

# Exploration of Housing Adequacy for City Resilience Using Principal Component Analysis

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Received June 9, 2020; Revised November 2, 2020; Accepted November 11, 2020

## Cite This Paper in the following Citation Styles

(a): [1] Enobong B. Equere, Eziyi O. Ibem, Oluwole A. Alagbe, "Exploration of Housing Adequacy for City Resilience Using Principal Component Analysis," *Civil Engineering and Architecture*, Vol. 9, No. 5, pp. 1659-1666, 2021. DOI: 10.13189/cea.2021.090534.

(b): Enobong B. Equere, Eziyi O. Ibem, Oluwole A. Alagbe (2021). *Exploration of Housing Adequacy for City Resilience Using Principal Component Analysis*. *Civil Engineering and Architecture*, 9(5), 1659-1666. DOI:10.13189/cea.2021.090534.

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**Abstract** Public housing schemes in developing countries like Nigeria have been assessed from different perspectives. In spite of this, housing development strategies are yet to efficiently meet the needs of contemporary urban society, especially those needs associated with rapid influx of human population in countries of the Global South. Rapid population growth impacts on the social, economic and environmental fabrics of the community. In the same vein, housing for resilient city is said to offer characteristics that would enable housing to relate efficiently with the socioeconomic, physical and environmental demands of the city. However, studies on assessment of housing for city resilience are rare. This study aimed to investigate the environmental characteristics of mass housing schemes that will enhance the adequacy of residential neighbourhoods to efficiently absorb the adverse impacts of rapid urban population growth and promote city resilience. A cross sectional survey of 345 residents in seven selected public housing estates in Abuja, Nigeria was carried out using a structured questionnaire designed from the findings of the review of literature. The data were analysed using descriptive statistics and principal component analysis. The results revealed that the participants felt that housing units' features were generally adequate, while the neighbourhood environmental features were grossly inadequate for city resilience. The four main dimensions of housing adequacy evaluation were the sizes of service provision, plots for houses, availability of utilities, neighbourhood and maintenance facilities; provision of

spaces for study room, guest room, laundry and home-based enterprise in dwelling units; the size of housing units and interior spaces; and the provision of car parks, security and educational facilities in the housing estates. The study highlights the specific areas of priority attention in public housing provision in order to ensure that housing developments promote cities resilient to rapid population growth.

**Keywords** Housing Adequacy, City Resilience, Principal Component Analysis, Rapid Population Growth, Survey

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## 1. Introduction

The role of housing in providing accommodation for the world's population cannot be over emphasized, especially in the face of rapid increase in the number of people living in cities across the world. It is projected that about 68% of the world population will live in urban areas by 2050 [1], an increase from the current 55%. About 90% of that increase is expected to take place in Asia and Africa [1]. Specifically, in Nigeria, the growth rate projections have been about 2.56% per annum [2]. The population of the Federal Capital Territory (FCT) is also increasing rapidly with an estimated rate of 4.0 % per annum [3]. The United Nations Report [4] and the Nigerian Demographic Profile (NDP) [5] indicate that the Nigeria's housing deficit is

about 17 million units, while the Nigeria National Bureau of Statistics (NBS) reported that as at 2013, the estimated housing supply was put at between 12 and 14 million housing units [6]. This huge housing supply deficit has partly contributed to the proliferation of informal housing, unplanned settlements and slum dwellings in urban areas and cities, especially in countries in the global South [7]. These developments can contribute to the exacerbation of congestion, overcrowding, crime, waste and pollution and rapid spread of contagious diseases such as Coronavirus Disease (COVID-19) is currently ravaging the world. In view of the above, a lot of research attention has been focused on evaluating adequacy of public housing in meeting the needs of the occupants like several studies have done in the past [5, 8, 9].

