategy is generally considered to reduce greenhouse gas (GHG) emissions associated with energy use in buildings, in the context of the Paipe community, it is primarily considered because of the insufficient supply of basic electricity, as observed from the field survey. As Paipe is within the Federal Capital Territory (17 km from the centre), the climatic data of the Federal Capital (Abuja) were used for site analysis because of a lack of specific data. Abuja, under the Köppen climate classification, features a tropical wet and dry climate. The region has three annual weather cycles. This includes a warm, humid rainy season and an extremely hot dry season. The rainy season begins in April and ends in October, when daytime temperatures are approximately 28–30 °C and nighttime lows are around 22–23 °C. During the dry season, daytime temperatures can soar, reaching 40 °C, and nighttime temperatures can drop to 12 °C, resulting in chilly evenings. The average humidity range in Abuja is between 60 and 70 percent [55]. A design consideration for a tropical climate is one that minimises the heat gain to the building while enhancing natural ventilation [56].

Site Features

A sketch of the site in Figure 7 shows a visual description of its features. The main access to the site was to the west. There are a few huts towards the north and some scattered trees, which could be a source of shade and cool air for the proposed building. Restricted access to the site could limit the variation in the design options. Figure 8 shows the topography and access to the site from the main road. The gradient was relatively flat, and there were no large structures within the site.

The principle adopted for energy-efficient design in the tropical climate of Paipe is the use of a passive design approach. "Passive design is a design that works with the environment to exclude unwanted heat or cold and take advantage of sun and breezes" [57]. This is the most important principle because it provides designers the opportunity to design buildings in a way that tends to reduce their energy demands in the early stages [54]. Orientation and natural ventilation are passive design strategies used for this building. It is essential to consider this, because the objective is to create a low-cost structure suitable for low-income communities. Consequently, avoiding heat gain and increasing natural ventilation are primary strategies for achieving comfort without the use of mechanical systems. Initially, the heat gain was minimised by optimising the building orientation. To minimise solar heat gain through the long facade, the optimal orientation in the tropics is rectangular, with the long axis running east–west [58]. The east- and west-facing walls received the most solar radiation, particularly during the summer. Therefore, these walls should be as small as possible with minimal or no openings [56]. Natural ventilation is achieved by increasing airflow to maintain a comfortable temperature and reduce the effects of high humidity. To maximise the benefits of natural ventilation, the design of a building should place a premium on the prevailing winds and cross-ventilation. Cross-ventilation is accomplished by minimising internal barriers to cool breezes and maximising the number of openings facing the wind direction. Each room must have at least two openings for effective cross-ventilation. The types of windows and doors should be chosen such that more airflow enters the building [59].

