

**Assessment of Physical Vulnerability Indicators' for Developing Adaptive Architectural Design Strategies in Flood-prone Residential Areas of Lagos, Nigeria**

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**Being a PhD Thesis Submitted to the Department of Architecture, Faculty of Environmental Design and Management, Lead City University, Ibadan, Oyo State, Nigeria**

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## Certification

This is to certify that, Saudat Oluwakemi AJIJOLA with matriculation number LCU/PG/003262 carried out this research work titled „Assessment of Physical Vulnerability Indicators for Developing Adaptive Architectural Design Strategies in Flood-prone Residential Areas of Lagos, Nigeria“ in the department of Architecture, Faculty of Environmental Design and Mangement, Lead City University, Ibadan, Oyo State, for the award of Doctor of Philosophy Degree (PhD) in Architecture. The thesis is an outcome of an independent and original work. I have duly acknowledged all the sources from which the ideas and the extracts have been taken. The project is free from any plagiarism and has not been previously submitted to any other institution.

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(Head of Department)

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**Date**

## **Dedication**

With the greatest honour, glory and adoration to God Almighty, I dedicate this work to my Son, Heritage, Olasunkanmi; and my loving parents, Alhaji Adetunde Mojeed Ajijola and Mrs. Rosemary Ajijola, God bless them.

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To God, be the glory.

## Abstract

Households in urban flood-prone areas are particularly vulnerable to flood disaster. Therefore, adaptive-design responses based on vulnerability assessment are needed to mitigate growing risk and associated impacts. This study examines critical indicators influencing vulnerability of houses in the flood-prone areas of Kosofe, Lagos, Nigeria, by assessing household socio-economic characteristics, flood attributes, Neighborhood and architectural design characteristics of dwellings, and adaptive capacities exhibited. The study which, aimed to fill gaps in empirical research on contextual factors affecting exposure, susceptibility, and resilience of flood-prone households in Nigeria, was underpinned by vulnerability, social-ecological systems and adaptive capacity theories. A cross-sectional exploratory sequential research design was adopted. Common themes emerging from focus-group discussions were used in the questionnaire formulation. The survey was conducted among 385 households in the study area, with a return rate of 84.15%. Opinion survey of 35 experts also served as a guide in selecting relevant indicators. IBM SPSS statistics was used for the descriptive and factor analysis, relative importance indexes and linear regression. With a high  $R^2$  value = 0.975, explaining approximately 98% of variance. The result of linear regression analysis shows that flood depth ( $P=0.000$ ), building elevation ( $P=0.000$ ), absence of surrounding vegetation ( $P=0.000$ ), drainage system ( $P=0.000$ ), low income ( $P=0.000$ ), presence of household coping capacities ( $P=0.000$ ), flood duration ( $P=0.02$ ) and quality of buildings ( $P=0.04$ ), with a P value less than 0.05, have the greatest impact on physical flood vulnerability. Therefore, this study concludes that the most robust adaptive architectural design strategies for disaster risk reduction in flood-prone residential neighbourhoods are embedded within the identified physical flood vulnerability indicators: flood depth, building elevation, surrounding vegetation, drainage system, low income, household coping capacities, flood duration and building quality. It is thus recommended that these critical indicators be carefully considered when developing an adaptive architectural design framework for risk reduction in flood-prone areas.

**Keywords:** Adaptive Capacity, Exposure, Flood risk, Physical Vulnerability, Resilience, Susceptibility

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# Chapter One

## Introduction

### 1.1 Background to the Study

It is generally accepted that the interferences of human with the climate system is a main cause of climate change and the observed global warming<sup>1, 2</sup>. Given the inseparable link between climate change and development, the Intergovernmental Panel on Climate Change (IPCC) warns of a potential increase in the frequency and intensity of extreme weather events, such as extreme temperature changes, heavy rains and storms<sup>3, 4</sup>. Today, the devastating effects of climate change, together with continuous rapid urbanization, poor urban growth and land use, especially in developing countries, are the major causes of natural and man-made disasters such as sea-level rise, floods, tsunamis, landslides, earthquakes, cyclones, and erosion<sup>5, 6</sup>. Foreexample, hydro-meteorological hazards, including floods and droughts, are considered the most common hazards in Africa<sup>7</sup>.

Globally, floods are recognized as the most common disaster threatening urban security and community wellbeing. It has devastating socio-economic and psychological consequences such as casualty, death, damages to property and infrastructure, displacement of people from their homes, financial loss and loss of livelihoods<sup>8</sup>. Over 50% of all deaths and over 30% of global economic losses from natural disasters are caused by floods<sup>9</sup>. Aqueduct floods, a modern global tool for measuring flood risks, vulnerability and associated impacts around the world projects that by 2030, about 15 million people and urban properties worth \$177 billion will be impacted annually by coastal flooding<sup>10</sup>. In Africa's fastest growing coastal megacity, Lagos, Nigeria, the built environment have been impacted by severe perennial flooding particularly during the rainy season with the most devastating episode witnessed in 2011 with estimated loss of between ₦82 billion and ₦123 billion at that period<sup>11</sup>.

Despite considerable investment in flood risk prevention and management, flood-related disasters continue to wreak havoc, even in many regions of the world, with the most intense in the urbanized floodplains areas of

coastal cities<sup>12</sup>. There are several reasons for the increase in flooding and related losses. Climate change undoubtedly plays an important role, but also changes in flow regimes such as general land use changes in watersheds, and loss of storage capacity due to floodplain reduction exacerbate flood conditions<sup>13, 14</sup>. Similarly, flooding has been exacerbated by hydraulic structures that are supposed to protect people from flooding. Traditional (structural) flood protection measures such as levees separate the floodplain from active waterways so that they no longer function as storage areas, leading to higher flood peaks and faster transit times downstream<sup>15</sup>. Consequently, managing flood occurrences in urbanized flood-plain areas due to climate and land use change becomes more complex.

Regardless, floodplain areas continue to attract urban development from human settlement, thereby increasing exposure and vulnerability of households within the area to flood risk. Where, „exposure“ refers to the presence of vulnerable elements (e.g., people, buildings, services, infrastructure, or other assets) that can be destructively affected<sup>16, 17</sup>. Vulnerability is the level of harm that can be expected under given conditions of exposure, susceptibility, and resilience<sup>18</sup>. Susceptibility is the likelihood that hazardous events will occur due to local element conditions or due to the inability of inherent characteristics to withstand the impact of an hazard<sup>19</sup>. Resilience, on the other hand, is the ability of a vulnerable element to anticipate, absorb, cope, resist, and recover from the impacts of a flood risk<sup>20</sup>. Therefore, flood risk within an area results from the interactions between flood hazard, exposure, and the vulnerability of the exposed elements-at-risk.

With increasing flood risk and associated physical and socio-economic damages in coastal cities across the world; it is of utmost importance to focus on practical strategies which can help households in flood-prone communities adapt to floods by reducing its impacts<sup>21</sup>. Existing literature shows that effective strategies to reduce vulnerability and build adaptation to flood disasters are through vulnerability assessments to develop adaptation plans<sup>22</sup>. These empirical strategies are data dependent and require all kinds of information on contextual factors that influence vulnerability. More so, designing and constructing flood resilient housing scheme is a very complex undertaking and its performance has many aspects; because the vulnerability, or

resilience of houses and occupants to flood risk result from multiple factors such as such as the nature of the hazard experienced, neighborhood context and building design characteristics as well as issues surrounding socio-demographic characteristics and adaptive capacity of individuals and households<sup>23</sup>.

However, due to the paucity of such data in data-poor regions, there are limitations to the development of adaptive disaster risk reduction solutions in high-risk areas<sup>24</sup>. In Lagos, Nigeria and other cities in Africa, studies on physical vulnerability assessments and flood adaptation strategies are still limited<sup>12, 25</sup>. There is lack of knowledge and poor understanding of socio-ecological characteristics that influence the vulnerability and the resilience of flood-prone housing schemes to flood risks<sup>26, 27</sup>. Therefore, a detailed analysis of the contextual factors which influence the vulnerability of flood-prone houses will provide in-depth insight into the most robust building adaptation design solutions to reduce flood disaster risks. This is line with the three international framework agreements for a more preemptive approach to flood risk management. Based on the aforementioned, this research aims to evaluate indicators of physical vulnerability to guide the development of adaptive design strategies for mitigating flood disaster risk to residential buildings in flood prone communities in Lagos, Nigeria.

## **1.2 Statement of the Research Problem**

Over the last decade, the world has seen the adverse effects of climate change manifest, including increased flooding due to more frequent and longer rainfall, melting ice caps and rising sea levels, among others. As these adverse effects have increased, buildings and other physical assets have become more vulnerable to increased degeneration and possible destruction around the world, especially along coastal areas and low-lying communities. While the traditional strategies of micro and macro urban drainage systems have been successfully implemented; anecdotal evidence has shown these measures to be unsustainable as they were designed without understanding what actually causes the flooding problem, only displacing runoff in the watershed<sup>5, 28</sup>. Consequently, they have not been very effective in providing safety for the residents and preventing damages to buildings and other physical assets during severe flooding<sup>29</sup>. In addition, studies have

also linked the unsustainability of traditional drainage systems to the increasing sealing of areas from urbanization. The spatial distribution of impervious areas in cities is growing faster than the population itself, howbeit, the world population is estimated to increase by 72% between 2000 and 2030, while, urban areas with 100,000 or more inhabitants increase by 175% are expected<sup>30</sup>.

Cities in these areas will also have the greatest need for housing<sup>31</sup>. In order to adequately meet the economic and social need for more affordable housing while taking into account the increasing risk of flooding, buildings, as the smallest unit of urban space and as one of the most affected units by floods, should therefore be designed to take cognizance of resilience, so as to appropriately adapt, respond to, and absorb future risks. Unfortunately, the policy, regulatory and institutional arrangement for effective implementation of resilient housing development in Nigeria remains weak as limited progress has been made so far<sup>32</sup>.

These barriers are compounded by the nature of Nigeria's existing housing stock which is characterized by qualitative and quantitative deficiencies<sup>33</sup>. Previous empirical studies indicate that a vast majority of Nigerian city dwellers live in high-density, unregulated substandard informal settlements; many of the settlements characterized by a lack of basic and public infrastructure (e.g., roads, storm water drainage and sanitation, water, and solid waste disposal, and public facilities) and overcrowded housing are located in flood-prone areas<sup>34</sup>. For example, approximately 29.8% of the total land area of the city of Lagos is estimated to be subject to extreme flooding; and more than half of the population, about 8 million residents are vulnerable to flood disaster<sup>35</sup>. With current statistics and future population projections, ensuring flood risk reduction in urbanized floodplains of Lagos city under climate-induced disasters is crucial.

Furthermore, weak housing right and market pressures on inner-city land in most part of Lagos pushes most of the middle and low income residents to take residence in flood-prone areas where houses are affordable. Most of the available housing units within these areas are weak, low-quality and prone to maintenance problems since the materials used for its construction tend to be the cheapest available<sup>36</sup>. The highlighted problems

coupled with policy inconsistency, and the absence of a robust housing database also make it difficult to set any meaningful regulatory targets towards housing resilience. More so, there is no nationally endorsed framework on housing resilience and flood adaptation to guide the design and construction of buildings and infrastructure in urbanized floodplain areas of Nigeria<sup>37</sup>. The Federal and other state authorities in Nigeria still rely on the more generic climate change policies enacted years earlier in their attempt to uphold their own end of the bargain of the Kyoto protocol<sup>32</sup>.

Similarly, the dearth of knowledge about flood resilient technologies and flood resilient housing design approaches amongst Nigerian Architects and other construction professionals makes it difficult to develop substantive design-based responses to disaster mitigation in flood-prone areas<sup>38</sup>. More so, identifying these design strategies would rely on understanding vulnerability in all aspects of exposure, susceptibility, and adaptive capacity. However, the lack of relevant data on the factors influencing physical flood vulnerability in these areas presents a major limitation in selecting the most effective adaptation measures to reduce flood risk. Also, limited empirical studies have evaluated building adaptation strategies for flood disaster risk reduction in Nigerian cities<sup>39</sup>.

Most of existing research provides a generalized overview of flooding rather than the context of hazards in local conditions. For instance, prior studies examined current approaches to flood risk management by public and private organization in Lagos state<sup>40</sup>. The study notes that Lagos and Nigeria do not have specific provisions for building-based adaptation strategies for flood risk management. The author found the houses built over floodplains and natural waterways. However, these buildings are often not designed to accommodate additional stresses that come with flood disaster. Similarly, a critical review of flood risk management efforts in the city of Lagos acknowledged that the level of information available about floods experienced is a major limitation, and that flood modeling and a vulnerability assessment is a necessary requisites<sup>41</sup>. The only related study carried out in Kosofe Local Government Area, Lagos State, Nigeria

evaluated the environmental impacts of floods, and thus suggested that enlightenment programmes be carried out for residents about the causes, impacts and management of floods<sup>42</sup>.

While these various perspectives exist, none of the past studies examined adaptive architectural design strategies for flood disaster risk reduction from the perspective of „risk“ by mapping out vulnerability dimensions of exposure; susceptibility; and resilience. Therefore, this study sought to bridge this research gap in knowledge by assessing the most significant indicators for developing adaptive design strategies to reduce flood risk to residential buildings in flood-prone areas, using kosofe local government area of Lagos, Nigeria as a case study.