Notably, housing adequacy assessment deals with evaluation of how housing attributes are perceived by individuals and the standard reference to which such attributes are compared [10]. For this study, such standard references are environmental characteristics of housing for city resilience as evidenced in the review of literature. Housing Adequacy has also been categorized as qualitative and quantitative adequacy [11]. Physical adequacy of housing is measured to assess not just the extent to which the housing stock meets the standard of a decent home, but also to provide sustainable living environment [12]. Most studies on the evaluation of public housing have focused on adequacy of dwelling units, neighbourhood environment, services and infrastructure as well as the quantity of existing units compared to the demand as means of developing efficient and effective housing delivery strategies. It is however observed that in spite of these research efforts and the practical steps taken in some cases to address identified areas of inadequacies, mass housing schemes in many cities in the developing countries are yet to adequately meet the requirements that would enable them effectively absorb the adverse impact of rapid population growth currently experienced. This situation can be attributed to the dearth of research on housing for city resilience to rapid population growth. In view of the submission by [13] that provision of housing that better responds and adapts to the socio-economic, physical and environmental stresses (such as rapid population growth) the city will face, increases the city's capacity for resilience, empirical studies are needed to uncover aspects of mass housing provision that will help enhance the capacity of urban areas to cope with the challenges associated with rapid population growth.

It is against this background that this study sought to examine the adequacy of the physical and environmental attributes of housing in absorbing the impact of rapid population growth in Abuja, Nigeria. This was in order to make suggestions on those aspects of mass housing provision that should be strengthened to improve city resilience to rapid population growth. The research was guided by two key research questions. These are:

1. To what extent are the housing units and neighbourhood characteristics in the studied public housing estates adequate in promoting resilient city?
2. What are the dimensions of housing adequacy assessment as they relate to the capacity to cope with rapid population growth in the selected housing schemes in the study area?

This study is considered valuable in improving understanding of the extent to which current housing development strategies are providing housing environments that are adequately meeting the needs of the end users. It also makes contribution to knowledge by revealing specific areas that must be given more attention in mass housing delivery in ensuring that housing developments contribute to fostering resilient cities, especially in the developing countries in sub-Saharan Africa.

## 2. Literature Review

The review of literature covers the concept of housing for resilient cities and the environmental characteristics of housing for resilient cities.

### 2.1. Concept of Housing for Resilient Cities

Resilient cities are those large urban settlements that are able to develop strategies for coping with shocks and stresses to their social, economic and environmental challenges [14, 15]. In addressing these shocks and stresses, a city becomes adequately prepared to respond to adverse events or threats, and better positioned to deliver basic functions to all the populations [16]. Furthermore, [17] asserted that housing that would promote city resilience would offer characteristics that enable it relate efficiently with such social, economic and environmental exigencies of the city. It was based on this premise that this study sought to identify the underlying dimensions of housing characteristics that can promote city resilience.

Housing is an integral part of human settlement that fulfils basic need and has a profound impact on the quality of life, health, welfare as well as productivity of man [18]. Conventional housing designs, therefore, are primarily configured to shelter, preserve and protect lives and properties of the occupants, as well as achieve conducive spatial provisions for carrying out functions for which such housing was designed. However, Vale *et al.* [17] posited that resilient housing is critically distinct from housing for resilient cities. While resilient housing would entail characteristics that would offer efficiency in the building itself, housing for resilient city offers characteristics that would enable housing relate efficiently with the socio-economic, physical and environmental demands of the city. This study considered such stress associated with the impact of rapid population growth on the physical and environmental fabrics of the city, and how it influences

housing that could promote city resilience. This study, therefore, sought to address Laddaga's [19] assertion that contemporary cities try to satisfy the urgent need of providing shelter for an increasing urban population, but are not adaptable enough to issues or attendant tendencies of housing at large.

## 2.2. Physical and Environmental Characteristics of Housing for Resilient Cities

The literature reviewed identified features and environmental characteristics of housing that contribute to city resilience in the face of rapid population growth. With rapid population growth, the greatest environmental demand identified is related to the availability of land to meet the basic needs of housing provisioning. Residential land is the section of the city or urban area apportioned for residential purposes and other amenities that would support housing. Land use planning provides the basis upon which a locality could establish what its pattern of land use ought to be [20]. Such planning can also be utilized to assess the existing development patterns and project growth corridors. A guide for the allocation of land in residential neighbourhoods [20] was presented as being 50%-60% for residential housing plots; 15%-25% for roads and streets; 3%-5% for commercial activities; 2%-3% for services industries; 6%-8% for outdoor recreation; and 10%-15% for utility facilities.