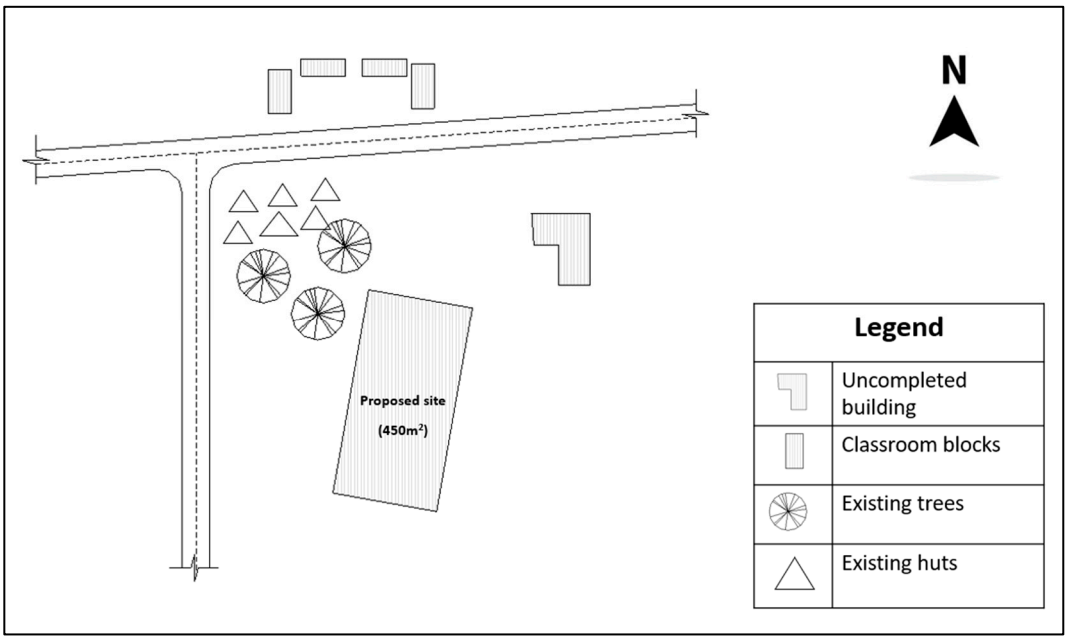


Figure 7. Proposed site characteristics.

Figure 8. View of the site showing topography and access to the site from the main road.

4.1.4. Summary

From field surveys, interviews, and observations, significant socio-cultural characteristics related to residents' lived experiences were deduced. The data highlight important political and economic realities, and how they intersect with personal agency, sustainability, and geomorphology as fundamental design elements. Interviews and field surveys collect information on social factors such as residents' lifestyle, income, and available infrastructure. The results revealed that the residents had a low-income and a family size of six or more. They typically construct their own dwellings, cultivate their own food, and sell a very small surplus. Most residents operate small businesses from their homes and rent out extra rooms to generate income. The need for space to store and process agricultural products has implications for housing designs. In general, residents prefer standard modern architecture with sandcrete blocks, indoor kitchens, toilets, and alternative cooking methods, such as gas or electric stoves. Nonetheless, this cooking method is feasible only if the required infrastructure is in place. Currently, they lack the electricity and water necessary to maintain modern housing, and their income is insufficient.

The analysis of the above data shows the complexity of the relationship between what residents have done and what they want and need. Iwuagwu, Onyegiri, and Iwuagwu [43] show that economic concerns are more important to low-income people than their more basic housing needs. For example, some people would live in a slum near a job rather than in a rural area with more comfortable amenities. Similar analyses [2,53] show that the political and economic realities of people's daily lives have a big impact on what and how they are willing to live in spaces. As a result, satisfaction levels are reconstructed to emphasise the best alternatives, as opposed to actual cultural or socio-economic norms or ideals.