### **1.3 Justification for the Study**

This study is invaluable considering the risk caused by climate change and the limitations of existing flood management systems. Therefore, this research is justified on various fronts.

First, issues linked to climate change such as changes in rainfall patterns, global warming, and general rise in sea level; have heightened the need to make built environment components not just resistant, but adaptable to a changing environment<sup>3</sup>. Flood intensity and frequency have increased dramatically in many coastal cities, making residents more vulnerable to severe flooding<sup>43</sup>. Given the limited capacity and resources to cope, coupled with a lack of flood insurance cover by most individuals in Lagos city; residents are at risk of significant losses from floods. This study is thus, justified on the ground that it will contribute to existing knowledge about housing adaptation for disaster risk management in flood-prone urban settlements.

Second, flood-prone settlements are where exposure to climate change impact is most acute. The distinct vulnerability of these settlements is related to their physical location, which is often situated on unstable soils; the socio-economic characteristics of the population, such as high levels of poverty and illiteracy, which mean that these communities are less able to cope with climate impacts; and the marginalization of these communities, because urbanized floodplain areas are not recognized as part of the larger urban fabric<sup>44</sup>. Yet,

these areas provide home to some 1 billion people<sup>45</sup>. However, due to the contextual nature of the factors that influence vulnerability and the lack of reliable data on the characteristics of residents in vulnerable settlements, developing adaptive solutions to reduce flood risk becomes challenging. This research is thus justified in seeking to fill this gap by examining the socio-demographic and economic characteristics of residents in flood-prone areas, as well as the attributes of their flood experience.

Third, in Nigeria, the lack of substantive design-based disaster mitigation responses to guide architects and urban planners in flood-prone areas has increased the vulnerability of local communities to natural disaster<sup>46</sup>. Generally, the issue of disaster risk reduction is usually not considered in the spatial planning and building development process within flood-prone communities<sup>47</sup>. This makes it necessary to develop a framework to guide design professionals on adaptive strategies for reducing physical vulnerability. This study is thus justified on the grounds that it attempts to examine the neighbourhood characteristics, architectural design features of houses, and adaptive coping capacities exhibited by households in the study area, which are vital to assessing current susceptibility and resilience to flood risk, and to also channel the efforts of professionals in designing neighborhoods and buildings that are well adapted to mitigate flood impacts.

Lastly, this study is also justified as it attempts to bridge the knowledge-gap in the existing body of literature on building adaptation. Prior to now, research on climate adaptation measures in buildings focused on thermal comfort and energy consumption in buildings than on flood disaster risk reduction<sup>48</sup>. However, evidence in literature shows the enormous adverse impacts of physical flood vulnerability to buildings. However, the lack of relevant data on physical vulnerability indicators inhibits efforts towards developing building-based flood risk management solutions<sup>41, 25</sup>. This study is therefore justified because it attempts to bridge this gap by investigating indicators with the most influence on physical flood vulnerability, which will guide the eventual adaptation strategies for reducing flood risk to buildings and their occupants. Furthermore, it is imagined that the eventual adaptive architectural design strategies can be seen as supporting a Disaster Risk Management (DRM) approach as defined in the United Nation Office for Disaster Risk Reduction (UNDRR) and United

Nations Development Program (UNDP): „*The conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development*“<sup>49</sup>.

The outcome of this research promises to be beneficial to Architects, urban designers and diverse stakeholders in the built environment, including the academia, professionals in the construction industry, property developers, home owners and occupants as well as relevant local physical planning authorities and policy makers in Lagos state and Nigeria.

#### **1.4 Aim and Objectives of the Study**

The aim of the study is to examine the most critical indicators influencing the vulnerability of flood-prone residential buildings in Kosofe Local Government Area of Lagos, Nigeria. This is with a view to identify the most robust adaptive architectural design strategies to improve housing resilience to flood disaster risk. In order to achieve the aim of the research, the specific objectives are to:

- i. assess the demographic and socio-economic characteristics of residents of the flood-prone areas of Kosofe Local Government Area of Lagos State, Nigeria;
- ii. examine the attributes of the flooding experienced in the study area;
- iii. assess the neighbourhood characteristics and Architectural design features of the existing housing schemes in the study area;
- iv. investigate the adaptive capacity of households in the study area to flood risk;
- v. determine the extent to which socio-economic characteristics, flood attributes, neighbourhood/architectural characteristics, and adaptive capacity of households influence physical flood vulnerability in the flood-prone areas of Kosofe Local Government Area of Lagos State, Nigeria.

## 1.5 Research Questions

In order to achieve the goal set out in this study, the following research questions have been raised with a view to providing answers to them in the course of this research:

- i. What are the demographic and socio-economic characteristics of residents in the flood prone areas of Kosofe Local Government Area of Lagos State, Nigeria?
- ii. What are the attributes of the flooding experienced in the flood prone areas of Kosofe, Lagos State?
- iii. What are the neighbourhood characteristics and architectural design features of the existing housing schemes in the flood prone areas of Kosofe, Lagos State?
- iv. What is the adaptive capacity of households in the study area to flood risk?
- v. What significant socio-economic; neighbourhood and architectural design features, and adaptive capacities have the most influence on physical flood vulnerability in the flood-prone areas of Kosofe Local Government Area of Lagos State, Nigeria?

## 1.6 Hypotheses

The hypothesis has been developed based on the idea that factors of exposure, susceptibility and resilience exhibited by a socio-ecological system determines its physical vulnerability to flood risk, and the eventual adaptation options for flood disaster risk reduction.

$H_0$  = There is no significant linear relationship (correlation) between X and Y in the study.

$H_a$  = There is a significant linear relationship (correlation) between X and Y in the population.

Where, X= demographics and socio-economic characteristics of the residents; flood attributes experienced; Neighbourhood characteristics and architectural design features of buildings; and adaptive capacity.

Y= physical flood vulnerability of residents.

It is expected that higher exposure to flood risk, lower susceptibility and higher adaptive capacity should tend to lead to lower physical flood vulnerability and increased tendency for building resilience/adaptation to flood risk.

### **1.7 Significance of the Study**

Housing policies, plans, strategies related to disaster risk reduction (DRR) and climate change are based on community realities. Floodplain communities are particularly vulnerable to climate change. Their socio-economic vulnerability traditionally reflected in the five forms of housing deprivations: limited access to water and sanitation, unstable rents, overcrowding, and precarious housing structures; is exacerbated by climate vulnerability<sup>50</sup>. Residents of flood-prone areas often depend, at least in part, on climate-related livelihoods such as agriculture, and they also rely on their assets to protect against and recover from flood disasters<sup>51</sup>. Being located outside the „formal“ urban fabric, means that innovative approaches to climate adaptation are needed. Successful adaptation to climate change therefore requires increased attention to the most vulnerable communities. Indeed, making these informal settlements more resilient to climate change could be a transformative process towards sustainable urban development. UN-Habitat has assisted in conducting Vulnerability Assessments (VA) for cities through the Cities and Climate Change Initiative(CCCI). In all assessment, climate change hotspots include informal settlements. The resulting climate Change Action Plans will thus help in the development and formulation of policies that include targeted actions to build the resilience of these communities as part of a global system of addressing risk and vulnerabilities.

The climate vulnerability of informal settlements has been recognized in many cities around the world, giving new impetus to improve settlements and build resilience. To help align building and improving resilience at the sub-city level, new community-centered design strategies and processes are needed. This study is significant as it attempts to provide guidance for architects, and urban designers tasked with facilitating flood adaptation at the neighborhood level, with emphasis on the building-level and on the vulnerability factors of

exposure, susceptibility and resilience of households. The importance of identifying critical indicators influencing physical vulnerability in providing a starting point for the development of adaptive architectural design strategies is the central focus of this study. As such, the outcome of this study can inform targeted policies on architecture and planning as it relates to climate change induced flooding; and also empower built environment professionals, home-owners, and particularly vulnerable people in the built environment to work together to drive development, rather than following externally designed and instigated development initiatives.

## **1.8 Scope of the Study**

The study area is Kosofe Local Government Area of Lagos State, Nigeria. Kosofe is the most flood vulnerable residential neighbourhood in Lagos, Nigeria<sup>35</sup>. There are over 35 communities in Kosofe LGA. However, the most vulnerable communities based on proximity to the lagoon will be surveyed in this study (Figure 1.1 in Appendix). The selected flood-prone communities within Kosofe are Owode-Ajgunle, Agboyi and Oworonshoki respectively (Figure 1.1 in Appendix). The neighbourhoods within the selected communities are Oworonsoki, Ifako, Alapere, Orisigun, Kosofe, Ajelogo and Akanimodo, Mile 12, Agboyi-1, Agboyi-2, Owode-Onirin, Irawo, Ajgunle and Odo-Ogun.

This study was delimited to households living about 30m to 70m from River Agboyi and Ogun River respectively; representing the most vulnerable to less vulnerable buildings. The housing schemes to be investigated are self-help residential buildings. The selection is based on the idea that most of the houses in the flood-prone areas of the communities are privately owned. More so, flood disasters are more traumatic for homeowners as they represent personal investments and therefore, given the lack of flood insurance cover and very little government support, homeowners are at risk of major losses in the event of severe flooding<sup>39</sup>.

The study area is located near a uniform plain with vulnerable areas located in the lower floodplain of the Ogun River, the channel that feeds into the Lagos lagoon. This makes the region highly vulnerable to

flooding. In recent years, the unrestricted influx of people into the study area has pushed construction work into flood-prone areas. A Geographic Information System (GIS) analysis via IKONOS high-resolution satellite imagery of parts of the study area clearly revealed building encroachments along the riverbank of the area<sup>39</sup>. The study also showed that buildings were inside the meander itself, which would soon transform into a ox-bow lake, and that erosion along the banks had narrowed the river bed (Figure 1.2 and Figure 1.3 in Appendix). The Study Area's exposure to flood hazard and the anthropogenic influences from building development, both contribute immensely to the communities' vulnerability to flood risk. This trend is however not sustainable and therefore underscores the need for innovative adaptive building design approaches for flood-disaster reduction. It also justifies the delimitation of this study to existing residential buildings in the flood-prone areas of Kosofe Local Government Area of Lagos, Nigeria.

### **1.8.1 Context of the Study**

Kosofe was first established in 1980 and abolished in 1984, it was thereafter re-established on 27th November 1996, along with four other local governments areas in Lagos State, in line with efforts bring government closer to the people<sup>42</sup>. The birth of Kosofe LGA therefore marked a step towards improving the well-being and living conditions for the residents of the area. It was also an opportunity to strengthen solidarity between indigenous peoples and local residents. Kosofe is located in the northern part of Lagos state. It is surrounded by three local government areas namely: Ikeja, Ikorodu and Shomolu. It also shares a boundary with Ogun State<sup>52</sup>. There are 10 polling stations covering an area of 178.85sq/km with its headquarters at Ogudu<sup>55</sup>. In 2006, the National Population Commission estimated the population of Kosofe at 682,772 people comprising 358,935 males and 323,887 females<sup>53</sup>. Using a growth rate of 3.18%, the current population is estimated at 1,570,376.

Most of the original inhabitants of Kosofe LGA were „Aworis“, and their main occupations were mat-weaving, farming and fishing<sup>42</sup>. However, due to its location as the gateway to Lagos State and the hospitality of the indigenes, Kosofe is home to people from northern and eastern Nigeria who does business at Mile 12

and Ketu<sup>56</sup>. As a result, Kosofe is now a highly built up residential and commercial area, with houses built on floodplains and natural waterways<sup>39</sup>. Vegetation whose root system should have intercepted runoffs has been modified to accommodate urban sprawl associated with growing urban population. The short-sighted design of most existing drainages is inadequate to successfully handle the local storm-water flow<sup>42</sup>. A combination of poor urban planning and prejudicial anthropogenic activities have contributed to inducing to the high incidence of floods in the area.

### **1.8.2 Physical Geography of Kosofe**

Kosofe's main vegetation is rainforest, but today the area is fully developed<sup>42</sup>. The climate is characterized as a humid tropical savanna (Köppen climate classification). The major water body in the area is the Ogun River<sup>39</sup>. The areas under study have similar temperature and precipitation pattern and are characterized by two rainy seasons, with heavy rainfall from April to July and the lighter rainfall from September to November<sup>40</sup>. There is an August break usually characterized by a relatively dry season and a longer dry season from December to March. Geologically, the area belongs to the Dahomey Sedimentary Basin, a sandy coastal plain containing outcrops of silt, clay, and fine to coarse sand sediments. Kosofe is blessed with a wetland ecosystem, which has undergone significant spatial changes due to rapid urbanization and unplanned development<sup>54</sup>. The environment has been disturbed by the construction of housing, market and other infrastructure.

### **1.8.3 Kosofe Urban Planning and Housing Condition**

Kosofe Local Government Area is the only local government area in Lagos State that does not have a model city plan<sup>55</sup>. Although in the later part of 2020, the Lagos State Government (LASG) inaugurated a technical committee to liaise with consultants towards preparing the Kosofe Sub-Region Master plan; which is envisioned to be a comprehensive development policy for the Sub-region over the next 20 years, while focusing on sustainable inclusive environment. This was deemed necessary in view of the rapid development

in Kosofe and the imperatives of ensuring orderliness in the Sub-region, which comprises of three important local council development areas (LCDAs) namely Kosofe, Agboyi-Ketu and Ikosi-Isheri<sup>39</sup>.

