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Liveability Considerations: Towards Designing Sustainable Public Housing in Niger State, Nigeria

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ABSTRACT

This study investigates liveability in the context of sustainable public housing in Niger State, Nigeria, where existing housing efforts have fallen short of residents' satisfaction. Recognizing the critical link between liveability indicators and environmental sustainability, this research aims to identify key liveability variables that could be integrated into the design and construction of sustainable public housing. Employing a mixed-method approach, the study involved cluster sampling for selecting housing estates and units, followed by the administration of 910 questionnaires containing 102 questions on liveability variables. Analytical techniques, including Hierarchical Cluster Analysis, Factor Analysis, and Multiple Regression Analysis, were used to group, refine, and validate the liveability variables. The results revealed 21 significant variables that collectively could achieve a 92.9% satisfaction rate among residents if incorporated into public housing design. These findings underline the potential of addressing liveability in the pursuit of sustainable housing solutions, offering insights for urban planners, architects, and policymakers. By focusing on the residents' perspectives, the study contributes to a more user-centred approach in public housing development, promoting long-term satisfaction and reducing the need for post-occupancy alterations.

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Highlights:	Contribution to the field statement:
-Liveability Variables for housing in the area identified. -Sustainable housing design variables identified. -The housing environment study approached from 3 basic construct-Housing Units (HU), Housing Estate (HE) and Housing Estate Neighbourhood (HUN). -Analysis achieved through Satisfaction Rating and Multiple Regression Analysis (MRA). -Data Collection was Residents' Centred.	Liveability study in the study area is greatly enhanced leading to the identification of variables that can be applied in the provision of sustainable residences. This would lead to outright stoppage or minimize incidences of alterations which result in more cost and loss of architectural value.

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1. Introduction

Public housing estates in Nigeria are the dwellings that are provided to public officials by the national, state, or local government (Bashari et al., 2019; Saliu et al., 2023). However, housing issues have had a detrimental influence and the nation's housing sector now has inadequate housing standards among the many concomitant concerns of urbanization (Nwachukwu et al., 2023; Owusu et al., 2023). This is corroborated by Pane et al. (2023) that the negative impact of urbanization is that population growth outweighs economic and industrial development processes in especially urban areas leading to problems such as housing needs, limited land, marginalized local communities, and environmental degradation. Therefore, despite efforts by different levels of government to provide decent public housing by succeeding administrations, the bulk of public housing in Nigeria's urban centres shares the general lack of infrastructure in these housing schemes (Ibimilua and Ibitoye, 2015; Owusu et al., 2023). Similarly, since the State's establishment in April 1976, the government's attempts to provide public housing in Niger State have not produced many positive outcomes. Public housing shortages in the major towns of Minna, Bida, Suleja, and Kontagora seem hard to overcome due to continuous rural-urban migration, particularly among public officials. These housing estates in the state are dominated by widely practised illegal and uncontrolled development trends with buildings created without taking into account zoning, subdivision regulations, or current building and health laws. This is why all the urban areas in the state are experiencing unplanned and uncontrolled growth, which has left extensive population living in residential environments with overstretched urban infrastructure, including electricity and water supplies, and growing environmental problems like air pollution, polluted waterways, inadequate clean water supplies, untreated sewage, chemical contamination of soils, piles of uncollected and decaying garbage, loss of forests and green space, and poor roads. In order to meet the demand for housing from the populace, the state government needs to identify a sustainable public housing strategy that calls for the implementation of a thorough urban management reform. This will lead to public housing that prioritizes the built environment and space quality, addressing concerns like safety, usability, and physical aesthetics, with a focus on how public spaces, transportation infrastructure, and residential areas are designed.

As a result of the decrease in residential environments in urban areas, the term "liveability," which comes from the word "liveable," has gained popularity. It denotes that something, such as a dwelling, is conducive to comfortable living (Lowe et al., 2013; Alderton et al., 2019; Alidoust, 2023; Covato and Jeawak, 2023; Owusu et al., 2023). According to Thanoon and Haykal (2020), liveability is the state of the built environment that takes into account the needs and expectations of residents in order to improve the environment's aesthetic appeal and enhance people's quality of life overall. They emphasized once more how the term has expanded to encompass a wide range of concerns that add significance to the idea of liveability, including accessibility, walkability, comfort, safety, and service availability. This assertion is supported by Levi and Lopez's (2013) perspective, which maintains that liveable environments are places that people enjoy and that meet their needs by fostering their well-being and supporting a sustainable ecosystem. However, from the standpoint of design (American Institute of Architects [AIA], 2005) contended that liveability was better defined in a limited setting, where a liveable environment recognizes its own unique qualities and places great importance on the design processes that help control growth and change in order to enhance but maintain those qualities. Accordingly, the liveability of public housing depends on a variety of factors that combine to make it an appealing place to live as well as features that support neighbourhood satisfaction, a sense of community, and environmental sustainability (Fernando and Coorey, 2018; Nastar et al. 2019). Thus, to sum up, liveability is the term used to describe the attributes and traits that contribute to a residential setting's desirable quality of life and allow its inhabitants to live comfortably there. However, sustainability refers to the capacity to meet present-day needs without jeopardizing the ability of future generations to meet their own (Dempsey et al., 2009). It is the process of carrying out operations in a way that effectively conserves resources and satisfies current population demands without jeopardizing the ability of future generations to meet their own needs.

The study on Liveability has assumed a very important concern and thus serves as a substitute tool for making decisions on the implementation of the design, planning, and construction of urban environments, it is believed, therefore, that more interest on its study and application by all players in the built environment can result in creating living environments that are suitable for the residents to live in. In the long run, residents do not necessarily have to make changes, once built, to make such places suitable to live in. Further, in Niger State Public Housing, the changes or alterations made to public housing after they have been occupied by the users are evident and are termed re-configurations, conversions, addition, and extension of spaces (Isah et al., 2015). These changes can lead to the loss of architectural composition of the housing and the aesthetic landscape the housing is meant to convey to give the users a feeling of satisfaction in owning a house. There is also the cost and pain such changes can bring to the housing owner in trying to make the houses liveable after paying huge sums of money to acquire them. However, since indicators of liveability have been linked with environmental sustainability (Lowe et al., 2013), the aim of the study is to identify the liveability variables in the study area so that they can be applied in the design and construction of sustainable public housing.