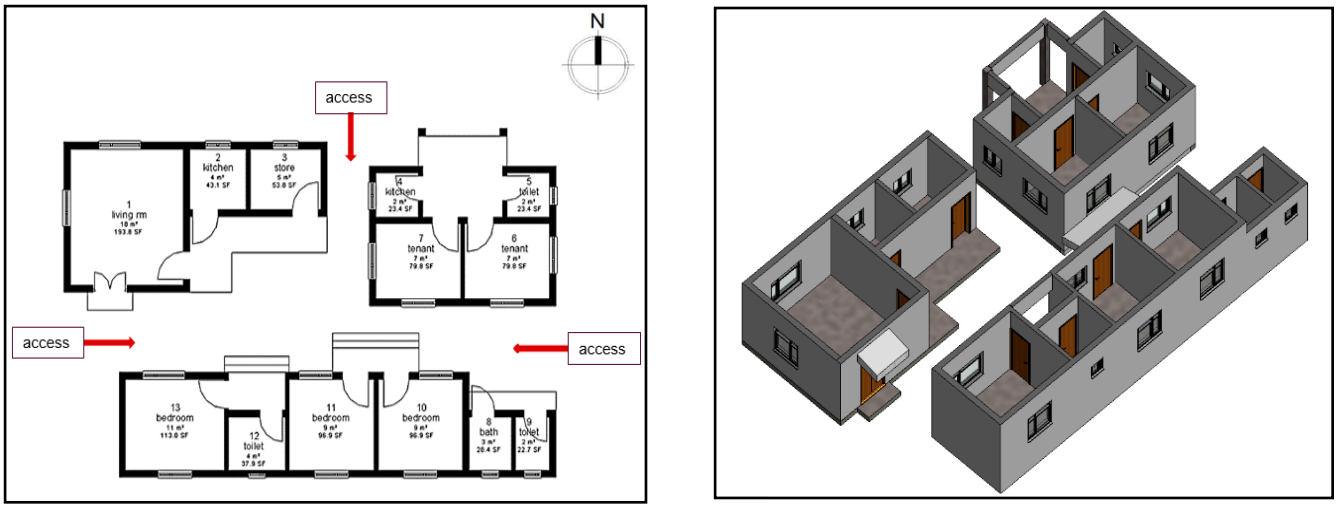
4.2. Design Outcomes

The proposed design options were derived from information gathered through interviews, field surveys, and site analysis. Typically, houses have four or more bedrooms with extra rooms to rent out. Therefore, for this proposal, a five-bedroom house was adopted with three rooms for the family and two separate rooms for tenants. The courtyard, as

observed in the field survey, is an integral part of the design that serves several functions. Most residents indicated that they slept outside during the hot season due to insufficient ventilation. To address this issue, all bedrooms and living rooms have two windows placed at strategic points for cross-ventilation. The courtyard is also a means of enhancing natural ventilation by allowing free movement of air. Two proposed design options were presented to the community. The first design (option 1) was based on the needs of residents in accordance with their socio-cultural building practices and the free flow of functions. The second design (option 2) was determined by the enclosed design layout and was influenced by socio-economic preferences. Residents were presented with two options, highlighting their advantages and disadvantages, respectively.

Option 1: Based on needs.

Figure 9 shows the first proposed design layout. This is based on a cluster design that is common in this area. This research revealed that homes were constructed in phases for financial reasons. Additional rooms can be added when funds are available. In terms of the distance between the blocks of rooms depicted in Figure 4 (Section 4.1.2), this is comparable to field survey observations. It has been proposed that the courtyard serves multiple purposes, including food preparation, family gatherings, and sleeping during extremely hot nights. The toilets are located at the rear of the house for privacy and easy drainage access. To facilitate sharing, bathrooms and toilets were separated. The master bedroom has its own bathroom, which other family members may use. The tenants had their own kitchens and bathrooms in a separate building. The orientation of the rectangular building with its short axis facing east and west, as well as the minimisation of openings to prevent solar heat gain, is described in Section 4.1.3.



(**a**) (**b**)

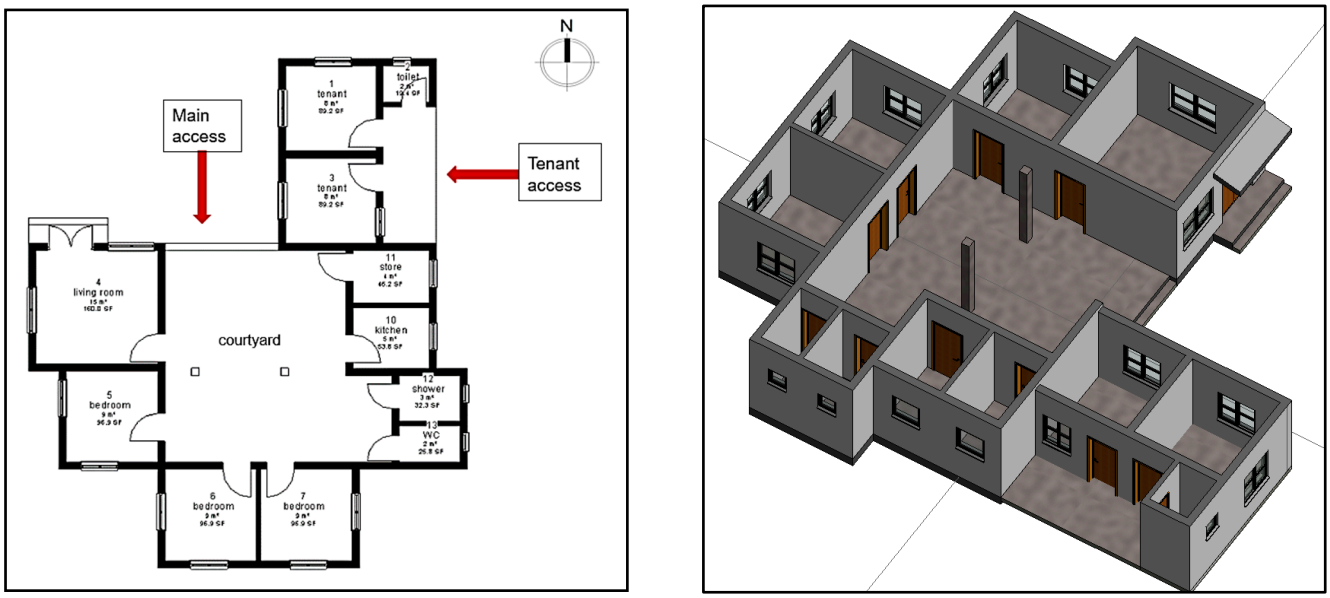
Figure 9. (**a**) Floor plan (not to scale). (**b**) Axonometric view.