Notably, Kosofe local government suffers incessantly from unmitigated flooding, often resulting in building damages, disruption of communication, loss of lives and properties as well as the spread of various diseases as a result of degraded urban environment<sup>42</sup>. Kosofe has witnessed rapid deterioration of many of its neighbourhoods resulting in the proliferation of slums; mainly due to the swampy and poorly drained nature of the soil, coupled with burgeoning population trends that characterize most part of Lagos State (see figures. 1.4, 1.5, 1.6 in Appendix).

It should be noted that the Lagos State Physical Planning Permit Regulations specified that the minimum setback to water bodies such the ocean, lagoon shore-line, river bank or creek shoreline, and the edge of a gorge, canal or drainage shall not be less than 150 metres, 50 metres, 15 metres and 10 metres, respectively<sup>55</sup>. However, it is observed that despite these regulations, enforcement continues to pose a serious challenge as a large number of buildings and other structures have been built and are still being built on drainage paths, floodplains, and close to the coast<sup>47</sup>.

### **1.9 Limitation of the Study**

The major limitation of this study bothered on data collection. The study adopted focused group discussions and questionnaire survey in the qualitative and quantitative phase respectively, which had its drawbacks in terms of difficulty in accessing interviewees and respondents. The limitation was addressed by seeking permission with the representatives of the landlord association and residents of the areas investigated, and by ensuring that the items in the questionnaire were designed using simple English void of ambiguous statements. The research process was also clearly stated to respondents, providing the aim and objectives, so that responses obtained would be as true as possible without external influences.

## 1.10 Operational Definition of Terms

1. **Adaptation:** The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.
2. **Adaptive Capacity:** The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
3. **Climate Change:** A long-term change in the average weather patterns that have come to define Earth's local, regional and global climates.
4. **Disaster Risk Reduction:** A systematic approach to identifying, assessing and reducing the risks of disaster.
5. **Exposure:** Exposure is defined as the predisposition of a system to be disrupted by flooding due to its location in the same area of influence.
6. **Flood:** An overflow of water that submerges land that is usually dry.
7. **Coastal Flood:** A sudden and abrupt inundation of the coastal environment caused by a short-term increase in water level due to a storm surge or extreme tides.
8. **Flash Flood:** A rapid flooding of low-lying areas that begins within 6 hours, and often within 3 hours of the heavy rainfall (or other cause).
9. **Fluvial Floods** or a river flood: a flooding that occurs when water level in a river, lake, or stream rises and overflows onto the surrounding banks, shores and neighboring land.
10. **Pluvial Floods:** A flood independent of an overflowing water body
11. **Flood Plain:** Any land area susceptible to being inundated by floodwaters from any source
12. **Flood-Prone Areas:** A relatively flat or low land area adjoining a stream, river or watercourse, which is subject to partial or complete inundation; or, any area subject to usual rapid accumulation of run-off of surface waters from any source.

13. **Flood Risk:** The measure of vulnerability to flood with consideration to the likelihood of flooding and the total value of the assets at risk
14. **Flood Risk Management:** Efforts to reduce the human and socio-economic losses caused by flooding while taking into account benefits from floods.
15. **Hazards:** The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.
16. **Physical flood vulnerability:** This is the extent to which the built environment, including buildings and physical assets are susceptible to floods due to exposure, a perturbation, in conjunction with its ability (or inability) to cope, recover, or basically to adapt.
17. **Resilience:** This is the capacity of a system to adjust to actual or expected climate impacts based on pre-disaster preparedness, coping capacity during and post-disaster and external interventions in post disaster.
18. **Risk:** The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.
19. **Stormwater:** Water that comes from precipitation and ice/snow melt; which either soaks into exposed soil or remains on top of impervious surfaces, like pavement or rooftops.
20. **Susceptibility:** This is defined as the elements exposed within the system, which influences the probability of damage during severe floods.
21. **Vulnerability:** The extent of harm, either physically or emotionally, which can be expected under certain conditions of exposure, susceptibility and resilience. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

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## Chapter Two

### Literature Review

#### 2.1 Conceptual Review

##### 2.1.1 Concept of Physical Flood Vulnerability

The concept of physical vulnerability to flooding refers to the susceptibility of the built and natural environment to the adverse effects of flood hazard<sup>1</sup>. In other words, physical flood vulnerability refers to the extent to which physical structures (human shelter), mainly buildings are susceptible or exposed to the adverse effects of flooding. Different social groups or classes within a society are differentially at risk, both in terms of probability of occurrence of an extreme flood event and helping different classes to recover; therefore, for vulnerability to exist, the capacity of the population to absorb, respond and recover from the impacts must be taken into consideration<sup>2</sup>. Physical vulnerability to flooding can affect urban and rural areas, causing damage to homes, businesses, transportation routes and other essential facilities. For this reason, assessing physical flood vulnerabilities can provide the basis for the development of mitigation or adaptation strategies aiming to reduce hazard consequences.

Vulnerability is a multifaceted concept used to explain the tendency or predisposition of assets to be adversely affected by hazards. Vulnerability of a community has social, economic, physical, environmental, institutional and cultural dimensions, all of which are linked<sup>3</sup>. Studies have emphasized that physical vulnerability is a primer for other vulnerability dimensions; more so, physical vulnerability in particular is directly connected to monetary loss and interruptions that are in the center of the interests of several stakeholders including governments, authorities, insurance companies, engineers, and homeowners<sup>4</sup>. The capacity to predict damage is increasingly seen as an important step towards disaster risk reduction. Several approaches have been developed over the years for the assessment of physical vulnerability. A review of methods used for the assessment of the physical vulnerability of buildings to flooding suggests that there are mainly three methods used, namely: vulnerability curves, the multivariate methods, and the indicator-based methods<sup>5</sup>.

Vulnerability curves and multivariate methods used for damage prediction are commonly referred to as flood damage models. Flood damage models generally rely on complex mathematical algorithms to estimate the potential economic losses associated with flooding, based on factors such as water depth, velocity and duration. However, these models

can be difficult to validate and may not accurately reflect local conditions or full range of impacts associated with flooding<sup>6, 7</sup>. In contrast, indicator-based approaches is more flexible and rely on a more qualitative assessment of flood risk, based on a range of indicators such as land-use, soil type, drainage patterns, building material, construction type, number of floors, level of maintenance, ground floor material, and the presence of vulnerable populations or infrastructure<sup>1, 8</sup>. By considering a range of indicators, the indicator based methods can provide a more holistic assessment of flood risk that incorporates both the physical and social dimensions of vulnerability.

Therefore, both flood damage models and indicator-based approaches have their strengths and limitations, and the choice of approach will depend on the specific needs and context of the decision making process. However, indicator-based approaches are preferred where a more comprehensive and integrated assessment of flood risk is required. The main practice of an indicator-based approach is the use of composite indicators. Vulnerability indicators are defined as variables that are operational representations of a property or quality of the system. The outcome of the indicator-based approach is indexed and represents the level of vulnerability on a scale assigned by expert judgment to reflect policy priorities or theoretical data<sup>9</sup>. More specifically, flood vulnerability indicators measure the extent of vulnerability to flooding. This method uses three flood vulnerability factors, namely exposure (E), susceptibility (S) and resilience (R). Where exposure and susceptibility positively affect vulnerability; and resilience negatively affects vulnerability. Due to exposure, susceptibility and resilience affect vulnerability to flooding. Exposure and susceptibility indicators increase vulnerability to flooding; while indicators relating to resilience reduce vulnerability to floods<sup>10</sup>.

In summary, four key components of physical vulnerability assessment are identified to be relevant in this study (see Table 2.1). Firstly, the presence of a climate hazard; secondly, there must be exposure (of people, livelihoods, species or ecosystems, etc.); thirdly, there must be some degree of susceptibility (of physical elements, neighbourhood and housing) and fourthly, there must be resilience (as adaptive capacity)<sup>11</sup>. This is typically concerned with the resources a system can draw upon to respond to uncertainty. Each of the components is discussed in the next section.

**Table 2.1: Basic components of Physical Vulnerability assessment identified in literature**

<b>Components of Physical Vulnerability</b>	Hazard <sup>12</sup>	Exposure <sup>13</sup>	Susceptibility <sup>14</sup>	Resilience <sup>15</sup>
<b>Characteristics</b>	Flood disaster	People at Risk of flood disaster	Physical elements that influence likelihood of flood disaster	Adaptive Capacity to cope with flood impacts
<b>Criteria adopted for this study</b>	Flood attributes (Pattern, causes and impact)	Interaction of hazard, demographic and socio-economic characteristics	Neighborhood characteristics and architectural features	Pre-disaster preparedness, coping capacity and post disaster recovery
<b>Applicable Theories</b>	<b>Vulnerability</b>	<b>Socio-ecological System thinking</b>	<b>Vulnerability</b>	<b>Adaptive Capacity</b>

Source: Researcher's Summary from Literature Review, 2023

### 2.1.2 Concept of Hazard

The concept of hazards arises from the interactions between humans and the environment<sup>16</sup>. Natural hazards are combination of different physical processes and human activities that cause different disasters. Thematically, hazards are characterized by their location, intensity, frequency and likelihood<sup>17</sup>. A hazard is any physical event or condition that can lead to death, personal injury, property damage, infrastructure damage, agricultural damage, environmental damage, business interruption, or any other form of damage or loss<sup>18</sup>. More so, a hazard is an extreme natural or man-made event that exceeds acceptable levels within or beyond a specified period of time, impedes adaptation, and results in catastrophic loss of property, income and life<sup>5</sup>.

It is also considered as an extreme natural event with some potential for negative consequences. In other words, it is a potentially dangerous physical event, phenomenon or human activity that can lead to loss of life, injury, property damage, social and economic disruption or deterioration. This means that hazards can be potentially dangerous, especially if they occur in densely populated areas, and can have serious consequences in those areas,

depending on the intensity of the hazard and the vulnerability of the elements at risk. Disasters are social phenomena that occur when a community is disrupted in a particular way and suffers losses due to natural or human processes<sup>19</sup>.

In linking hazard to flood disaster, a hazardous event can affect an uninhabited area, but a disaster can exist only if there are people and processes associated with it<sup>20</sup>. Hazards are processes and disasters are consequences or reactions to hazards. Disasters are measured in human terms (deaths, injuries, and economic losses) resulting from the hazard. Hazards always lead to extremes, but not all extreme lead to disasters. Disasters usually occur as a result of interactions between the socio-economic and physical impacts of hazardous processes and vulnerable populations. Flood disaster is now a negative impact of flooding on people's socioeconomic systems. Of all natural disasters, flooding is the most frequent<sup>21</sup>. It is one of the most devastating and pervasive threats facing the world. The causes can be linked to hydrological factors such as rainfall patterns, precipitation intensity, and the infiltration capacity of the soil; topographical factors such as the slope and shape of the land, and drainage patterns; and human related factors such as deforestation, urbanization, and the alteration of natural drainage systems, inadequate land use planning, improper infrastructure design, and poor maintenance of drainage systems<sup>22</sup>.

Generally, there are several types of floods, but they are mainly categorized into the following classes: fluvial (river floods), coastal floods (storm surges), and pluvial floods (flash floods and surface waters) (see Table 2.2). Also, flood losses can be classified into direct and indirect losses<sup>23</sup>. Where, direct losses are caused by floodwater coming into physical contact with buildings and their occupants; and indirect losses affect networks and social activities. Also, flood consequences may be classified as tangible and intangible (see Table 2.3). Tangible and intangible consequences can be further grouped into direct and indirect flood losses. Where, direct tangible losses include damage to private buildings and contents, destruction of infrastructure such as roads and rail roads, erosion of agricultural soil, destruction of harvest, and damages to livestock. It could also involve evacuation and rescue measures, business interruption inside the flooded area, and high clean-up costs. On the other hand, direct intangible losses involves loss of life, injuries, loss of memorabilia, psychological distress, damage to cultural

heritage, and negative effects on habitats/ecosystems. In addition, indirect tangible losses are disruption of public services outside the flooded area, induced production losses to companies outside the flooded area (e.g., suppliers of flooded companies), and high cost of traffic disruption; while indirect intangible losses include inconvenience of post-flood recovery, trauma, and loss of trust in authorities<sup>24</sup>. Flood damages and impact can be felt by a building and its occupants in a number of ways. These include damage to building fabrics and services; damage to contents and fittings; disruption of businesses; loss of income and livelihood; and loss of lives, and displacement of people from their homes<sup>25</sup>.

**Table 2.2: Flood Types, Causes and Processes**

<b>Flood Type</b>	<b>Causes</b>	<b>Processes</b>
Fluvial flooding (river)	Rainfall and melting snow	Occurs when the water level of a river, lake, or stream rises and overflows the surrounding banks or neighboring land.
Coastal flood	storm surge and wave action	Occurs when there is sudden and abrupt flooding of the coastal environment due to a rise in water level.
Pluvial (flash floods and surface water)	Increased impermeable surfaces, inadequate, clogged and poorly maintained local drainage systems (storm sewers, culverts, and drainage ditches and swales).	When run-off exceeds the design capacity of the drainage system, water begins to rise and fill low areas near system entrances and along open ditches.