2. Literature Review

2.1 Liveability Studies in Nigeria

According to Omuta(1988), the employment, housing, amenity, educational, nuisance, and socioeconomic dimensions of a city are just a few of the mental perceptions that are combined to form its environmental issues, which then translate into a spatial expression that represents the liveability of the city. Additionally, the quality of the local environment and, consequently, its acceptance, are determined by how well these criteria have been met. The collection of outside factors that affect the life of an individual or group residing in an environment is what Omuta (1988) defined as the environment. According to the study, the quality of the environment will vary depending on where you are because this collection of external conditions varies. The study further assumed that the surroundings of specific types of people affect their social lives, how they view their neighbourhood, and how happy they are to live there.

According to Asiyanbola et al. (2012), the deterioration of the environment, which is a reflection of poor management, including the control of urban activities and the ability to foresee future changes, is a factor in the liveability issue. The report stated that the urban canters' essential services and amenities were mostly in a state of decay, and that residents' dissatisfaction with their living environments contributed to the area's low liveability. Accordingly, the issue of liveability is best illustrated by the worsening environmental conditions, which are a result of inadequate management, including the control of city operations and the capacity to foresee future developments. The quality of the roads, garbage collection, public transportation, cleanliness, street lighting, security, crime rate, pollution, water supply, interpersonal relationships, school quality, shops, drainage system, and power supply are some of the basic facilities and amenities that study identified as being important enough to measure residents' satisfaction and determine whether the urban centers are liveable places. According to the study, the majority of urban centers' basic amenities and facilities are in poor condition, and the people who live there are not happy with their living environments. As a result, the area's liveability is not to the residents' satisfaction. Also, Babalola et al. (2022) stated that the degree to which a place's attributes can meet the needs of its inhabitants in terms of their economic and socio-cultural needs, their health and well-being, and the preservation of the ecosystem and natural resources is referred to as the liveability of the environments. The study found that there are numerous hazards to liveability in a mountain-based environment, including mining on the mountain, hazardous erosion, and trouble getting water for domestic use which amongst others lead to wall/building cracks, insomnia, and noise pollution.

Lawanson et al. (2013) stated that affordability and accessibility to basic necessities are the two main factors that Africans consider when determining liveability. The theory that a city is a dynamic living organism that continuously reinvents itself for the benefit of its residents was adopted by this study and as such, balance is necessary for a city to function properly. The study went on to assert that the African definition of liveability places more emphasis on communal living, good neighborliness, and open living arrangements; while centering on the sustainability of life with regard to access to basic necessities. The study came to the conclusion that while religious freedom, tolerance for others, and the preservation of cultural heritage were all deemed important, infrastructure was a key indicator of urban liveability.

Using low-income housing in Niger State as a case study, Mohit and Iyanda (2015) investigated city liveability and housing in Nigeria. They identified several important dimensions of liveability evaluation by the respondents, such as housing characteristics, economic vitality, neighbourhood amenities, and safety situations. In another study, Iyanda and Mohit (2015) examined the use of confirmatory factor analysis (CFA) with a focus on five underlying dimensions and a measurement scale in the liveability assessment of public low-income housing in estates. These five measurement constructs—housing unit characteristics, neighborhood amenities, economic vitality, environment of safety, and social interaction—were confirmed. The empirical findings validated the theoretical model by demonstrating that each of the eighteen items/indicators was essential in determining the liveability of public low-income housing. The study concluded that the use of CFA applications in evaluating the liveability of public low-income housing has potential.

2.2 Liveability Linked with Sustainability

In order to generate data that would influence public perceptions and contribute to the creation of sustainable, liveable, and healthy communities, Lowe et al. (2013) collaborated with the Department of Health of the Victorian State Government and the University of Melbourne to undertake a research program. According to this study, there is a connection between the concepts of liveability and social determinants of health because environmental sustainability is a crucial element of both liveability and health. Additionally, the research highlighted the close relationship between liveability and healthy communities, highlighting that similar factors influence both. Accordingly, the study found that liveability is a subset of sustainability (refer to Figure 1) and that none of its characteristics are in opposition to the goals of sustainability.

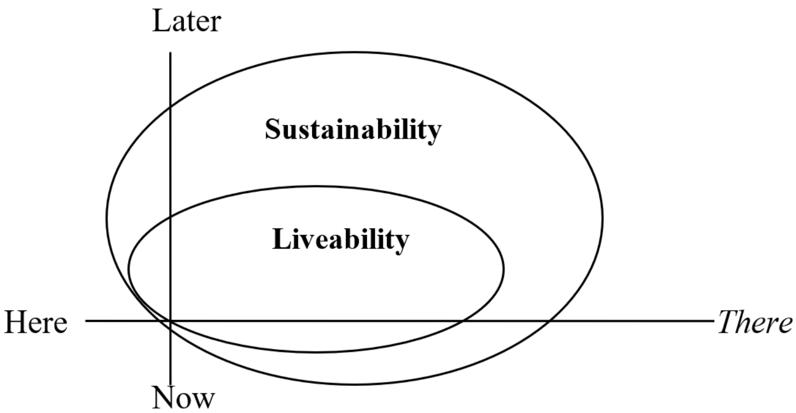

Figure 1. Liveability as a subset of sustainability (Lowe et al; 2013).