The advantage of this design is the ability to build in stages based on available funds and capacity. As shown in the floor plan, allowing access to the compound from three directions, namely north, east, and west, facilitates free movement. As desired, the kitchen could be either open or covered. Material considerations indicated that in terms of comfort, the heat avoidance strategies employed by the strategic orientation of the blocks would make the rooms cooler during the warm season [11]. The large spaces between the blocks of rooms and the placement of windows facilitated the flow of air for natural ventilation. The disadvantage of this design is the lack of security and privacy owing to the open layout. However, appropriate precautions can be taken using appropriate security locks, burglar-proof doors, and windows. Although these measures would be costly, the benefits of securing the building outweigh the cost implications.

Option 2: Based on preferences.

Figure 10 depicts the second proposed design layout that prioritises their preferences. It is based on the residents' desire to be close to the kitchen and bathroom. The courtyard is the focal point of the design and serves multiple functions; therefore, it is an integral component of this design. Because of its size and location, functions such as food drying may not be suitable.

The advantages of this layout are security and privacy, owing to having only one access point. Its compact design makes it easier to build and use small plots of land. The courtyard can be used as an additional living space during the warm season. The placement of windows and doors for cross-ventilation to cool the rooms is the most important climatic factor. The tenants have separate access and utility services. The main disadvantage of this design, particularly in terms of building funds, is that it cannot be built in stages. Other disadvantages include a restriction on movement due to access through one side and inadequate ventilation during hot periods due to the small size of the courtyard.



(**a**) (**b**)

Figure 10. (**a**) Floor plan (not to scale). (**b**) Axonometric View.

Summary

The user-centred design (UCD) method utilised in this study reveals crucial design considerations for low-income households:

- The significance of socio-cultural artefacts like the courtyard;
- The evolving use of these features with respect to current economic and socio -political realities;
- Communal activities and an in-depth situational analysis of the dynamics surrounding the use of shared spaces, materials, and customs in multicultural populations;
- Leisure activities;
- Work–life integration;
- Personal hygiene and education;
- Decision-making hierarchies, political participation, and agency.

5. Conclusions

This paper aimed to develop sustainable housing design prototypes that meet the social and cultural needs of Paipe, a low-income Nigerian community. Due to disregard for the inhabitants' way of life, previous attempts to provide low-cost housing were ineffective. Therefore, involving them in the process gives them a sense of ownership and satisfaction. This is consistent with the adequate-housing programme of the United Nations, which aims

to ensure that the housing needs of the population are met through an enabling process in which users play a central role. This research showed the significance of adopting a user-centred design (UCD) method to provide low-income communities with sustainable housing. Focus should be placed on developing a design that is simple to construct and maintain by end users. The literature review revealed that community participation and consultation are crucial to achieving a sustainable development objective of providing adequate housing for all. Data collected through this process were used to produce two design options. Although the residents desired modern buildings with modern amenities, the lack of available infrastructure and income makes it impossible to support such amenities.

This study demonstrated that achieving a sustainable design based solely on user preferences is challenging. Therefore, it is preferable to consider their needs and provide a design and functionality that is appropriate. To create a sustainable design, the most important factors to consider are climatic characteristics and the way of life of the people. Future considerations could include ideas regarding continuous participation; the educational needs of local participants, particularly with regard to modern hygienic requirements, governance, and advocacy; and the utilisation of materials.

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