Source:<sup>26</sup>

Additionally, property damage due to flooding are unique to each flood event; however, they occur depending on the flood attributes (volume, depth, flow velocity, contaminant level, flood duration and source), and building characteristics (construction materials and, pre-flood building condition) (see Table 2.5)<sup>27</sup>. In general, the longer a flood lasts, the greater the damage. This is mainly because many buildings are made of hard and porous materials such as brick and blocks. Therefore, the longer the flood stays, the longer the water will be absorbed by the

building structure and the longer it will take for the building to dry and repair. Therefore, building repair increase with the flood of inundation. Also, the level of preparedness of the population for the event also affects property damages<sup>28</sup>.

However, the lack of technical information on material suitability, and previous flood experienced has overtime prevented the construction industry from selecting and developing alternatives that perform better during floods<sup>29</sup>. Therefore, it is imperative that adequate information concerning flood characteristics, its influencing factors, and impact on people and physical elements exposed are provided in order to reduce flood impacts and map out ways to improve resilience.

**Table 2.3: Classification of Flood Losses**

Forms of Flood Losses	Measurement	
	Tangible	Intangible
<b>Direct</b>	<ul style="list-style-type: none"> <li>• Damage to private buildings and contents</li> <li>• Destruction of infrastructure such as roads and rail roads</li> <li>• Erosion of agricultural soil, destruction of harvest</li> <li>• Damage to livestock</li> <li>• Evacuation and rescue measures</li> <li>• Business interruption inside the flooded area</li> </ul>	<ul style="list-style-type: none"> <li>• Loss of life, injuries, loss of memorabilia</li> <li>• Psychological distress, damage to cultural heritage</li> <li>• Negative effects on habitats/ecosystems</li> </ul>
<b>Indirect</b>	<ul style="list-style-type: none"> <li>• Clean-up costs</li> <li>• Disruption of public services outside the flooded area</li> <li>• Induced production losses to companies outside the flooded area (e.g., suppliers of flooded companies)</li> <li>• Cost of traffic disruption</li> <li>• Loss of tax revenue due to migration of companies in the aftermath of floods</li> </ul>	<ul style="list-style-type: none"> <li>• Inconvenience of post-flood recovery</li> <li>• Trauma</li> <li>• Loss of trust in authorities</li> </ul>

Source: <sup>22</sup>

### 2.1.3 The Concept of Exposure

The concept of exposure in physical flood vulnerability refers to the proximity of people and/or physical objects to flood damage<sup>30</sup>. Exposure may also be referred to as the identification of elements in areas where hazardous events may occur<sup>31</sup>. Therefore, if population and economic resources are not located in a potentially hazardous environment, there would be no disaster risk issues. Exposure encompasses the location, density, and value of assets that are located in flood-prone. While literature and common usage often mistakenly confuse exposure and vulnerability, they are different. Exposure is a necessary but insufficient determinant of vulnerability. It is possible to be exposed but not vulnerable (for example living in a floodplain but having sufficient resources to modify the structure and behavior to mitigate potential losses). However, to be vulnerable to an extreme event, it is necessary to be exposed to the risk. Exposure is a critical component of understanding flood vulnerability as it involves identifying and quantifying the potential losses and damages likely to be sustained by people and assets located in areas susceptible to flooding.

Exposure is dynamic, change over temporal and spatial scales, and depends on economic, social, geographic, demographic, cultural, institutional, governance-related, and environmental factors<sup>32</sup>. Furthermore, the factors affecting exposure vary widely depending on the hazard situation, the stage of the disaster and the state of the country<sup>33</sup>. For people, especially the poor, high exposure are linked to environmental mismanagement, rapid demographic change, rapid and unplanned economic processes, unsafe urbanization, poor governance, and limited livelihood opportunities. Inequality also affects responses and coping mechanisms, putting more people at risk. For example, demographics, changing location requirements and the gradual decline in the availability of safe land mean that people and their activities will almost inevitably be located in potentially hazardous locations.

According to a recent study, 1.81 billion people worldwide (23% of the world population) live in areas at high risk of flooding<sup>26</sup>. Also, urban growth trends in cities indicate that population densities are increasing at an unprecedented rate<sup>24</sup>. Densely populated areas concentrate more people and property, increasing the likelihood of flood damage and loss of life. These areas are particularly vulnerable to flash flooding due to the high surface

impermeability and reduced ability of soils to penetrate the ground<sup>34</sup>. Additionally, densely populated areas may have limited evacuation routes and emergency resources, which can exacerbate the impact of a flood event.

Many researchers believe that higher levels of exposure are a by-product of the differences that exist between economic and societal groups. Members of the lower economic groups are disproportionately exposed to flood hazards due to their lack of basic amenities and may live in slums or flood-prone areas where property prices are generally low<sup>35</sup>. Based on this existing literature, people with low incomes and wealth are more likely to live in flood-prone areas due to the higher cost of living in safer areas; which can lead to a concentration of lower-income households in these areas. Low-income households may also lack the resources to take precautionary measures or recover from flood damage<sup>2</sup>.

Furthermore, education levels can influence awareness and understanding of flood risks, as well as the ability to access and use flood-related information and resources<sup>36</sup>. Higher educational attainment is associated with lower exposure to flood risk. Also, older adults and individuals in poor health may be more vulnerable to the impacts of flooding, as they may have limited mobility and resources to respond to flooding events. However, social capital and community resources are important determinants of the ability to cope with and recover from flooding events. Individuals who have access to strong social networks and community resources may be better equipped to prepare for and respond to flooding events<sup>37</sup>. Therefore, socio-economic factors appear to have a stronger influence on exposure to flood risk than the physical environments. This is because they determine where and how people live and work. Exposure assessment covers the process of estimating or measuring the extent, frequency, and duration of exposure to hazard and the number and characteristics of the exposed population<sup>38</sup>.

Measuring exposure requires a thorough understanding of the components and how these factors collectively contribute to community vulnerability. These approaches include methods that rely primarily on statistical data collected from publicly available resources and approaches that involve community surveys. Efforts to quantify vulnerability usually take into account a limited number of parameters such as physical aspects such as buildings and mortality; and economic aspects of vulnerability, but social vulnerability is poorly understood and difficult to

measure. In most countries, primary statistical information is collected through the census, but this information rarely includes information on building construction and socio-demographic data necessary to assess population vulnerability. Moreover, such statistics are often only available at a geographical aggregate level, making them difficult to use effectively in vulnerability assessments. Issues also include access to restricted data, confidentiality, accuracy, consistency and lack of openness<sup>39</sup>.

Despite the fact that many statistical data sources have been used to develop exposure models. However, the development of exposure databases for the purpose of vulnerability assessments across geographic scales and for different hazards and types of risks represents a significant challenge. The challenge is exacerbated by the fact that exposure data is multi-faceted and complex, and the responsibility of data collection and storage seldom, if ever, lies with a single organization. An important area of disaster research considers exposure through hazard impact. This approach often speaks of directly or indirectly affected populations. Direct impacts include injury, illness, and other health effects, evacuation and displacement, as well as economic, social, cultural, and environmental damages. Indirect impacts refer to additional consequences that cause unsafe or unhealthy conditions over time due to economic, infrastructure, social, or health and psychological disruptions and changes. The main problem is identifying who has been affected and when. It is difficult to determine the consequences of a disaster because there are many indirect pathways leading to it. The situation is further complicated when populations are exposed to hazards repeatedly or continuously, with different time-to-effects. More recent approaches, however, combine remote sensing satellites and computational techniques such as crowdsourcing and drones with ground-based data from imagery and statistics to map population distributions and physical characteristics of the natural and built environment with great precision.

From the literature review, it is obvious that exposure is dynamic and its influencing factors are multifaceted. Therefore, measuring exposure requires an integrated approach that aggregates on one hand, the hazard attributes, its influencing factors and hazard impact; and on the other hand, the demographic and socio-economic characteristics of the population.

#### 2.1.4 Concept of Susceptibility

Susceptibility is the element exposed within a system that affects the probabilities or likelihood of damage during hazardous floods<sup>40</sup>. In the context of physical flood vulnerability, susceptibility refers to the degree to which a system, such as a community or a physical structure, is susceptible to damage or disruption as a result of flooding<sup>41</sup>. It refers to the inherent characteristics or qualities of the system that make it more or less vulnerable to flooding. Susceptibility can be influenced by many environmental and physical factors, such as the location and topography of the area, the condition and age of infrastructure, the types of building materials used, and the presence or absence of natural features such as vegetation and wetlands<sup>42</sup>. For example, a community that is located in a low-lying area near a river, with buildings constructed with materials that are easily damaged by water, and with inadequate drainage and flood protection infrastructure, is likely to be more susceptible to flood damage than a community with buildings that are constructed with flood-resistant materials, effective drainage systems, and located in higher elevations.

Therefore, flood susceptibility analysis is necessary to effectively prevent and mitigate future hazardous events, especially in recent years when extreme rainfall and flood intensity occurs due to global warming and climate change. Flooding within a region is influenced by many environmental and human factors. For example, factors that typically contribute to flooding include meteorological conditions (such as heavy rainfall), landscape features (such as watershed slope, area, and shape), and other parameters (such as land use, land cover, and soil permeability)<sup>9</sup>. Flooding is primarily caused by extreme rainfall, but is then exacerbated by other factors such as the duration and nature of the rainfall. It is also influenced by the hydraulic characteristics of the basin and its extreme response to rainfall due to steep slopes and high drainage density<sup>43</sup>. In addition, less permeable soils accelerate surface runoff and reduce the incubation period required for floods. Also, changes in land use and urbanization can make any watershed more susceptible to floods. Thus, complex interactions between hydrological and climate conditions and the landscape and morphological characteristics of the watershed can lead to catastrophic floods<sup>44</sup>.

However, a lot of the flood susceptibility assessments do not fully consider the spatial pattern and building characteristics in the analysis of factors that influence the likelihood of flooding occurrences<sup>39</sup>. In real terms, neighborhood spatial characteristics and architectural features of buildings can also play a major role in defining a community's susceptibility to flood risk<sup>45</sup>. Recent studies have highlighted the role of urban growth in flood proneness. It is a general idea that urban areas with a high percentage of impervious surfaces, such as concrete and asphalt, are more prone to flooding due to the reduced ability of the land to absorb water<sup>46</sup>. In addition, neighborhoods characteristics in terms of the drainage systems, proximity to water sources, landscaping and vegetation, influence the risk of flooding. Communities with effective drainage system, such as stormwater drains or retention ponds, are less likely to experience flooding. Also, neighborhoods located close to rivers or other bodies of water are at a higher risk of flooding. Similarly, neighborhoods with a lot of vegetation, such as trees and grass, can help absorb water and reduce the risk of flooding<sup>47</sup>.

Furthermore, architectural characteristics such as building elevation, foundation type, and building materials, also determine physical susceptibility to flood damage<sup>48</sup>. Homes and buildings that are constructed at a higher elevation are less likely to be affected by floodwaters. Also, buildings with raised foundations or flood-resistant materials such as concrete or masonry are less susceptible to flood damage<sup>49</sup>. Similarly, buildings made with materials that are resistant to water damage, such as metal or concrete, are less likely to be damaged by floods<sup>50</sup>. Other factors identified in literature as influencing susceptibility are the age and condition of infrastructure. Older infrastructure, such as pipes and drainage systems, may be more prone to failure during heavy rainfall events<sup>51</sup>.

It is important to note that many of these factors interact with each other, and that the susceptibility to flood risk can be influenced by a combination of these characteristics (see Table 2.5). Notwithstanding, understanding susceptibility is important for identifying and assessing the physical vulnerability of a system to flooding, and for developing and implementing effective strategies to reduce risk and increase resilience<sup>52</sup>. By identifying and addressing the factors that contribute to susceptibility, it is possible to reduce the likelihood and severity of flood damage, and to improve the capacity of the system to recover from flooding.

### 2.1.5 Concept of Resilience

The word –resilience takes its origin from the Latin word *resi-lire*, meaning to spring back. Prior to the 19th century, resilience, as a design principle was an inherent aspect of traditional building construction knowledge in which buildings were designed to provide for unknown uses and adaptation<sup>53</sup>. Afterwards, the 19<sup>th</sup> century engineering concept of resilience emerged. This concept had its origin in material technology, and was based on the elastic behaviour of materials over a single equilibrium<sup>42</sup>. Today, resilience as a concept involved a shift from the engineering approach to ecological system which is based on the assumption that socio-ecological systems, like urban systems are characterized by multiple equilibrium and diverse adaptive capacity. Over time, resilience has been widely used in engineering and ecological systems, although its application in natural hazard management is relatively new; understanding the distinctions is fundamental to defining and approaching hazard management.