Davern et al. (2023) noted that because of a close connection between liveability and sustainability, the Australian Urban Observatory (AUO) saddled with measuring liveability of Australian cities amongst its mandate, has a comprehensive collection of aggregated, place-based urban liveability indicators linked to the Sustainable Development Goals, social determinants of health and urban planning. The study stated further that AUO was developed to translate research evidence to improve observation, understanding of inequities, and action through policy, planning and advocacy to create equitable, sustainable, healthy and liveable places. Also, Pandel et al. (2010), stated that a residential built environment is influenced by people's physical and mental health and is created through the interaction of lifestyle and the designated area. The study noted that the built environment's effects on people's physical and mental health have an effect on how well residents function, which in turn has an effect on how liveable the area is. Accordingly, AIA (2005), reasoned that since architects are in charge of creating the built environment, a sustainable framework for creating more liveable communities was developed giving architects the tools they need to put together the principles that

create more liveable communities by determining how well the living conditions in towns, cities, and neighbourhoods support people's health and safety.
Also, Khorrami et al. (2021), stated that the liveability standards in urban planning can significantly reduce the incidence of diseases like cancer and mental illnesses by improving urban lifestyle and socioeconomic status, which are major contributors to the rising burden of these conditions. Higgs et al. (2021) also stated that the development of liveable neighbourhoods can reduce important modifiable risk factors for diseases like cardio-metabolic disease, in part by increasing opportunities for physical activities. These findings are consistent with a growing body of research that suggests that liveable cities have the potential to promote sustainable lifestyles as well as health. Furthermore, according to Chi and Mak (2023), liveability is a crucial aspect of city planning and is essentially related to the general health of people and communities. It is evident from the above that liveability and sustainability are closely related to the point where liveability-determining factors in a housing environment can also be applied to sustainable housing.

2.3 The Liveability Principles in Sustainable Built Environment Design

Sustainability is the capacity to meet present-day requirements without jeopardizing the potential of future generations to do the same (Abbakyari et al., 2023; Star, 2023). A procedure is said to be sustainable if it can be repeated without having a negative impact on the environment by conducting activities in an extremely efficient and resource-conserving manner (Abbakyari et al., 2023). Sustainability requires balancing social, economic, and environmental needs in order to maximize the likelihood of maintaining human well-being over the long term. Thus, affordable building materials and technologies, local climate, and soil conditions should all be taken into account in sustainable design (Rusch and Best., 2014). The study went on to say that cultural influences are important because they affect how people use buildings and the systems they contain.
One way that sustainability is expressed is through sustainable housing, which is defined as housing that considers the long-term environmental, social, cultural, and economic balance of the housing stock and its occupants as well as the economic development of all income groups (Rusch and Best., 2014). Also, Abbakyari et al. (2023) pointed out that sustainable housing development is defined as housing that satisfies current needs without impairing the ability of future generations to satisfy their own needs. Further, sustainable housing should be affordable, and the planning and construction processes should be used to strengthen communities and the abilities and talents of individuals (Rusch and Best., 2014). In the study, housing is seen as key to sustainable development since housing is one of those fundamental social conditions that determine not only the quality of life and welfare of people but also that of places. Therefore, the location of homes, their quality of design and construction, and their integration into the social, cultural, and economic fabric of communities all have a significant impact on people's daily lives, health, security, and well-being. Because homes are physical structures with a long lifespan, these factors also have an impact on future generations. Additionally, Star (2023) stated that the following steps should be taken into account by the philosophical sustainable design approach: respecting natural systems (emulating the function of the element of nature); individualism (respecting the diversity of individuals); nature (ecosystem principle); the Cycle of Life (nature's balance); natural resources (preservation principle); and the process (holistic thinking principle). Also, Pane et al. (2023) indicated that sustainable housing is positively correlated with variables such as social, environmental, community development, and economic variables as such housing should promote environmental preservation, economic development, and social equality.

The Government of Ireland (2009) states that the goal of sustainable residential development is to create high-quality homes and neighborhoods that people genuinely want to live in, work in, and raise families in. These are places that will function well now and in the future for our children and their children's children. This suggests that the concept of sustainable housing involves the timely and economic integration of community facilities, schools, jobs, transportation, and other amenities with the housing development process (Government of Ireland, 2009). The study outlined design guidelines based on sustainability principles to include: "*Prioritise walking, cycling and public transport, and minimize the need to use cars; Deliver a quality of life which residents and visitors are entitled to* *expect, in terms of amenity, safety and convenience; Provide a good range of community and support facilities, where and when they are needed and that are easily accessible; Present an attractive, well-maintained appearance, with a distinct sense of place and a quality public realm that is easily maintained; Are easy to access for all and to find one's way around; Promote the efficient use of land and of energy, and minimize greenhouse gas emissions; Provide a mix of land uses to minimise transport demand; Promote social integration and provide accommodation for a diverse range of household types and age groups; Enhance and protect the green infrastructure and biodiversity; and Enhance and protect the built and natural heritage."*

Additionally, according to Abu Hassan et al. (2011), sustainable housing development should assess building forms for housing performance as well as measure the area developed in accordance with sustainability criteria, specifically environmental, social, and economic, as well as site/land uses, communication, and transportation. It is the type of housing that prioritizes enhancing well-being by comprehending people's needs in their living and working environments. It necessitates the integration of numerous sustainability factors, including location, construction materials, aesthetics, security, and well-being, all of which have an impact on present and future generations.

3. Materials and Methods

3.1 The Study Location

The study was conducted in Niger State, Nigeria; however, the housing estates selected for the study were located in Minna, Bida and Kontagora. Niger State is located in the North-Central geo-political zone of Nigeria (see Figure 2) and was created in April 1976 from the former North-western state, with Minna as the state capital. The State is placed between latitude $8^0$20" and $11^0$20" North and longitude $3^0$40" and $7^0$40" East. The total land area of the state is 76,363 square kilometres representing approximately 8% of the total land area of Nigeria. Niger State is bounded by the Federal Capital Territory at the southeast, Kaduna State at the North, Kwara and Kogi States at the North West. The State has a boundary with the Republic of Benin to the west. The State comprises of 25 Local Government Areas (LGAs) and is one of the largest States in Nigeria in terms of land mass. The State had a population of 3,311,375 persons by the provisional result of the 2006 National Population Census.