Appropriate land use patterns can be engaged in determining densities that can sustain the envisioned levels of consumption [21]. This suggests that poor land use appropriation could result in faulty density projections that may encourage congestions, stress on infrastructure and services, housing shortages, poor housing quality resulting from overcrowding and development of settlements on unsuitable land and imbalance in provision of infrastructure. All of these are known to be inimical to the quest to achieve city resilience, especially, in areas or regions such as developing countries, with marginal resources to meet the service supply needs of a majority of the citizens. Density is a critical factor in the viability of cities, irrespective of their nation's level of development. Moreover, a strong community spirit, which is a resilient characteristic, is linked to densities [21]. Density is a numerical measure of the concentration of individuals or physical structures within a given geographical unit [22]. In a residential area, density is given as the number of persons per hectare (pph). Approved density per land area is considered desirable from the stand point of public health and safety [23]. In addition, density is also considered as the level that determines the quantum of support services to be provided for the residents. It is perennially known that a smaller population will not support essential services [21], while too dense population may be advantageous in terms of economy of scale but can put more pressure on the services provided.

While people-density may result in overcrowding, loss of privacy, competition for use of space and facilities and

in turn create social conflicts, Cheng [22] argued that with proper management and organization, the closeness that arises from high people-density can be used to facilitate social interaction and promote good neighbourhood relations, which are characteristics of housing for resilience; and the increased building density can help mitigate the problem of overcrowding. High building density which can allow more open space for communal use may also help to establish social interaction and consolidate the sense of community. Design attributes such as the overall size of buildings, space between buildings, variety in building facades and visual access to open and green space are acknowledged as contributing factors to the perception of density, in what is termed perceived density [22]. Perceived density emphasizes the interaction between the individual and the environment, and these can be controlled through the built form and architectural features. In the face of rapid population growth, the relationship between the building density and urban form becomes crucial.

Furthermore, as population increases so does the need for infrastructure that would service the housing for the population. Such housing infrastructure would include, access roads, water services, sewage and waste disposal, gas distribution, (where applicable), electricity distribution and so on. The concerns for adequate future services, appropriate infrastructure provision and the construction of well-designed homes are fundamental when considering housing planning application [24]. More people imply more households, more roads, more cars and more demand on available services. From findings of the literature reviewed, some of the impacts of rapid population growth on housing are expressed in the level of adequacy of the housing units, neighbourhood environmental features, land use, density, and infrastructure distribution; which in turn influence resilience of the residential environment to the impact of rapid population growth.

## 3. Research Methods

The study reported in this paper is part of a larger research project conducted to evaluate public housing for resilience to rapid population growth in Abuja, Nigeria. The data used in this study were derived from a section of the questionnaire for the larger research. The research design was a cross-sectional survey and the research population comprised 7690 housing units from seven estates surveyed, namely: Maitama, Asokoro, Kado, Gwarimpa II, Gwarimpa Team 7, Old Karu and Kubwa (Phases 1, 2, 3, and 4) Estates, all in Abuja, the Federal Capital city of Nigeria. The Yamane [25] formula was used in determining the sample size for the study as follows:

$$n = \frac{N}{(1 + Ne^2)} \quad \dots \text{Equation (1)}$$

$$n = \frac{7690}{(1 + 7690 + 0.05^2)} = 380$$

Where 'n' = Sample size, 'N' = Population size, 'e' = Margin of error = 95% A sample size of 380 was obtained. Adjustment was made for non-response with a non-response rate of 5%, to arrive at the final sample size of 400.

The data collection instrument used was a questionnaire designed by the researchers. Specifically, characteristics of housing for resilient city were identified from the review of literature and used in the development of the questions included in the questionnaire. The literature review revealed 13 variables for assessing the adequacy of housing units' features and 15 variables for the adequacy of the neighbourhood environmental features. In the survey, respondents were asked to indicate the level of adequacy or inadequacy of the variables on a 5-point Likert-type scale of Very Inadequate=1; Inadequate=2; Not Sure=3; Adequate=4; and Very Adequate=5. The internal consistency of the 28 variables investigated was ascertained using Cronbach alpha reliability test. A value of 0.96, greater than the acceptable value of 0.70, was obtained.