On the one hand, resilience in engineering is usually perceived as the ability of a system to return to equilibrium or a steady state after a disturbance or to a state that existed before perturbation occurred<sup>54</sup>. In this case, resilience is measured exclusively based on recovery, this implies that the faster the full functionality of the system is restored, the more resilient it is. Thus, in engineering resilience, the system may undergo risks and stresses but still maintain the old stable state of functionality. Ecological resilience on the other hand challenges the universality of a stable state for every ecosystem, to which it is assumed to eventually return after a disturbance. In reality, systems do not operate near equilibrium; and as such, several researchers have challenged the equilibrium paradigm<sup>55</sup>. Their thoughts are based on the idea that ecosystems contain many components and diverse processes, and returning to the previous state is extremely difficult if not impossible. Based on this view point, resilience is defined as a system's ability to tolerate change and reorganize or renew itself after disturbance(s)<sup>56</sup>. In other words, the focus of ecological resilience is the ability of a system to adapt and persist regardless of the risks and stresses it might have experienced; and it is measured by the magnitude of the disturbance that can be endured before the system shifts or changes its structure. Fundamentally, engineering and ecological resilience are two divergent and opposing system properties. From all indications, any change from the

old stable state is considered abnormal in engineering resilience, whereas, fluctuations are considered normal in ecological resilience as long as it can birth a new system that is stable and functional.

In the design and management of the built environment, engineering and ecological resilience theories have been applied. On the one hand, the recovery characteristics of engineering resilience are pertinent if a system is to be considered resilient<sup>57</sup>. Socio-ecological systems like built up floodplains which operate more like a complex open systems with diverse interacting agents will on the other hand require some level of self-organization, adaptive capacity, and redundancy to be considered resilient. It can therefore be inferred from the existing literature that resilience denotes the capacity of a system, community or group to resist, adopt, accommodate and reclaim from the impacts of hazards in a timely and efficient manner, including reclamation of its vital infrastructures and functions<sup>58</sup>.

Howbeit, ecological resilience is considered more appropriate for addressing flood risks that arise from the interactions between coastal dynamics and urban system<sup>59</sup>. For example, flood associated risks in urbanized flood plains are directly influenced by climate, socio-economic indicators, built infrastructure and riverine processes. Also, flooding occurs naturally along every river and coastal channel. Empirical studies suggest that building resilience to flood risk is based on the idea of –living with floods rather than fighting them, and rooted in the philosophy that flood is a natural process which societies can adapt to by being prepared and having the right attitude towards flood damage reduction<sup>45</sup>. Therefore, effective flood risk management based on resilience theory stems from two ideologies. First is the recognition that flooding cannot be completely prevented as integral environmental dynamics; in order words, socio-ecological system loses resilience when these environmental dynamics is artificially suppressed to promote stability through command-and-control management. Second is the understanding that flooding itself is an agent for resilience because each flood presents a learning opportunity for cities to adjust their internal structures and processes and to build knowledge that leads to diverse coping strategies cumulated over time so as to become better prepared for future risks. Hence, the concept of resilience in flood management is focused on building resilience as opposed to maintaining stability<sup>44</sup>. Considering that this

research seeks to assess how existing flood prone housing stock can be adapted for flood resilience. The study will consider specific criteria for resilience in developing a framework for flood adaptation.

Since resilience reflects a level of performance or condition, there should be factors or variables that can be utilized to measure it. Fundamentally, resilience is a theoretical construct and is not directly observable. It is context specific to time, space, livelihood and shocks; this fact makes framing a generic indicator of resilience a bit difficult<sup>54</sup>. However, there has been significant progress in developing resilience measurement frameworks, for example, the Norris model of resilience; the 3-D Resilience Framework; and \_costs of resilience models. The Norris model of resilience proposes that resilience can be measured in three layers: adaptation in the pre-disaster, adaptive capacity during the disaster and intervention in post-disaster (see Table 2.4).

Each layer has different characteristics and lead to specific outcome. The first layer entails the pre-disaster level of functioning or adaptation and the occurrence of a stressor/event. There are two pathways in this model, either stability is maintained through resistance, or there is a transient dysfunction which may lead to a re-adaptation or continued dysfunction in post-disaster. In the second layer of the model, adaptive capacities are considered.

**Table 2.4 : The Three Layers of Measurement of Resilience**

<b>Phase</b>	<b>Description of variables</b>	<b>Outcome</b>
<b>Pre-Disaster</b>	Pre-disaster level of adaptation and the occurrence of a stressor	Resistance to maintain stability, or Transient dysfunction that lead to re-adaptation or continued dysfunction
<b>Disaster</b>	Adaptive Capacity (resources, characteristics and conditions)	Improved resilience and post-disaster adaptation
<b>Post Disaster</b>	Intervention	Adaptive capacity for resistance in pre-disaster, and resilience during the event and in post-disaster.

Source:<sup>60</sup>

These include the factors that influence the resilience process and affect the trajectory towards post-disaster adaptation (see Table 2.5). The third layer of the model is the interventions, which are in twofold: during the pre-

disaster and post-disaster. Pre-disaster interventions can be used to improve the adaptive capacity for resistance, while post disaster intervention can be used at the time of the event and after to support resilience.

**Table 2.5: Summary of Conceptual Review**

Components	Characteristics of Variables
<b>Hazard</b>	Flood attributes Factors that influence flooding Flood impacts
<b>Exposure</b>	Hazard characteristics Demographic characteristics of the population Socio-economic characteristics of the population
<b>Susceptibility</b>	Neighbourhood characteristics Building characteristics
<b>Resilience</b>	Pre-disaster level of adaptation Adaptive coping capacity during disaster Post disaster Intervention

Source: Researcher's Summary from Literature Review, 2023

## 2.2 Theoretical Review

Theoretical frameworks are 'blueprints' or guidelines for inquiry based on existing theory in a field of study and often represent research hypotheses<sup>61</sup>. It consists of a combination of theoretical principles, structures, concepts and theories. Theoretical frameworks thus provides a theoretical basis for understanding, analyzing and designing methods for studying problems, making research findings more meaningful and generalizable. To better understand the indicators that influence physical vulnerability to flood risk for the purpose of improving adaptation, it is imperative to underpin this study on self-explanatory and testable theories. The present study considers the basic components of Physical Vulnerability assessment identified in literature, and as such, the theories identified for studying physical vulnerability (see Table 2.1) include the Vulnerability theory, Socio-ecological System theory, and Adaptive Capacity. The next section critically reviews these three theories.

### 2.2.1 Vulnerability Theory

Vulnerability is a potentially harmful condition in a socio-ecological system which increases susceptibility to disasters<sup>62</sup>. It shows how susceptible the system is to damages. Vulnerability is also defined as a function of a system's exposure, sensitivity or susceptibility, and adaptive capacity<sup>1</sup>. Some researchers see vulnerability as the opposite of resilience, while others see vulnerability as part of resilience<sup>63</sup>. In other words, resilience is a negative function of vulnerability and a positive function of adaptive capacity; where, resilience is achieved by reducing vulnerability and improving adaptive capacity. Also, some studies consider resilience and vulnerability as related concepts that are distinct but complementary if not mutually exclusive<sup>64</sup>. Additionally, theories of sustainability, resilience, adaptability, and vulnerability interact and interrelate to create urban sustainability<sup>65</sup>. Where, resilience is the ability of a system to respond, absorb, adapt or recover from shock; and vulnerability is when the system or any part of its constituents becomes susceptible to harm due to external forces or pressures. However, studies have argued that in discussing resilience, connections should be made with vulnerability in order to effectively deal with disasters in practical setting so as to help the people affected<sup>66</sup>. Similarly, recent studies also found that the resilience of urban systems depends on the presence, spatial distribution and social disparity of vulnerabilities; thereby delineating the relationship between vulnerability and resilience<sup>56</sup>.

The concept of vulnerability has its origin in the field of natural hazard and is increasingly used in a various research fields<sup>67</sup>. Vulnerability causes damages to lives, property and livelihoods from any hazard or natural disaster. This means that vulnerability is a system of physical, economic, social or political vulnerability of a community to damage caused by a dangerous event<sup>68</sup>. The concept of vulnerability in the context of the disaster management literature is too complex and diverse. In general, it refers to the vulnerability of a community to be harmed from an event, and is often determined by the community's geographic location and other factors<sup>29</sup>. A primary goal of vulnerability assessment in disaster risk reduction is to discover how to support marginalized people and places; and resilience also talks about the 'resilience for who and what'. Both expressed concern about the potential catastrophe of welfare systems for vulnerable end-users. Both are seen to be concerned about the disadvantaged end-recipients of the potential disasters to a social system.

Also, vulnerability literatures from a legal perspective claim that everyone should not only be treated equally but also have equal access to social institutions<sup>11</sup>. For example, the focus on marginalized and vulnerable groups that was part of vulnerability research is now part of resilience analysis, where vulnerability primarily affects vulnerable groups. This idea is supported by studies indicating that disasters are caused by vulnerabilities, not threats<sup>3</sup>. And from the human point of view, so-called risk factors are normal environments with important ecological and social functions. However, such incidents are considered dangerous because of their potential harm to society. In other words, there are no disasters without vulnerabilities. Therefore, identifying and understanding vulnerabilities and their underlying factors is important for flood preparedness and management practices<sup>6</sup>. Vulnerability analysis matrix examines the demographic and socioeconomic variables that affect a community's ability to cope with stress. Therefore, vulnerability analysis requires a more comprehensive approach, including qualitative, subjective, proportional and contextual approaches, as well as quantitative, objective, absolute and non-contextual approaches. Relevant measurable factors include structural, economic, social, educational, political, institutional, cultural, environmental, ecological, climatic, and ideological dimensions<sup>3</sup>. In particular, all these characteristics of vulnerability can be associated with natural disasters.

It is clear from the above discussion that flood-prone communities that do not consider vulnerability components and factors create neighborhoods that are susceptible to flood disaster risk. This in turn leads to physical damages and losses, and disruption of socio-economic activities. As such, vulnerability analysis plays an important role in disaster prevention. Therefore, in this case, physical vulnerability analysis is critical to identify the characteristics of the system that influence exposure, susceptibility and resilience to flood disaster risk for the purpose of developing a framework to guide adaptive design strategies for flood disaster risk reduction.

### **2.2.2 Socio-ecological Systems Theory**

A system is a set of interacting and interdependent parts that form a complex whole<sup>69</sup>. Systems thinking emerged in the 20th century as a belief that the world is systemic. This means that phenomena are understood as emergent properties of interdependent wholes<sup>70</sup>. The socio-ecological system (SES) theory was developed in the 1980s by the Resilience Alliance, a voluntary group of scientists from different disciplines, to study the dynamics SES and

its evolutionary potential. However, several scientific schools are interested in their study. This theory builds on concepts such as adaptive cycles, sustainability, vulnerability, resilience, adaptability, transformability, and hierarchy and creates a knowledge base for managing complex adaptive systems and aims to achieve sustainable development in theory and in practice<sup>71</sup>. Consequently, the structure of SES appears in many methodologies in the literature on action research, active-adaptive planning, participative design workshops and search conferences<sup>72</sup>.

The concept of socio-ecological system (SES) emerged as a product of open systems thinking developed by von Bertalanffy to explain life phenomenon<sup>73</sup>. This theory explains that a system is a complex of interacting elements and that they are open to, and interacts with their environments<sup>68</sup>. It is argued that the socio-ecological perspective takes the open systems principle as its intellectual framework of ideas. Socio-ecological systems are based on the concept that humans are part of nature rather than separate from it. The distinction between social and natural systems is arbitrary and artificial, and the socio-ecological system theory (SES) arose from the recognition of the close interactions between societies in terms of socio-economic and natural systems<sup>74</sup>. The SES theory recognizes that the human dimension is shaped and is in turn shaped by the environment, so that societies and ecosystems are interconnected and co-evolve across scales.

In essence, social-ecological systems theory has proved to be influential in addressing complex human-nature couplings, and as such instrumental for addressing flood hazards that arise from the interaction between riverine and urban fabrics<sup>75</sup>. Considering that this study seeks to assess how flood prone homes can be adapted for improved performance and disaster risk reduction, it is imperative to consider and analyze all the factors associated with various systems (such as social, economic, public policy and environmental stresses) that influence flood risk in an urbanized floodplain. This would provide a concise analysis of the system so as to be able to suggest adaptive strategies for risk reduction.

### 2.2.3 Adaptive Capacity Model

Some studies have perceived adaptive capacity and adaptability as the same. It is assumed that adaptation is a manifestation of adaptive capacity and a means of reducing vulnerability<sup>76</sup>. In other words, in any system, higher levels of exposure and sensitivity to climate stimuli or threats make it more vulnerable and higher levels of adaptive capacity make it less vulnerable. In providing a clearer explanation, some authors suggest that adaptive capacity is similar or closely related to many other commonly used concepts, including adaptability, response capacity, coping ability, robustness, flexibility and is also used as an alternative term for resilience<sup>77</sup>. In this context, adaptability refers to the dynamic ability to derive and unfold multiple evolutionary trajectories through loose connections between pre-existing social agents, thereby enhancing the system-wide ability to respond to unexpected changes<sup>78</sup>. Response capacity describes the ability to manage both the causes of environmental change and the consequence of that change<sup>79</sup>. In contextualizing this, coping capacity consists of resistance (the ability to absorb impact and continue to function) and resilience (the ability to recover from post-impact loss<sup>80</sup>). In fact, other studies had related this to robustness, which is a system's ability to remain functioning under disturbances<sup>81</sup>. Furthermore, it is also associated with flexibility, which implies the quality of diversification (number of options and strategies are available to prevent or reduce any negative impacts and to take full advantage of opportunities should a disaster occur) and preparedness (availability of appropriate responses to mitigate, respond and recover as quickly and efficiently as possible from a disaster)<sup>82</sup>. All of these constitute resilience, defined as the capacity of a society or an ecosystem to adapt to disruptions, to self-organize, and to adapt to stress and change while maintaining the same structure and same basic operation.