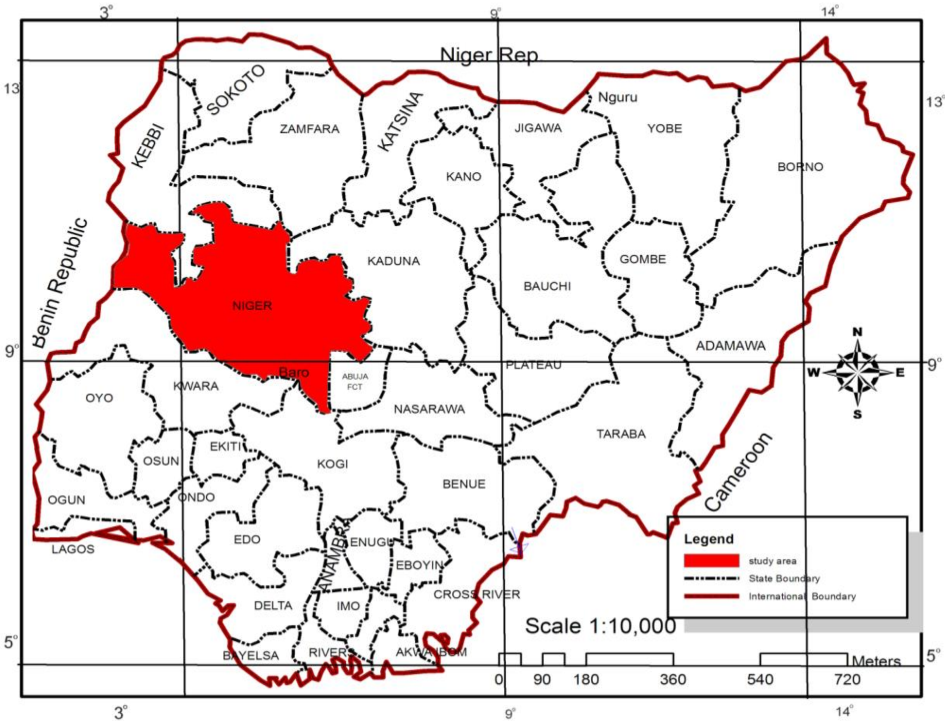

Figure 2. Location of Niger State in Nigeria.

3.2. Data Collection

The questionnaire, which included two parts and questions based on liveability indicators and dimensions identified from the literature, was the primary instrument utilized for data collection. The respondents' demographic characteristics, including gender, age, level of education, household size, and residential environment characteristics, such as dwelling unit size, tenure type, length of residence, and former housing type, were in the first section termed personal data and general information. The second section which was the data on the Residential Environment (shown in Table 1) was made up of questions about satisfaction assessments of the residential environment built on three-level hierarchical constructs of Housing Units—HU, Housing Estates—HE, and Housing Estate Neighbourhoods—HEN (Fernando and Coorey, 2018 used a 3-level construct). Each of the levels had a minimum Cronbach's alpha of 0.70.

Table 1: Three-level constructs with their liveability dimensions and indicators upon which questions were based.

Level Construct	Liveability Dimensions	Liveability Indicators Identified
Housing Unit	Sizes of spaces	Sizes of Plot, Living Room, Dining Room, Kitchen, Bedrooms, Storage, and Outdoor Activity Setback; separation between houses; House's distance from the road
	Physical quality of Building	Walls, ceilings, roofs, windows, doors, floors, and the provision of toilets.
	Ventilation and Natural Lighting	Natural ventilation and lighting in the living room, dining room, bedrooms, kitchen, and toilets/bathrooms.
	Noise Sources	Noise from vehicles, nearby buildings and neighbours' activities, noise from equipment.
	Affordability	Cost of property, rent for a house, water and electricity costs, the rate for land usage, and the price of public transportation.
Housing Estate	Public services available in the housing estate	Green Space for Relaxation; Children's Play Area; Internal Road Network; Car Parking provision; Walkways for Pedestrians; Police Post; Street Lighting; Estate's Medical Facilities; Shopping Centres/Corner Shops; Facilities for education in the Estate.
	Relationship, management, security, and land usage.	Mix Land Use, Housing Type Mix (Types of House Units), Management of Waste, Estate Maintenance, Management of Security, and Good Neighbourliness in the Estate
Housing Estate Neigh-bourhood	Distances from these neighbourhood facilities to the estate	Places of employment, educational institutions, medical facilities, shopping facilities and Local market, public libraries, recreation facilities, fire stations, and police stations
	Facilities in the neighbourhood	Local Public Space, Main Electricity, Water Supply, Public Transportation Access, Major Access Road, Pedestrian Walkway, Petrol Station, Repair Shop, and Public Toilets.
	Noise, security and identity	Noise in the neighbourhood, environmental cleanliness, distance from the highway, proximity to activities that produce noise, vegetation buffering the highway, and the state of public safety; Feeling of Identity and Belonging.

3.3 Sampling Technique

The sampling technique for the study was cluster sampling and systematic random sampling techniques. The cluster sampling first involved the grouping of the study area into three clusters in line with the Independent National Electoral Commission (INEC-the Nation's electoral umpire) senatorial division of Niger State. This resulted into Niger South (with 8 Local Government Areas-LGAs), Niger North (with 9 LGAs), and Niger East (with 8 LGAs) covering all the 25 LGAs the State is made up of. The next step was the selection of one town from each of the three clusters based on being the headquarters of the senatorial division, a local government headquarters and as well having the highest number of housing estates. This resulted in the selection of Minna, Bida, and Kontagora. Another cluster of housing estates with fully completed and occupied housing units was formed in each case from which four and two each were randomly selected in Minna (Four selections being the State

Capital), Bida and Kontagora. Finally, the selection of housing units within the selected housing estates was done using a systematic random sampling technique whereby the 1st, 3rd and 5th selections were done alternately along and across the streets until the entire housing estate was covered in each case.