The study involved the administration of structured and pre-tested questionnaire to the heads of the households of the estates surveyed. One copy of the questionnaire was administered by hand to the household heads or adult representatives found in the dwelling units at the time the survey was conducted. All 400 copies of questionnaire were distributed. A total of 345 copies were returned and analysed. This represented around 86.3% response rate.

In the analysis of the data, the 28 variables were first evaluated using descriptive statistics to show the mean adequacy scores, representing the average adequacy score given by all the respondents. The 28 variables were further subjected to factor analysis. A prior suitability of the survey data for this analysis was ascertained by conducting the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and the Bartlett's Test of Sphericity. The KMO test produced 0.94, which is above the acceptable value of 0.6, while the Bartlett's Test of Sphericity was significant at 0.000. Therefore, factor analysis is appropriate. Factor extraction using Varimax Rotation method with Kaiser Normalization was used to identify the dimensions of housing adequacy assessment in the research. The principal component analysis (PCA) which is a variant of factor analysis for ordinal/ interval dataset was used here because it helped to reduce the dimensionality of variables in a data set, in order to identify the correlation and patterns among features in that data set. This is so that the variables can be transferred in to a data set of significantly lower dimension without loss of any information. It is presumed that accurate housing assessment depends on the correct analysis of the contributing factors. The use of principal component analysis made it possible for the different variables to be aggregated and correlated with one another under the various dimensions.

## 4. Results

### 4.1. Respondents' Perception of Housing Adequacy

The results of the respondents' perception of adequacy of housing units' and neighbourhood environmental features in their estates are presented in Tables 1 and 2. Based on mean scores and standard deviation of the variables, the variables of most concern to the respondents present the highest mean values. It can be seen that on the one hand, of the 13 variables used to assess the adequacy of features of housing units (Table 1), the five highest variables of most concern to the respondents (and their mean values) were the overall size of housing units (3.64), size of bedrooms in the house (3.61), number of toilets and bathrooms (3.49), the number of bedrooms in the house (3.46) and the size of kitchen (3.46). On the other hand, the size of storage space, available space for study and provision of visitor/ guest room were of the least concern to the respondents, having mean values of 3.11, 2.93 and 2.91 respectively.

**Table 1.** Descriptive statistics of adequacy of housing units' features

Adequacy of Housing Units' Features	Mean	Std. Deviation	Ranking
Overall size of housing unit	3.64	1.11	1
Size of bedrooms in the house	3.61	1.09	2
Number of toilets and bathrooms	3.49	1.12	3
Number of bedrooms in the house	3.46	1.12	4
Size of kitchen	3.46	1.28	4
Size of children play area	3.40	1.26	5
Circulation area	3.38	1.31	6
Space for laundry room	3.37	1.22	7
Size of outdoor cooking area	3.25	1.28	8
Space for business activity	3.23	5.32	9
Size of storage space	3.11	1.28	10
Space for study	2.93	1.24	11
Visitors / guest room	2.91	1.30	12

For the 15 variables used to assess the level of adequacy of the neighbourhood environment features, the results in Table 2 show the mean of the most adequate features. The five highest variables of most concern to the residents (and their mean values) are the sizes of plots for houses (3.89); adequacy of potable water supply (3.87); roads and streets (3.72); available places of worship (3.62), and frequency of waste disposal (3.61). The three least adequate neighbourhood features were the availability of healthcare facilities, maintenance facilities, and available recreational and sporting facilities, having mean values of 2.97, 3.14 and 3.23, respectively.