Adaptive capacity began to emerge as a basic organizing concept during a Workshop on Adaptation, Climate Variability, and Change organized by the Intergovernmental Panel on Climate Change (IPCC) in April 1998 in San Jose, Costa Rica<sup>17</sup>. Adaptive capacity has been approached and defined differently by various disciplines. Adaptive capacity is often used to refer to *-a vector of resources and assets* and is generally considered as four sets of interconnected resources: economic or financial, social, informational, and community<sup>58</sup>. In disaster resilience literature, the concept of adaptive capacity is used to describe conflicting impacts that reduce the

impact of exposure and susceptibility to the hazard<sup>83</sup>. In other words, adaptive capacity is the ability of a system to adapt its properties or behaviors to improve its ability to cope with existing and future climatic conditions.

In practice, adaptive capacity is the ability to develop and implement effective strategies to cope with or respond to changing hazards and pressures in order to reduce the likelihood and magnitude of adverse impacts from climate-related hazards<sup>84</sup>. Based on the characteristics above, adaptive capacity refers to the set of abilities of a person or system to change or modify itself or its environment in order to perpetuate its existence and reduce negative impact. Adaptive capacity is therefore interesting because it relates to the variable aspect that gives any interventions the possibility to change the characteristics of the system.

Since adaptive capacity reflects a level of ability or condition, there must be factors or variables that can be used to measure it. Studies suggest that adaptive capacity is influenced by many factors, such as existing infrastructure and assets, and potential for expansion/ scale, social and human capital, and previous experience in mobilizing external support, including the presence of formal organizations and effective local government that can mediate interventions and structural services<sup>85</sup>. Similarly, other related studies argue that adaptive capacity is determined by variables such as technology, resources, authority, human capital, social capital, sensitivity, information, credibility and public perception<sup>86</sup>. Adaptive capacity is therefore a set of characteristics of a system that concerns both physical (infrastructure, material wealth, technology) and social/institutional (human capital, political legitimacy, institutional strength) factors. It has been proposed that these properties can be used to assess how well different systems adapt<sup>88</sup>. As explained above, this adaptive quality depends on resources (e.g. technology, wealth, information/ knowledge), human capital (e.g. education, security), social capital (e.g. property rights), political legitimacy (e.g. credibility, accountability) and public perception (e.g. reflection, awareness, responsiveness).

Such multiple forms of –capitals provided within the Sustainable Livelihoods framework, are important independent variables, whether analyzed at the household or community level<sup>87</sup>. Adaptive capacity is therefore dynamic, context-dependent, exists and is shaped by interdependent scales. The determinants of adaptive capacity

are specific to the adaptive systems and their properties<sup>26</sup>. Similarly, research shows that adaptive capacity is an underlying quality that emerges when a system detects a threat. It is therefore difficult to define a metric that directly measure adaptive capacity. A number of indicators of a system can determine its behavior and response to unpredictable changes, but society itself is a complex system too difficult to model. Moreover, the adaptive capacity of a system goes beyond its ability to cope; successful coping does not necessarily imply adaptation and adaptation is –probably minimal when existing coping mechanism are successful. From this perspective, adaptation and adaptive capacity generally refer to long-term proactive adjustments, whereas those that are more reactive in nature and short-term adaptations are called coping strategies<sup>74</sup>. The process of adaptation requires the ability to learn from past experiences to deal with current climate and apply those lessons to deal with future climates<sup>88</sup>. Therefore, the ability to learn from experience is also a determinant of adaptive capacity. It is therefore imperative that in assessing adaptive capacity, consideration should be given to levels of adaptation, coping capacity and existence of intervention for recovery.

**Table 2.6: Theoretical Framework and Research Objectives**

<b>Research Objectives</b>	<b>Research objectives</b>	<b>Applicable Theories</b>
1	To assess the demographic and socio-economic characteristics of residents of the flood prone areas of Kosofe , Lagos State, Nigeria;	Systems thinking/ vulnerability
2	To investigate the attributes of the flooding experienced in the study area;	Vulnerability
3	To assess the neighbourhood characteristics and Architectural design features of the existing housing schemes in the study area;	Systems thinking/ vulnerability
4	To examine the adaptive capacity of residents of the study area to flood risk;	Adaptive Capacity
5	To investigate the extent to which socio-economic, neighbourhood characteristics and architectural design features as well as the adaptive capacity of the existing housing schemes influence the physical flood vulnerability in the study area;	Vulnerability

Source: Researcher’s Summary from Literature Review, 2023

## 2.3 Review of Empirical Studies

### 2.3.1 Flooding, Flood Risk, Impacts and Management

Globally, rapid urban population growth and associated increase in demand for physical development have been widely documented in literatures<sup>89</sup>. The effect of rapid urbanization on storm water runoff is also well documented in literature<sup>69</sup>. This situation has been further compounded as the world continue to experience extreme weather events characterized by more frequent intense and sudden downpours, whose severity in terms of impact within the built environment depends significantly on the level of vulnerability and exposure to these events. Unfortunately, communities in large floodplain area continue to increase, and avoiding floods occurrence in these areas remains challenging<sup>90</sup>. Extreme weather and other weather events, also increase vulnerability to extreme floods by altering the resilience, coping, and adaptive capacity of communities, societies, or socio-ecological systems affected by such events. Thus, in recent years, due to the physical and socio-economic effects of flood (including threats to lives and livelihoods of residents, as well as direct and indirect economic impacts), flood risk mitigation has become increasingly popular around the world<sup>24</sup>.

The costs linked with flooding are increasing in many places due to the combined effects of the increasing concentrations of people and assets in areas at high risk of flooding (related to land use, urbanization and development practices); and the increasing frequency and severity of climate-related weather events (e.g. changing storm, rainfall patterns and sea level rise). Today, floods account for around a third of economic losses from natural disasters worldwide<sup>11</sup>. In the United Kingdom (UK), the risk of flooding is expected to increase with losses rising from £1.3 billion in 2017, to £2.1 – £12 billion by the 2080s<sup>91</sup>. Already, insured property market loss from February 2020 flood in the UK is estimated at around £297million<sup>24</sup>. The situation is even more dramatic in a country like china as about 137 million residents have been affected by high-intensity flash floods, which had caused diverse fatalities and economic losses<sup>25</sup>. Lessons learnt from flood wrecked coastal city like Louisianan, United States of America (USA) revealed that hurricane Katrina started out as a natural disaster but became a man-made disaster due to failure of structural levees and a lack of preparedness, which resulted in approximately

1,200 deaths and \$108 billion in property damage<sup>92</sup>. Many roads and buildings were damaged; and till date, the city and by extension the residents are still in the process of recovery from the aftermath of disaster.

In Lagos, Nigeria, the cost of flooding is increasing in many areas due to the combined impacts of increasing concentrations of people and resources in areas of high risk of flooding, as shown in table 2.7 for flood impacts studies in Lagos, Nigeria.

**Table 2.7: Studies on Flood Impacts in Lagos, Nigeria**

S/N	Findings
1	In September, 2020, reports of floods in 3 local government areas of Lagos (Apapa, Mushin and Surulere) affected 15,385 people, the National Emergency Management Agency provided food and construction materials to assist residents <sup>27</sup>
2	The biggest impacts on Lagos, 38% of residents experienced damages to properties, disruption of daily activities, displacement, hospitalization and loss of lives respectively <sup>88</sup>
3	In 2012, seven people died in Lagos as a result of flooding; people were injured and a number of unknown houses was destroyed <sup>88</sup>
4	In July 2011, the floods caused by heavy rains resulted in about 17 to 25 deaths (although more than 100 deaths were mentioned in another report), displacement of around 5,000 people (although an IFRC report stated that 5,393 households were affected, and it appears that some reports may have confused these figures with damage estimated at between USD 200 and 320 million) <sup>93</sup>
5	In 2010, the flood of Ikorodu, Lagos caused ‘general losses’, several thousands of residents were displaced, out of which 1,765 was housed temporarily for 10 months by the Lagos State government <sup>94</sup>
6	81% of the survey respondents reported an increase in transportation costs and breakdown of vehicles making it difficult to travel <sup>37</sup>
7	More than half of all respondents to a Lagos-wide survey had experienced property damage worth more than NGN 52,000 (USD 330), which is more than one month’s income for three-quarters of the respondents <sup>91</sup>

- 8 In many areas of Lagos, drainage channels carrying raw sewage and solid waste overflow during floods, contaminating water sources and spreading waterborne diseases, although the prevalence of diseases has not been estimated<sup>20</sup>.
- 9 In a survey of residents in four communities in Lagos, 91% of respondents cited \_repeated visits to health centres due to health problems and increased medical costs as the main impact of the floods<sup>91</sup>

Furthermore, growth in population and continuous physical development in flood-prone areas exacerbate the risk of flood damages and losses. As such, when flooding occurs in these areas, buildings and its contents are most often subject to structural and electrical damages, appliance damage, growth of mold and mildew, damages to septic tanks (see Table 2.8 below). Obvious structural damages include buckling floors, cracks in roof or foundation, broken or frayed electrical wires, and damaged switches. Similarly, heating, ventilation and air conditioning system (HVAC) may be compromised and water heaters and refrigerators can be damaged. Furthermore, molds can grow on any damp surface such as walls, floors, furniture, and clothes within 24-48 hours; and damages to septic and contamination of well water.

**Table 2.8: Flood Damages in Homes**

Type	Features
<b>Structural And Electrical Damage</b>	Buckling floors and cracks in roof or foundation Broken or frayed electrical wires Damaged switches
<b>Appliance Damage</b>	Heating, ventilation and air conditioning system (HVAC) may be compromised  Water heaters and refrigerators can be damaged
<b>Mold And Mildew</b>	Molds can grow on any damp surface (walls, floors, furniture, clothes) within 24-48 hours
<b>Septic And Well Water Systems</b>	Clogged Septic tank filters by debris may prevent it from accepting water.  Sediments may be carried into wells and contaminate drinking water

Source:<sup>95</sup>

This situation is usually traumatic for most people and recovery may take a while. In fact, the most severe flood scenario impacts are related to physical illness, psychological stress, flood-related water and safety issues, and dispute with insurance and construction companies, exacerbating psychological health problems<sup>96</sup>. For example, poor solid waste management is reported in most cities in West Africa; consequently waste mixes with floodwaters as it moves through the flooded area, including people's homes<sup>97</sup>. However, affected people can be left without clean water for drinking and hygiene for weeks or even months. All of this can lead to outbreaks of deadly diseases such as typhoid fever, malaria, hepatitis, and cholera.

In addition, fatalities are generally caused by flash floods that occur without advance warning, rather than by events such as river flooding and storm surges that may receive advance warning<sup>40</sup>. Injuries can also occur when residents return to clear up after a flooding event. Similarly, the lack of medical care after flood damage, poisoning from ruptured pipes, storage tanks, soil contamination and an increase in related illnesses can escalate the negative impacts of large floods<sup>21</sup>.

The combined economic and physical impact of floods highlights the significance of mitigating flood risk, particularly in at risk areas. Current flood risk management (FRM) approach in the UK is based on the principles of risk analysis. In other words, risk is quantified according to the probability of flooding and the severity of consequences such as human health, economic activity, and environmental impacts<sup>25</sup>. Till date, implementation of sustainable drainage systems (SuDS) to manage fluvial and pluvial floods is required by the Flood and Water Management Act (FWMA) for new developments in the UK<sup>93</sup>. In Lagos, Nigeria, there is a general low level of awareness in the practice of Sustainable Urban Drainage System (SUDS)<sup>98</sup>. The general practice in managing flood risk has been mainly through structural interventions such as expansion and maintenance of drainage infrastructures within the city heartland; demolition of homes in flood-prone area; relocation and resettlement schemes for the residents of vulnerable areas, as well as with non-structural measures such as pre-disaster predictions, warnings and emergency management<sup>37</sup>. Whereas in China, the FRM strategy in use was inspired by Low Impact Developments (LID) in the US, SuDS in the UK, and Water-sensitive Urban Design in Australia. The focus was to upgrade existing urban drainage infrastructure and utilize more naturally inspired drainage

systems. This strategy usually referred to as the Sponge City concept was adopted in 2013 to reduce the magnitude and frequency of flooding events in china<sup>25</sup>.

It is clear from empirical studies that there has been a gradual shift from the traditional risk control to risk reduction. The disaster reduction viewpoint is based on the need to identify effective solutions to reduce the negative impacts of flood hazards. Over the last two decades, this ideology has experienced a transition from structural flood control towards an integrated flood risk management approach. In this context, structural measures aim to reduce flood risks by using channels and natural and man-made barriers to contain waters in rivers and seas; while the non-structural measures can be effective in reducing vulnerability and developing the capacities of socio-ecological systems to cope with floods through multidisciplinary approaches<sup>42</sup>. Non-structural measures include flood risk mapping, zoning and land use planning, flood vulnerability assessment, flood proofing, flood modeling, institutionalization of policies, flood awareness campaigns, flood insurance, flood forecasting, relocation of properties, resettlement of human population, and green infrastructure planning<sup>6 5</sup>.