3.4 Data Analysis

The first aspect of data analysis was carried out for the purpose of identifying the key liveability elements for public housing delivery. To successfully achieve this, the number of variables in the dataset generated in the study had to be whittled down using Hierarchical Cluster Analysis (HCA) and Factor Analysis (FA). So, HCA was used to group variables into clusters based on similarity and FA was employed to reduce the number of variables in each cluster to those variables that were responsible for the greatest proportion of variance in the data.

The Hierarchical Cluster Analysis (HCA) was used to determine key number of variable clusters based on similarity. Rather than use K-Means or Two-Step Clustering, HCA was the preferred technique because of its ability to handle the clustering of variables, as opposed to the other clustering techniques which are used primarily for the clustering of cases, not variables. The determination of the optimal number of clusters was carried out through a trial-and-error process. Solutions were sought for a range of clusters, beginning from three and ending at seven. Within this constraint, a number of other settings were varied. These included the cluster method and the interval measure. The choice was found to lie between three cluster methods (between-groups linkages, nearest neighbour and furthest neighbour). In the case of interval measures, the choice lay between the squared Euclidean distance and Pearson correlation.

Factor Analysis was then employed to reduce the number of variables in each cluster to a manageable number, representing those variables that were responsible for the greatest proportion of variance in the data. A simple procedure was followed; the appropriateness of the cluster for factor analysis was checked using the Kaiser-Meyer-Olkin (KMO) statistic; thereafter the extraction of factors was carried out based on their eigenvalues. The final stage consisted of identifying what variables best fit the factors that had been extracted and rotated. Extraction of factors employed the Principal Components Analysis (PCA) method, while extraction was based on the Direct Oblimin approach. This approach had a number of advantages over other comparable techniques such as Varimax; chief among these advantages was the production of a structure table which allowed the underlying structure of the data to be seen.

Finally, a further analysis on the identified liveability variables was done to determine the major variables which affect liveability. The Stepwise method of Multiple Regression Analysis (MRA) was employed to investigate the cogency of the identified liveability variables by measuring how well the variables predicted the Resident Perceived Satisfaction Index (RPSI) which was the average satisfaction of residents with the housing. MRA utilised a total of twenty-one (21) out of the 26 variables spread over 21 different models and excluded five of the variables which were outliers. The stepwise method of regression was used to develop 21 different models, which were then studied to see whether the variables could predict the RPSI, as well as which particular variables had better prediction ability.

4. Results and Discussions

4.1 The **Socio-economic Characteristics of Occupants:** -Given that 14% of respondents have completed secondary education and 85 percent have post-secondary education, the respondents' level of literacy is quite high indicating that the understanding of the questionnaire's content was quite good. According to the respondents' housing tenure, the majority (70 %) of them own their houses. 95 % of inhabitants have lived in the houses for at least two years or more, according to data on length of stay in the houses, which is a significant indicator of how well they know about the residential environment. On changes made to the housing units, up to 73 % of the occupants have made changes to their houses, showing the sizes of the houses in the estates have significantly changed from the initial plans. Rarely is aesthetics a factor in these modifications; they are typically made to accommodate changing family demands, particularly the addition of new spaces.

4.2The Result of HCA: Through minute study and comparison of both graphical and tabular outputs, the following combination was found to provide optimal results: the number of clusters was set at seven (7), Furthest neighbour was chosen as the cluster method while Pearson correlation was employed as the interval measure as shown in Figure 3. The HCA identified 26 variables out of 102 variables covering an average of 64% of the variability in the liveability of public housing.