**Table 2.** Descriptive statistics of adequacy of neighbourhood environmental features

Adequacy of the Neighbourhood Environment Features	Mean	Std. Deviation	Ranking
Sizes of plots for houses	3.89	5.25	1
Potable water supply	3.87	5.31	2
Roads and streets	3.72	1.09	3
Places of worship	3.62	1.23	4
Frequency of waste disposal	3.61	1.13	5
Power supply	3.61	5.30	5
Security of lives and property	3.55	1.20	6
Pedestrian walkways	3.52	1.12	7
Car parks	3.47	1.28	8
Educational facilities in the estate	3.47	1.20	8
Shopping facilities provided	3.45	1.19	9
Space for social and religious activities	3.37	1.19	10
Available recreational/ sporting facilities	3.23	5.30	11
Maintenance of facilities	3.14	1.18	12
Healthcare facilities	2.97	1.21	13

**Table 3.** Presentation of results of principal component analysis

Dimensions of Perception of the Environmental Features of the Estate	Factor Loadings	Eigen value	% of Variance	Cum %
<b>Dimension 1: Adequacy of size of service and children play areas, plots for houses, availability of utilities and neighbourhood facilities and maintenance facilities</b>		9.508	33.957	33.957
Adequacy of size of kitchen	.709			
Adequacy of size of outdoor cooking area	.708			
Adequacy of size of storage space	.817			
Adequacy of size of children play area	.589			
Adequacy of sizes of plots for houses	.658			
Adequate pedestrian walkways	.821			
Adequate roads and streets	.808			
Adequacy of available recreational/ sporting facilities	.718			
Adequacy of maintenance of facilities	.825			
Adequacy of frequency of waste disposal	.631			
Adequacy of potable water supply	.812			
Adequacy of power supply	.739			
Adequacy of shopping facilities provided	.821			
Adequacy of space for social and religious activities	.739			
Adequacy of healthcare facilities	.474			
Adequacy of places of worship	.467			
<b>Dimension 2: Adequacy of space for study, circulation, guest, laundry and home-based enterprise</b>	.855	4.876	17.413	51.370
Adequacy of space for study	.837			
Adequacy of circulation area	.776			
Adequacy of visitors / guest room	.779			
Adequacy of space for laundry room	.739			
Adequacy of space for business activity	.855			
<b>Dimension 3: Adequacy of size of housing unit and interior spaces</b>		2.906	10.379	61.750
Adequacy of overall size of housing unit	.774			
Adequacy of number of bedrooms in the house	.871			
Adequacy of size of bedrooms in the house	.881			
Adequacy of number of toilets and bathrooms	.834			
<b>Dimension 4: Adequacy of car park, security and educational facilities</b>		2.877	10.275	72.025
Adequacy of car park	.747			
Adequacy of security of lives and property	.691			
Adequacy of educational facilities in the estate	.62			

#### 4.2. Dimensions of Adequacy of Housing Evaluation by the Residents

The principal component analysis of the 28 variables of housing units' and neighbourhood environmental features extracted four main dimensions (components) based on eigenvalue of 1. The result in Table 3 displays the total variance accounted for by the four dimensions that have eigenvalue of 1 and above to be around 72%. Table 3 also shows the summary of the names, factor loadings, Eigenvalue and percentage of variance for each of the four dimensions (components) identified.

Examination of the result in Table 3 reveals the contributions of individual dimensions (components). The first dimension is adequacy of size of service and children play areas, plots for houses, availability of utilities and neighbourhood facilities, and maintenance facilities. This dimension accounts for around 34.0% of the variance in the 28 variables included in the analysis. It has 16 of the 28 variables loaded on it; and hence it is the dimension with the highest contribution to understanding the adequacy of housing units' and neighbourhood environment features in all the estates put together. The second dimension is adequacy of space for study, circulation, guest, laundry and home-based enterprise in the dwelling units. This second dimension accounts for around 17.4% of the variance in the 28 variables, and has five variables loaded on it. It is the next most important dimension of housing adequacy. The third most important dimension is adequacy of the size of housing unit and interior spaces, which accounts for around 10.4% of the variance in the 28 variables, with four variables loaded on it. The least important dimension is adequacy of car park, security and educational facilities, explaining around 10.3% of the variance in all the variables, and with three variables loaded on it.

### 5. Discussion

With regards to the adequacy of the housing units and neighbourhood environmental features, the respondents evaluated the sizes of their living space more adequate than other auxiliary spaces like guest room or study spaces. In addition, the sizes of plots of houses were considered more adequate than health care facilities provided on the estates. The findings of this study are consistent with the study by [26] showing that residents in public housing were mostly satisfied with the internal layout of rooms in their houses. In addition, Bonnefoy [27] argued that adequacy of housing features should be determined together with the particular needs of the people concerned, bearing in mind the prospects for gradual development. In other words, the type of housing provided should be matched with the needs of the people.