Studies have also indicated that integrated flood risk management approach is founded on three key considerations, namely: (1) the limitations of traditional flood control measures; (2) the need for a more people-friendly approach to flood management; and (3) the aim to reduce all impacts of extreme floods while reaping all the benefits of ordinary floods<sup>20</sup>. These considerations are encapsulated in diverse resilient model which typically includes prevention, protection, response, and recovery<sup>50</sup>. This is imperative because resilient measures are more appropriate due to climate uncertainty, and the flexibility to change from one to another alternative is significant. On the other hand, it is important to note that fundamental to the modern FRM is the idea of -living with floods rather than fighting them, it is rooted in the philosophy that flood is a natural process and societies can adapt to floods by being prepared and having the right attitude towards damage reduction<sup>74</sup>.

Overall, FRM still tends to be reactive, focusing on problems that occurred during a flood event rather than anticipating future risks and building resilience<sup>24</sup>. While research and innovations in FRM are developing, there is a great need to integrate 'building adaptation' and 'resilience' in flood management paradigm, by targeting

building codes. There is also urgency for people to take more significant roles and responsibility in enhancing flood resilience through diverse adaptation measures, particularly at the property level. This is particularly relevant to coastal cities where climate-change induced flooding is unavoidable. It is on the strength of the foregoing that this study seeks to assess the important indicators that influence physical vulnerability, and the current local property-based flood adaptation capacity, so as to leverage on the knowledge to promote flood adaptation.

### 2.3.2 Flood Adaptation Measures

Multifunctional landscapes based on the application of nature-based solutions have increasingly played an important role in flood management to achieve urban water and climate resilience. Consequently, blue-green infrastructure and nature-based solutions are ranked by rain water storage capacity<sup>99</sup>. Within the European Commission framework, Flood Adaptation Measures (FAMs) are assessed based on their ability to mitigate the risk of inundation and flooding in urban areas; and are categorized according to six functional objectives that describe the main water processes, namely: infiltration (to recharge aquifers), purification (to clean runoff), conveyance (to move stormwater), retention (to reuse rainwater), detention (to delay stormwater), and attenuation (to slow down flood water)<sup>100</sup>.

On one hand, Infiltration is thought to be the process by which rainwater seeps into the ground, maintaining the natural water cycle and replenishing aquifers. Infiltration can be achieved through a combination of several means such as infiltration walkways, bio-swales, infiltration ponds, infiltration wells, etc.<sup>101</sup>. They support urban flow control and several ecological functions including peak flow attenuation, base flow management, erosion control, groundwater recharge, water quality improvement, and evapotranspiration processes<sup>102</sup>. Purification, on the other hand, defines many wastewater treatment processes or mechanism such as sedimentation, filtration, evaporation, aeration, biotransformation, and phytoremediation. Various infiltration measures, such as green roofs, bio-swales, bio-retention and permeable walkways have been shown to be effective in treating contaminants from runoff<sup>103</sup>.

Plants play a key role in rainwater management and provide the opportunity to use various bioremediation and plant purification methods<sup>104</sup>. The effectiveness of purification measures in each individual case depends on the site configuration, climate, soil properties, vegetation, topography, and hydrology<sup>25</sup>. In addition, conveyance refers to measures to divert and move runoff from where it initially falls to its final outlet (such as, a basin, river, or lake). Rainwater conveyance is often necessary to avoid flooding from densely populated areas. Linear bio-swales, streams, infiltration ditches and dry streams provide conveyance to the urban storm water system<sup>105</sup>. Contaminants trapped by runoff during conveyance can be removed through sedimentation, aeration, filtration, and infiltration by using blue-green infrastructures<sup>106</sup>. Detention requires a relatively long-term storage of rainwater for later use or until it can be discharged into public sewer system or water bodies<sup>99</sup>.

Typically, detention facilities include built wetlands combined with ponds, bio-retention basins, green roofs, underground reservoirs, and cisterns. Integrating various systems provides both stormwater treatment, such as filtration, and storage that enables subsequent reuse of water. Furthermore, detention is the process that determines the short-term storage of rainwater. Detention time vary from a few hours to several days. Discharge typically occurs in adjacent surface waters<sup>98</sup>. Various nature-based solutions can have detention features. Detention measures can control peak flows, downstream flooding and soil erosion, and allow gravitational sedimentation of pollutants<sup>25</sup>. Attenuation, refers to engineered landscape interventions that intercept and reduces runoff pathways to provide multiple benefits, including flood control and improved water quality<sup>107</sup>.

Runoff attenuation typically involves reducing flows by wooden barriers, levees, ditches and weirs and the use of temporary storage ponds, riparian forest, and floodplain vegetation patches. Small- scale storage wetlands cluster can also be used for flow reduction and can be easily integrated into the landscape<sup>13</sup>. Literatures have also considered the identification of different types of landscape design for flood adaptation that are designed to respond to distinct contexts (*large, at the scale of urban or river basin; medium, at the site-scale; small, at the scale of the architecture / landscape architecture*). For example, a study highlighted eight types of flood adaptation, including: flood adaptation development, wetlands, bio-retention corridors, rainwater sponges, blue-green buffers, floodable wetlands, terraced wetlands, and water sensitive networks<sup>98</sup>.

Overall, as flood management in urban areas requires complex interdisciplinary skill across different disciplinary domains, more insight can be derived from a new classification of existing flood adaptation measures that can interpret the interrelations of specific urban contexts and distinctively designed solutions. Identifying Flood Adaptation types provides a set of optimal immersion solutions that provide a ‘\_toolbox’ to help landscapers and planners identify the most appropriate flood response mechanism for a design proposal.

### **2.3.3 Architectural Strategies for Flood Adaptation**

For many people, a home is their most important asset, often providing a place to live, including storage space for essentials and tools<sup>108</sup>. Residents in flood prone areas are particularly vulnerable and are at risk of flooding and associated losses. Considering flood resistance in the design, construction, and renovation of these can significantly reduce the damage to the homes of these vulnerable people. A number of design recommendations and response strategies are being implemented around the world in efforts to improve flood adaptation. Building guidelines identified four technical standards that must be met: (i) the ground level of the house must be higher than the largest flood ever, (ii) minimum floor area must be at least 10 square meters (m<sup>2</sup>), (iii) designed housing must be durable, and (iv) the roof must be strong enough to withstand the wind. Studies have also recommended the integration of resilient features of robustness, redundancy, and flexibility in building design and construction<sup>13</sup>. Where, robustness implies that houses are designed, constructed and maintained in anticipation of high-impact climate events<sup>109</sup>.

Failure of one system can be compensated for by another, thus avoiding serious consequences. Residential rooms, for example, are designed with a combination of reinforced concrete (RC) frames and RC slabs to form a vault that allows residents to escape in the event of major flood. This room protects the occupants even if the rest of the house collapses. Similarly, the rooms on the second floor serve as shelter for residents in case the lower floors are flooded. Redundancy is referred to as the spare ability to absorb extreme loads. Interacting components consist of identical similar parts and can be replaced in the event of failure of one or more parts. For example, the primary structure of a resilient home can be designed to be stronger than the primary structure of a conventional home. And flexibility means that actionable changes occur as circumstances change. Assets and functions are distributed

in such a way that a particular event does not affect them all at the same time, providing several means of meeting needs.

Another design proposal is the Pilotis architecture. It refers to a building on the ground resting on pillars, essentially a modern house on stilt. They are not uncommon in urban areas and are built en-masse, such as in Singapore, where 85 percent of the city-state's residents live in public housing, in high-rise buildings on pilotis. Locally known as the -void deck, the ground floor of the building was used as an open space while promoting ventilation and security<sup>42</sup>. There appears to be a renewed focus on traditional amphibian houses. This is a dry and wet house. Recent studies on adaptation has shown built systems need to be more resilient by developing local flood response capabilities for proper system-wide coordination<sup>45</sup>. Amphibious houses are being developed in the Netherlands and the UK, which can be placed on land but float vertically in floods<sup>42</sup>.

Furthermore, researchers and designers in the UK have adapted property flood resilience measures that do not require structural changes<sup>24</sup>. This may include measures such as raising electrical systems and appliances above flood levels, installing waterproofing materials and flood barriers, or elevating the property above the highest expected flood level<sup>93</sup>. The goal of property flood resilience is to minimize damage and disruption caused by flooding and to shorten recovery times. Other risk reduction strategies at the property levels are door and aperture guards, flood doors and external wall treatment<sup>110</sup>. In the short term, government can incentivize the adoption of property flood resilience. However, in the long term it is best if all low-lying buildings are raised or able to float above the maximum flood level. It is especially necessary when the water is highly polluted and floods can cause epidemics. To achieve system-wide (i.e., at the district or city scale) building adaptation, government may need to provide flood adaptation grants to households experiencing hardship.

#### **2.3.4 Determinants of Effective Architectural Design Strategies for Flood Adaptation.**

Buildings are long-term assets that provide opportunity for climate mitigation through adaptation. Although not all residents of affected buildings are equally vulnerable. The vulnerability of an individual building is greatly influenced by its adaptability. Building adaptability is defined as -the ability of a building to adapt effectively to

the changing demands of its circumstances, thereby maximizing its value throughout its life<sup>111</sup>. This includes both user adaptations to the building and the structural changes to the buildings. Adaptability of buildings is therefore essential to meet the changing needs of owners/users and the requirements of external factors over the life cycle.

Based on the foregoing, the concept of Adaptive architecture has evolved in order to ensure that buildings are well adapted to be more resilient in the face of a changing climate considering growing flood risks within the built environment, and its implication on building design and fabric, as well as building occupants and their well-being<sup>74</sup>. Adaptive architecture is basically about buildings that are specifically designed to adapt (to the environment, the people who live in it, objects they contain) either automatically or as a result of human interferences. In general, adaptive elements include building surfaces, components and modules, spatial features and technical systems<sup>112</sup>.

Several studies have attempted to assess the motivations and drivers of adaptive design. For instance, research has pointed to triggers not only in cultural, societal and organizational domains, but can also be related to communication and social interaction; whereas, other studies have argued that the stimuli for designing for building adaptability range from the local/ national scale to the building scale<sup>113</sup>. While the local/national scale includes economic, social, and environmental factors; the building scale on the other hand considers aspect of building obsolescence such as functional, technological, social, physical, legal, environmental and economic. This aligns with earlier studies which defines ‘Design for Adaptability’ as *–strategies used to prevent the environmental and financial impacts of building aging, and the associated resource consumption and material waste*<sup>114</sup>.

Studies have also attempted to explain criteria for building adaptability from a general perspective. For example, it is suggested that for a building to be adaptable it should be able to adjust to different functions, users and change in climate scenarios. On the other hand, noted that building design and policy responses play a vital role in adapting buildings for climate change<sup>115</sup>. Empirical examples from the UK highlight climate issues to consider

when planning building adaptability, including: location, site layout, building design, structure, envelope and materials, ventilation and cooling, drainage, water, outdoor spaces and connectivity<sup>116</sup>. Similarly, the Town and Country Planning Association (TCPA) Design Guidance on Climate Change Adaptation shows how adaptation options vary by geography and scale of development and draws on case studies from around the world to help guide effective adaptation. Also, the BRANZ report for AGO in Australia, uses cost estimates to assess the feasibility of adaptation options and address research needs, including the need for risk and status assessments and cost-benefit analysis of adaptation options<sup>74</sup>.

However, literature that explicitly describes the factors that determine effective architectural design strategies for enhancing building adaptability for flood resilience are lacking. Most of the existing studies address considerations for flood resilience within the broader community context. For instance, recent studies identified four concerns (Environmental, disaster management, socio-economic, and institutional/governance) in literature on flood resilience which may be applicable in adaptive architectural design planning (see figure 2.1 below). The authors noted that discovery from environmental concerns have highlighted the need to develop climate coping strategies. Similarly, the disaster management literature emphasizes the need for an integrated and resilient response to flood events based on the local context. The literature on socio-economic issues has combined the selection and implementation of options with an understanding of investments, disbursements and compensation, cost of climate change and flood risk in the absence of adaptation measures. All of the above activities are influenced by institutional and governance functions, such as existing policies, authorities, political conditions, and perceptions embedded in history and culture, as highlighted in the literature on institutional concerns and governance.