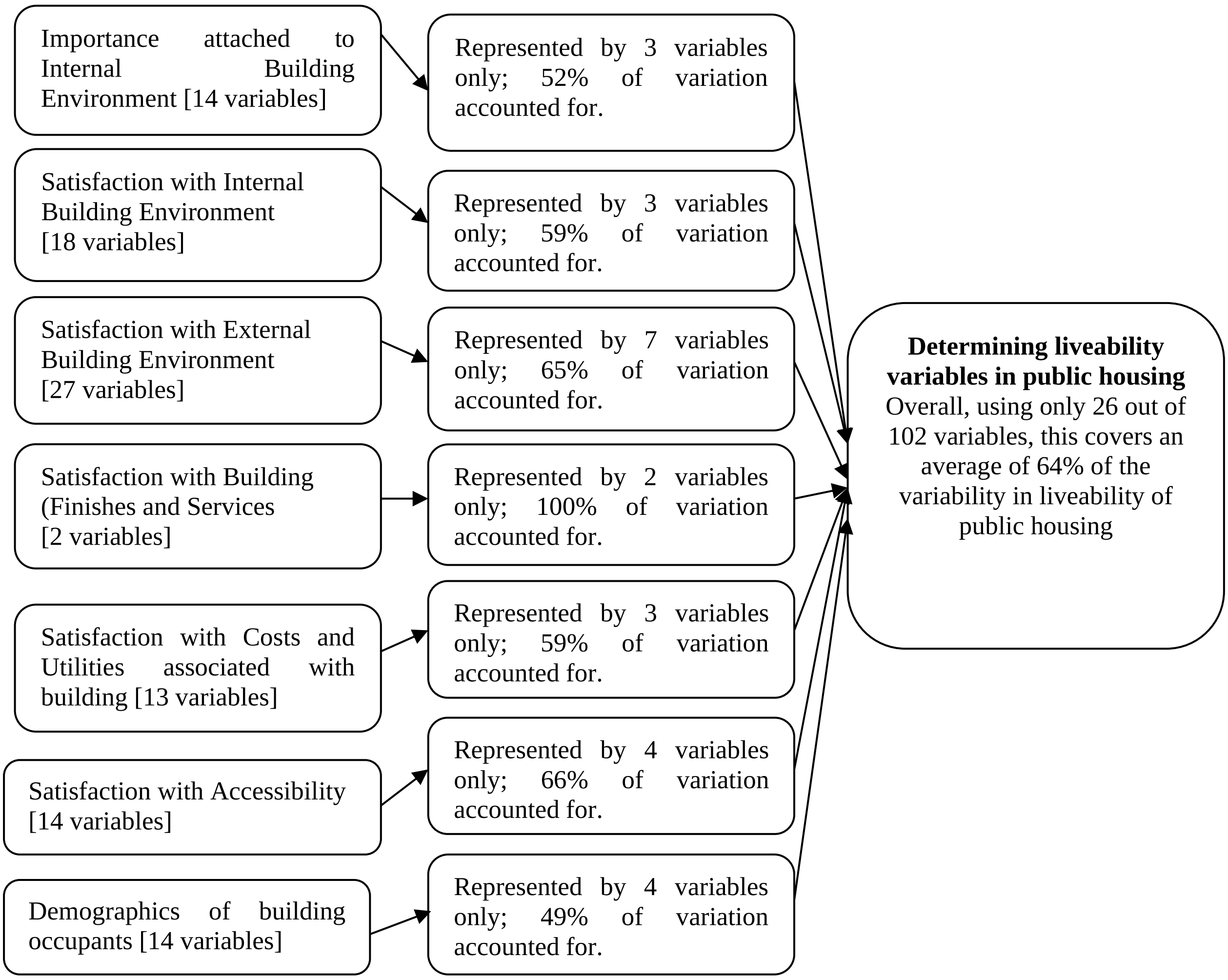

Figure 2. Clusters resulting from Hierarchical Cluster Analysis (HCA) conducted on 102 variables.

4.3 The Result of FA: -Since the FA was done cluster by cluster, the analysis for cluster 1 is briefly discussed as an example, while the pattern matrix tables for all the other clusters are shown revealing their key variables. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was above 0.6 for Cluster 1, while the significance value for Bartlett's Test of Sphericity was much lower than 0.5 (See Table 2). These were indications that the data were appropriate for factor analysis.

Table 2: KMO and Bartlett's Test for Cluster 1.

Test	Test parameters	Values
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.851
Bartlett's Test of Sphericity	Approx. Chi-Square	2955.974
	df	91
	Sig.	0.000

The result of the extraction of factors is presented in Table 3; three factors were extracted. The three factors cumulatively accounted for 52.413% of the variance in the data contained in Cluster 1. Inspection of the scree plot for Cluster 1 revealed that only three factors could be seen as being above the elbow; all other factors were below the elbow.

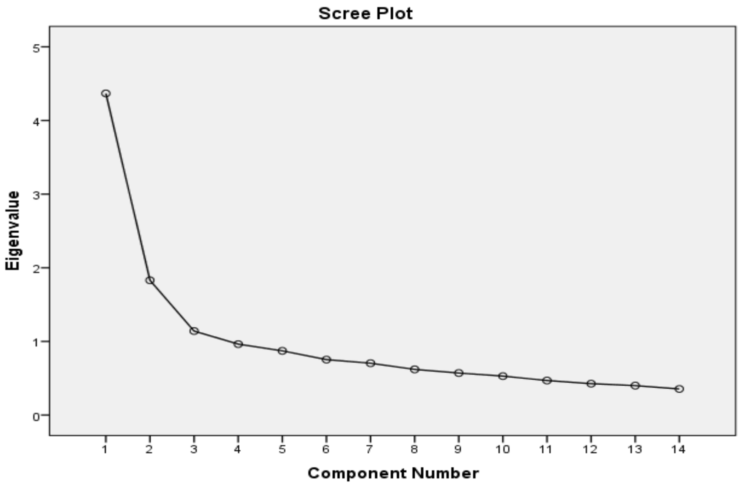

Figure 3. Scree plot for Cluster 1.

Rotation of the results obtained yielded the pattern matrix, which was presented as Table 3. This pattern matrix had been set to exclude small values that are less than 0.3 and to sort all values in order of size. The three variables that correspond to the factors extracted were easily identified as variables that possess the highest values within each column. To be eligible, a variable must also be minimally related to the other extracted factors. The three variables that match these criteria in Cluster 1 were distinguished by boldface type in the table, and are (i) Importance attached to Relaxation Space (0.777), (ii) Importance attached to Sleeping Area (0.836) and (iii) Importance attached to Outdoor Cooking Area (0.537).

Table 3: Pattern Matrix selecting the key variable in Cluster 1.

Variables	Component		
	1	2	3
Importance attached to Relaxation Space	**.777**		
Importance attached to Garden Space	.701		
Importance attached to Children's Play Area	.692		
Importance attached to Car Parking Space	.651		
Importance attached to Courtyard	.505		-.371
Importance attached to Storage Area			
Importance attached to Sleeping Area		**.836**	
Importance attached to Toilet/Bath Area		.818	
Importance attached to Indoor Cooking Area		.668	
Importance attached to Living Area		.615	
Importance attached to Guest Reception Area			-.840
Importance attached to Guest Sleeping Area			-.738
Importance attached to Outdoor Cooking Area			**-.537**
Importance attached to Dining Area		.323	-.537

Notes: Extraction Method: Principal Component Analysis
Rotation Method: Oblimin with Kaiser Normalization
Rotation converged in 8 iterations.

Table 4: Pattern Matrix selecting the key variable in Cluster 2.

Variables	Component		
	1	2	3
Satisfaction with Physical Quality of Walls	**.830**		
Satisfaction with Physical Quality of Windows	.814		
Satisfaction with Physical Quality of Doors	.796		
Satisfaction with Physical Quality of Floors	.791		
Satisfaction with Physical Quality of Roof	.734		
Satisfaction with Natural Lighting in Living/Dining		**-.824**	
Satisfaction with Natural Ventilation in Living/Dining		-.798	
Satisfaction with Natural Ventilation in Kitchen		-.779	
Satisfaction with Natural Ventilation in Bedrooms		-.779	
Satisfaction with Natural Lighting in Kitchen		-.749	
Satisfaction with Natural Lighting in Bedrooms		-.747	
Satisfaction with Natural Lighting in Toilets/Bathrooms		-.592	
Satisfaction with Size of Storage			**.823**
Satisfaction with Size of Setback for Outdoor Activities			.774
Satisfaction with Size of Dining Area			.693
Satisfaction with Size of Kitchen			.642
Satisfaction with Size of Plot			.571
Satisfaction with Size of Bedroom			.538

Notes: Extraction Method: Principal Component Analysis
Rotation Method: Oblimin with Kaiser Normalization
Rotation converged in 8 iterations.