The principal component analysis shows that the variables of environmental characteristics of housing that would efficiently absorb rapid population growth and

promote city resilience, can be explained in four dimensions: (i) adequacy of size of service and children play areas, plots for houses, availability of utilities and neighbourhood facilities and maintenance facilities, (ii) adequacy of space for study, circulation, guest, laundry and home-based enterprise, (iii) adequacy of size of housing unit and interior spaces, and (iv) a adequacy of car park, security and educational facilities. These results indicate that these are the most important aspects of the estate environmental features, which can promote city resilience that the residents considered in their evaluation adequacy of physical features of their estates. The implication of this is that the residents of the estates will more likely consider the estate adequate if the sizes of the service areas, the children play areas, the services facilities, and estate maintenance facilities are given adequate attention at the development and operation phases of the estates. It is evident from the result that the residents considered their social space and adequacy of public facilities in the estates as having higher influence than the personal space, which is the third dimension of overall house type, size of bedroom and number of toilets. The dimension with the lowest influence is the fourth, which is related to adequacy of car parks, security of lives and property and educational facilities. This reveals that the level of migrants into the cities does not regard the provision of car parks or the security of lives and property as immediate necessities of their housing needs.

In comparing the dimensions of adequacy of housing in this study with a similar study of selected public housing in Ogun state Nigeria on perception of housing adequacy as perceived by the residents sampled, the four identified dimensions identified were: 1) ambient condition of interior spaces, adequacy of security, utilities and neighbourhood facilities 2) social infrastructure 3) level of privacy and size of sleeping areas 4) living and dining areas in the residences [8]. It is obvious from these two studies that even though the dimensions of housing adequacy extracted in both studies are of similar components, the order or degree of importance of the components differs in both studies.

The current study shows that though the dimensions of housing adequacy evaluation using variables for city resilience may consist of the same components as dimensions of housing adequacy evaluation for other purposes, these components do not appear in the same order or degree of importance. For instance, even though the attributes of housing units were identified as a first dimension in the study of selected estates in Ogun State, yet they were presented as the third component in this study. Also, while the residents of the selected estates in this study considered estate maintenance facilities and management as dimensions of housing adequacy, the residents sampled in the study by [8] did not consider this factor for adequacy. The order of presentation of the dimensions of housing adequacy evaluation revealed in the

current study gives an indication of areas of priority to be addressed in public housing delivery in order to promote cities resilient to rapid population growth.

## 6. Conclusions

The study investigated adequacy of housing for city resilience to the impact of rapid population growth in seven selected public housing estates in Abuja, Nigeria. Based on the findings, these following two main conclusions are made. First, the residents of the estates who participated in the survey perceived their housing units' characteristics as being adequate, while the neighbourhood characteristics were evaluated as being inadequate on coping with the impact of rapid population growth within and around the neighbourhoods.

Second, the dimensions of evaluation housing adequacy for city resilience are noted to be: (i) size of service and children play areas, plots for houses, availability of utilities and neighbourhood facilities and maintenance facilities, (ii) space for study, circulation, guest, laundry and home-based enterprise, (iii) size of housing unit and interior spaces, (iv) car park, security and educational facilities.

This study implies that the characteristics of the dwelling units in mass housing schemes investigated have adequate capacity in coping with the impacts of rapid population growth. On the contrary, the neighbourhood environment lacks the capacity to cope with increase in the number of people residing the estates, hence, this aspect of housing provisioning is lagging behind when it comes to promoting city resilience. This calls for adequate attention to the neighbourhood environments of mass housing schemes.

Another implication of this study is that the four key dimensions identified are aspects the residents understand adequacy of housing in coping with the impacts of rapid population growth of the fabrics of residential neighbourhoods in cities like Abuja, Nigeria. Therefore, to ensure that mass housing schemes contribute maximally to promoting city resilience to the rapid population growth, housing developers should pay adequate attention to the aspects identified in this research. In this regard, the most important aspects of housing for resilient city include the provision of adequate service areas; children play area, utilities, neighbourhood facilities and maintenance of facilities in the estates.

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