Table 5: Pattern Matrix selecting the key variable in Cluster 3.

	Component						
	1	2	3	4	5	6	7
Satisfaction with Medical Facilities	**.708**						
Satisfaction with Maintenance	.693						
Satisfaction with Street Lighting	.637						
Satisfaction with Shopping Centres/Corner Shops	.628						
Satisfaction with Educational Facilities	.512					.470	
Satisfaction with Security Management	.438	.305					
Satisfaction with Waste Management	.396						
Satisfaction with Environmental Tidiness in Neighbourhood		**.756**					
Satisfaction with Vegetative Buffer from Highway		.693					
Satisfaction with Public Security in Neighbourhood		.660					
Satisfaction with Neighbourhood Noise		.648					
Satisfaction with Proximity to Noise Generating Activities		.613					
Satisfaction with Distance of Neighbourhood Highway		.518				.477	
Satisfaction with Noise from Equipment			**-.843**				
Satisfaction with Noise from Vehicles			-.795				
Satisfaction with Noise from Adjoining Buildings			-.745				
Satisfaction with Noise from Neighbours Activities			-.676				
Satisfaction with Green Area for Relaxation				**-.871**			
Satisfaction with Play Area for Children				-.823			
Satisfaction with Car Parking Facilities				-.768			
Satisfaction with the Distance of the House from the Road					**.808**		
Satisfaction with the Size of Living Area					.633		
Satisfaction with Distance between Houses					.626		
Satisfaction with Good Neighbourliness						**.697**	
Satisfaction with Sense of Belonging/Identity in Neighbourhood		.410				.628	
Satisfaction with Housing Type Mix							**.786**
Satisfaction with Land Use Mix				-.322			.507

Notes: Extraction Method: Principal Component Analysis
Rotation Method: Oblimin with Kaiser Normalization
a. Rotation converged in 8 iterations.

Reduction of the number of variables in Cluster 4

It was unnecessary to apply factor analysis to reduce the data in Cluster 4 because the membership of the cluster consisted of only two variables. These variables were (i) Satisfaction with the Physical Quality of the Ceiling, and (ii) Satisfaction with the Physical Quality of the Toilet Provision.

Table 6: Pattern Matrix selecting the key variable in Cluster 5.

Variables	Component		
	1	2	3
Satisfaction with Property Cost	**.871**		
Satisfaction with House Rental	.816		
Satisfaction with Water Rates	.655		
Satisfaction with Public Transport Cost	.608		
Satisfaction with Electricity Bills	.604		
Satisfaction with Land Use Charge Rate	.539		
Satisfaction with Major Access Road in Neighbourhood		**.890**	
Satisfaction with Internal Road Network		.884	
Satisfaction with Main Water Supply in Neighbourhood			**-.824**
Satisfaction with Local Public Space in Neighbourhood			-.736
Satisfaction with Main Electricity Supply in Neighbourhood			-.729
Satisfaction with Public Toilet in Neighbourhood			-.669
Satisfaction with Public Transport Access in Neighbourhood			-.601

Notes:Extraction Method: Principal Component Analysis
Rotation Method: Oblimin with Kaiser Normalization
Rotation converged in 8 iterations.

Table 7: Pattern Matrix selecting the key variable in Cluster 6.

	Component			
	1	2	3	4
Satisfaction with the distance of the Estate to a Fire Station	**.779**			
Satisfaction with distance of Estate to Public Library	.777			
Satisfaction with distance of Estate to Recreation Centre	.707			
Satisfaction with distance of Estate to a Police Post	.633			
Satisfaction with Police Post	.567			
Satisfaction with distance of Estate to Local Market		**.736**		
Satisfaction with distance of Estate to Shopping Centre		.685		
Satisfaction with Pedestrian Walkway		.524		.385
Satisfaction with distance of Estate to School			**-.857**	
Satisfaction with distance of Estate to Work Place			-.811	
Satisfaction with distance of Estate to Hospital		.490	-.660	
Satisfaction with Petrol Filling Station in Neighbourhood				**.832**
Satisfaction with Pedestrian Walkway in Neighbourhood		.342		.769
Satisfaction with Repair Workshop in Neighbourhood	.389			.581

Notes:Extraction Method: Principal Component Analysis
Rotation Method: Oblimin with Kaiser Normalization
a. Rotation converged in 8 iterations.

Table 8: Pattern Matrix selecting the key variable in Cluster 7.

	Component			
	1	2	3	4
Type of Religion	**.628**			
Number of People Living in House	.624			
Gender of respondent	-.623			
Length of Stay in the House	.458			
Type of Tenure of House	.436			.373
Age of Respondent		**.807**		
Marital Status of Respondent		.744		
Level of Education of Respondent		.481	-.376	-.343
Pervious House Type Occupied	-.405		-.637	
Name of housing Estate		.341	.628	
Size of House			**.566**	
Changes to House	.368		-.461	
Nature of Employment				**.672**
Number of Cars Owned				.648

Notes: Extraction Method: Principal Component Analysis
Rotation Method: Oblimin with Kaiser Normalization
a. Rotation converged in 8 iterations.

The overall structure of the variables extracted began from seven related groups of variables that collectively describe perceptions of liveability in public housing estates within the study area. Specific smaller collections of variables were then identified from each of these seven groups; this identification was based on these smaller collections of variables having almost the same power of describing the liveability status of public housing as the initial complete seven groups of variables as seen in the result of HCA conducted in Figure 2. This was because rather than collect information on 102 variables; an identical level of information could be obtained using only 26 variables as listed in Table 9

Table 9: Key Liveability variables resulting from HCA and FA conducted.

	Housing Components	Liveability Elements
1	Internal Building Environment	Spaces for Relaxation, Sleeping and Outdoor Cooking; quality of Walls, natural lighting in Living/Dining and Size of Storage.
2	External Building Environment	Provision/access to Medical Facilities, Green Area for Relaxation, Distance of House from Road, Environmental Tidiness; design must encourage Good Neighbourliness, Housing Type Mix and prevent Noise from Equipment,
3	Finishes & Services	Physical quality of Ceiling and Toilet Provision
4	Associated Costs and Utilities	Affordability of Property Cost, provision of Major Access Road in Neighbourhood, and Main Water Supply in Neighbourhood,
5	Accessibility	Reasonable distance of Estate to a Fire Station, Local Market, School, and Petrol Filling Station in Neighbourhood
6	Occupiers' demographics	Design affected by Type of Religion, Age of Respondent, Changes to House, and Nature of Employment

4.4 The Result of MRA: -The finding from the results in Table 9 is that all of the twenty-one models would predict the RPSI at relatively high levels of R^2. This revealed that all of the 21 variables were positively correlated with the RPSI, and could be used to predict 92.9% of the variation in the RPSI successfully.

Table 10: Result of MRA developed for strength of Liveability Variables.

Model	Independent variables	R	R^2	Change in R^2	Change in F-statistic
1	62	.604	.364	.364	338.221
2	62, 69	.726	.527	.162	202.245
3	62, 69, 85	.809	.655	.128	218.265
4	62, 69, 85, 039	.844	.713	.058	117.577
5	62, 69, 85, 039, 93	.868	.754	.041	98.610
6	62, 69, 85, 039, 93, 034	.888	.788	.034	94.616
7	62, 69, 85, 039, 93, 034, 91	.902	.813	.025	77.514
8	62, 69, 85, 039, 93, 034, 91, 54	.913	.834	.021	75.632
9	62, 69, 85, 039, 93, 034, 91, 54, 79	.923	.853	.018	71.639
10	62, 69, 85, 039, 93, 034, 91, 54, 79, 045	.931	.866	.013	58.283
11	62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97	.938	.879	.013	63.539
12	62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73	.944	.892	.012	65.299
13	62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73, 82	.949	.900	.009	50.194
14	62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73, 82, 037	.953	.907	.007	45.190
15	62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73, 82, 037, 88	.956	.914	.007	43.668
16	62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73, 82, 037, 88, 56	.959	.919	.005	34.338
17	62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73, 82, 037, 88, 56, 044	.961	.923	.004	31.341
18	62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73, 82, 037, 88, 56, 044, 77	.962	.926	.003	23.546
19	62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73, 82, 037, 88, 56, 044, 77, 042	.963	.928	.002	12.420
20	62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73, 82, 037, 88, 56, 044, 77, 042, 009	.964	.929	.001	8.487
21	**62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73, 82, 037, 88, 56, 044, 77, 042, 009, 003**	**.964**	**.929**	**.001**	**5.008**

Dependent Variable: RPSI (Resident Perceived Satisfaction Index)
Predictors: (Constant), 62, 69, 85, 039, 93, 034, 91, 54, 79, 045, 97, 73, 82, 037, 88, 56, 044, 77, 042, 009, 003

The identification of liveability elements for public housing resulted into six components which the built environment designers could adopt to ensure the liveability of public housing. These six components comprised of (i)Internal Building Environment—the focus here is on spaces for Relaxation, Sleeping and Outdoor Cooking; Ensure satisfactory quality of Walls, natural lighting in Living/Dining and Size of Storage; (ii) External Building Environment—this focuses on satisfactory provision/access to Medical Facilities, Green Area for Relaxation, Distance of House from Road, Environmental Tidiness; the design must encourage Good Neighbourliness, Housing Type Mix and prevent Noise from Equipment; (iii) Building Finishes and Services—the focus here should be on the satisfactory physical quality of Ceiling and Toilet Provision; (iv) Associated Costs and Utilities—this focuses on affordability of Property Cost, provision of Major Access Road in Neighbourhood, and dependable Main Water Supply in Neighbourhood. (v) Accessibility—the focus is on ensuring a reasonable distance of the Estate to a Fire Station, Local Market, School, and Petrol Filling Station in the Neighbourhood. The sixth component which is the Occupiers' demographics contains variables such as Type of Religion, Age of Respondent, Changes to House, and Nature of Employment that were eliminated by the MRA because they were outliers.

5. Conclusions

The study identified the liveability variables for the delivery of public housing in the study area. These variables contained within five components, are recommended for the built environment designers to adopt to ensure sustainable public housing in the study area. These 21 variables are contained within five components of External Building Environment; Internal Building Environment; Building Finishes and Services; Associated Costs and Utilities; and Accessibility. The research established that 73% of the residents have done one form of change in order to make the residential environment more liveable. The variables, if taken into account in the design and delivery of public housing, will result in sustainable housing stock that meets the satisfaction of the residents. This would also discourage unguarded alterations made to the housing units and environment once occupied by the owners.

Therefore, it is recommended that public housing delivery in the study area requires attention to be paid to environmental users' requirement before the professionals' expertise are brought to bear.

Finally, the dimensions and indicators that captured the concept of liveability in the study area are revealed in the study thereby providing literature to buttress the existing efforts on liveability studies in the area. This also gives guidance to the players in the environment as to what the liveability requirements of the residents are with respect to residential provisions.

The study also reveals a very efficient method for satisfaction assessments of the residential environment. This assessment method is based on a three-level hierarchical constructs of Housing Units, Housing Estates, and Housing Estate Neighbourhoods. This way, assessments of the residential environment can effectively be carried out anywhere.

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Conflict of interests

The authors declare no conflict of interest.

Data availability statement

The data that support the findings of this study are available.

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