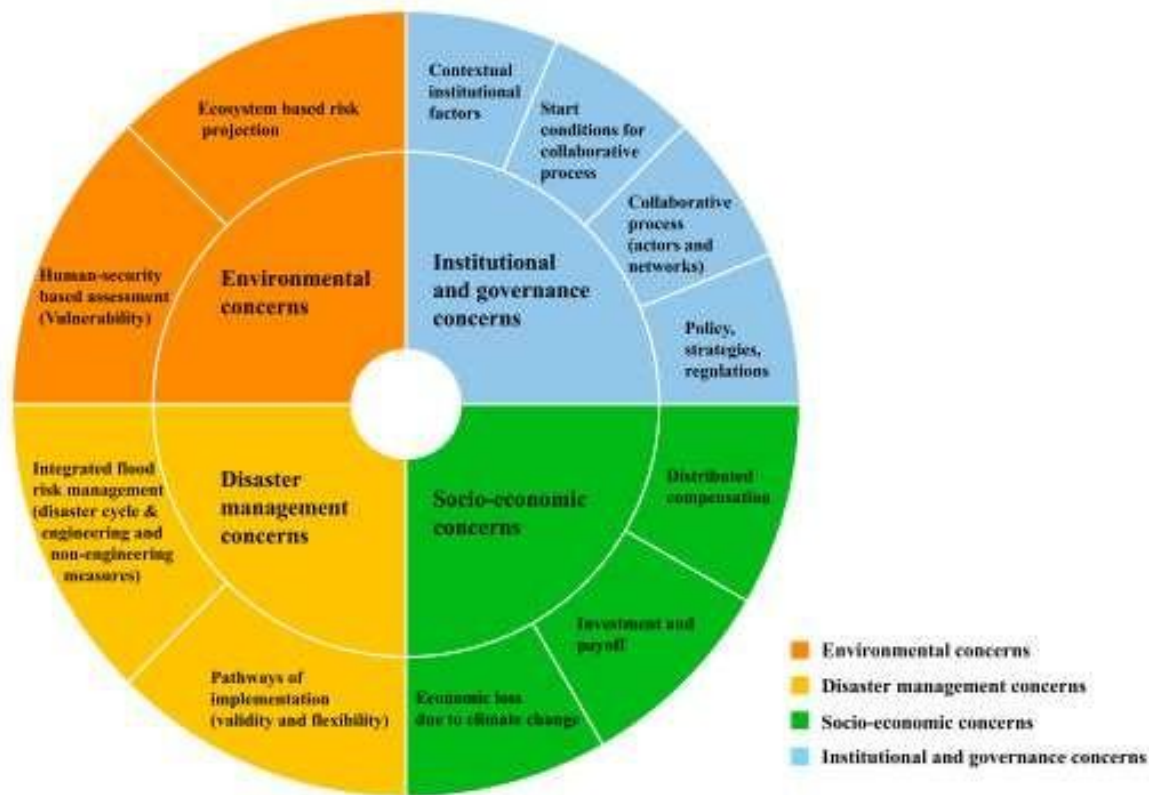


Figure 2.1: Four concerns for flood resilience

Source:<sup>114</sup>

Broadly, the triggers for flood adaptation in buildings refer to a variety of events (e.g., environmental, economic, financial) or actors (e.g., users, owners, external stakeholders), that may be external or internal to the building. Hence, an inference may be drawn that the factors that determine effective architectural design strategies for adapting buildings is multi-dimensional and varies from place to place, subject to levels of risk, available skill, funding, political will, and so on.

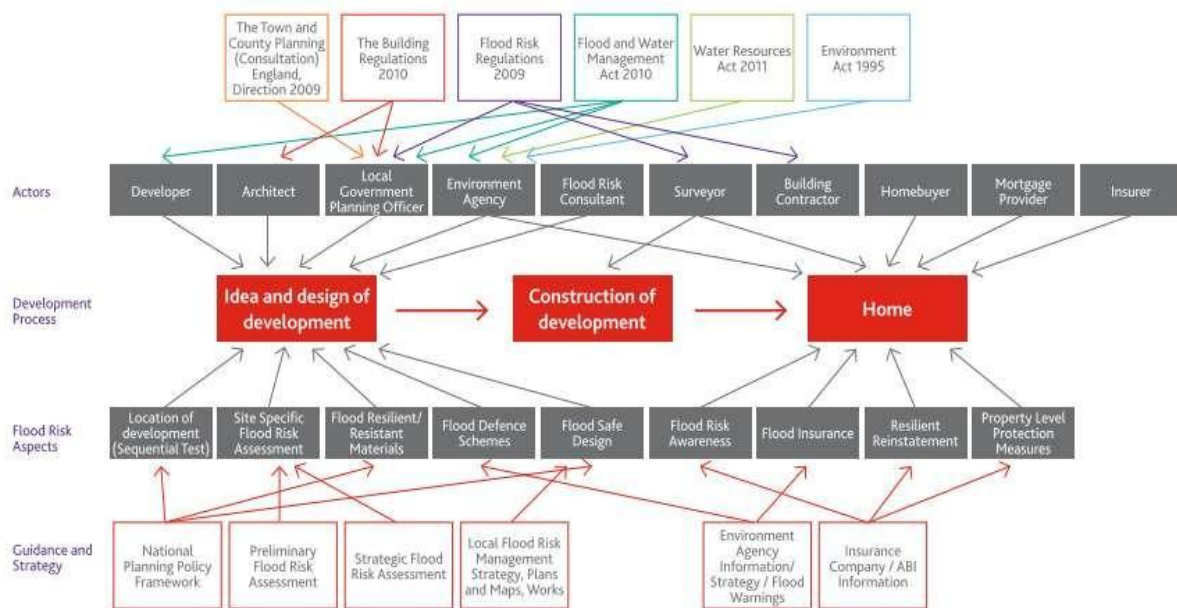
### 2.3.5 Building Codes, Regulations and Bye Laws on ‘Flood Adaptation’ and ‘Resilience’

The development, application and enforcement of building codes, regulations and bye-laws are potential solution for incorporating safety, environmental and other measures into the built environment<sup>24</sup>. Codes provide information and guidance on how buildings are constructed, which materials are used, how much energy or water is consumed, and whether it is designed to reduce vulnerability. Typically, building codes rely on historical climate data to predict issues that may occur during a buildings’ life cycle. However, considering today’s increasing flood risks and physical vulnerability in many regions of the world resulting from a changing climate,

population and development growth trends; there is a growing urgency for buildings as essential components of the built environment to be more resilient in adapting to climate risks<sup>88</sup>. Responding to climate change as it affects the built environment from an adaptive point of view require strategic approaches from policy, regulatory and institutional frameworks and capacities<sup>27</sup>. In resonance and considering the chief role these sectors plays in overseeing and providing guidelines on building related activities, it is imperative to explore existing codes on ‘\_building adaptation’ and ‘\_resilience’ to flood risks. This is to assess the various interventional actions that have been taken by government agencies saddled with the responsibility of protecting buildings from flooding.

From global perspective, climate change has been mentioned in some key policies in most countries that are signatories to the Kyoto protocol and the Paris agreement, yet some of these policies are simply too generic and does not directly address certain adverse effects of climate change in the built environment. By default, government standards and regulations as described in building codes and planning laws mainly focus on more general issues related to building designs. These include the maintaining of standards in the area of Health, Safety and Environment (HSE) as depicted in planning regulations, building codes and environmental impact guidelines. However, with increased flooding issues, some countries have had to be more concerned with developing specific policies or strategies in the area of architectural design, planning and landscape and the use of building materials to increase flood resilience.

For example, a whole range of policies and laws exists in the United Kingdom (UK) on risk prevention through planning policy and land use. Through the ‘-Planning policy guidance note 25: Property development and flood risk’ a document published by the UK government to provide guide on when and how flood risk should be taken into account during the different stages of planning, designing and building properties (see figure 2.2 below). The document also recommends floor level height design and as well as spatial inclusions or non-inclusions.



**Figure 2.2: Stages, rules, policies and organizations that influence the planning, design and building processes in England**

Source: adapted from Surminski and Mehryar<sup>24</sup>

Additionally, the Royal Institute of British Architects (RIBA) Policy Note of 2018 contains more practical and innovative examples of flood-resilient architectural designs. The policy note is inspired by multifunctional and adaptable urban design solutions such as the flood defense in Katwijk aan Zee, Netherlands that combines parking and hospitality amenities with storm-proofing; the floating settlement in Waterwoningen, Amsterdam and the urban development plan of Hafen City, Hamburg that doubles as its own flood barrier<sup>27</sup>. However, a detailed statutory guidance, building standards and regulations for such new flood resilient developments is still lacking. The London Plan, on the other hand, contains draft policies taking into account legal requirements, planning acts, sustainability assessments and regulatory assessments up to the year 2031. For example, section 5.12 of the policy is the planning decision which suggests that housing development should be approved a PPS25 test exceptions for flood resilient design and emergency planning. This part of the policy emphasizes that buildings should be designed with the ability for recover quickly after a flood (No.4, Paragraph C, Policy 5.12). Furthermore, Paragraph 7.19 states that –new buildings should achieve the highest standards of environmental, social and economic sustainability by meeting established standards of sustainable design and construction.

Similarly, the US government has provided standardized building codes that are updated every 3 years and specifically addresses the use of flood resistant materials for all structures in flood hazard areas. They also provided articles identifying some of these materials by their ability to withstand direct and prolonged contact with water, without sustaining damage requiring more than cosmetic repairs. The USA has also gone further by proposing future standards that use specific methods to determine the resistance of materials to flooding, as well as materials capable of resisting flood-borne pollutants<sup>74</sup>.

In Nigeria, the federal government and a number of civil society organizations have made efforts to mitigate risks, improve local and national adaptability and resilience to the adverse effects of climate change. For example, the Nigerian National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN) were developed to address the impacts of climate change 13 priority sectors<sup>27</sup>. The three (3) strategies with planning implications are as follows: i) to help reduce community vulnerability through participatory land use and housing planning, ii) to prevent building and cities from encroaching into vulnerable areas, high risk and low lying areas, iii) to stop inappropriate housing and settlement patterns in the face of climate change.

Unfortunately, none of the policy strategies proposed at the time addressed the specific problems of building design and building materials in the UK and US. The three cited points above that have planning implications are quite generic but in the years that followed, other documents such as the Federal Ministry of Environment Policy Document of 2005, section C, focused on flood prevention, mitigation, control, forecasting and warning, mapping, evaluation, provision of regulations to flood management and zoning. The strategies put forward to achieve its set objectives are flood plain regulations included in the building codes, flood plain zoning and introduction of flood control procedures as part of contract specifications in construction sites. Although, this policy document was released in 2005, the National Building Code released a year later in 2006 which ought to have reflected some of the strategies, had no mention of flood resilient designs, flood resilient materials or flood proofing.

However, in 2011, a more comprehensive flood control plan was drawn up in the Federal Republic of Nigeria National Environmental Regulations-Official Gazette<sup>27</sup>. It included 18 flood regulations, 3 inspection and enforcement actions, permit procedures and waivers. The regulations specified;

The requirement of special permits for location, planning and property development in areas vulnerable to flood hazards include but are not limited to ensuring the incorporation of flood mitigation measures in all infrastructural developments, including criteria for infrastructural development involving water diversions and other earth intrusive works, recommendations for use of flood resistant materials for all new construction, recommendations that the national building code incorporates the use of flood resilient electrical, heating, ventilating, plumbing and air conditioning equipment in all new construction in flood prone areas, the development of flood elevation data for public use to be ensured by the National Environmental standards and Regulation Agency (NESREA), the elimination of flood damage by promoting infiltration of rainwater through sewage and sanitary systems, and ensuring compliance and investigating all forms of violations.

The ordinance is more detailed and varied in scope than the two previous policies, but leaves the development and implementation of more specific control/mitigation measures to individual commonwealth states. This is mentioned in Regulation no. 4, which states that –applicants shall comply with the zoning and building codes of the specific states and local governments in which the development occurs|. This is because, in Nigeria, the Federal Government makes the laws and ordinances as they see fit based on their geography. This relieves the Federal Government of responsibility for the design and actual implementation of these regulations and places the burden of proof on the states.

In theory, however, the conditions for approval of floodplain construction plans for federal projects require that the following (Site Plans, Detail Plans, Construction Specifications, Drainage computations (for run-offs etc), Flood proofing details, Flood proofing certification, and Erosion control plans) be included when applying to NESREA.

The purpose was to ensure compliance of regulations across flood prone areas in the country, regardless of what State the project is to be domiciled in, but this is only in theory and not the case de facto; as they are not demanded for by the approval boards at the State level<sup>27</sup>.

On the other hand, Lagos State has enacted policies with more direct implications on planning that are pertinent to its environmental challenges induced by climate change. For example, out of the 44 strategies and measures contained in the Lagos State Climate Change Adaptation Strategy (LAS-CCAS) which is updated every 3 years; 14 are directly related to planning and urban design, while just one is directly related to architecture. The planning strategies include: community engagement in the participatory planning of their settlements in order to mitigate vulnerability to climate change; enforcement of land use zoning regulations, through restriction of building development in high risk areas, like the ocean front, flood plains and low-lying terrain; production of land-use maps of the main urban settlements in the State and periodically review them; preparation of a detailed master plan for urban settlements considering the challenges linked climate change and implement them; incorporate the various District and Model City Plans and ensure their implementation; complete and ensure regular review of all physical development plans in the State; foster the use of soft landscaping (i.e., grass in external areas of buildings) rather than concrete; intensify the process of providing green parks and open spaces in urban areas; develop a long-term physical plan for the coastal zone, using the principle of integrated coastal zone management; integrate a disaster prevention policy into the State's land use planning and development control; place strict control over all new land reclamation along the coast, increasing standard to 4metres above sea level with a requirement for sea defenses against storm surges; create buffer zones in physical planning to accommodate anticipated sea level rise; strengthen policies prohibiting building on water course; draw up and implement a Lagos State energy policy, integrating climate change considerations; while the architectural strategies is focused on encouraging the adoption of green architecture.

Although this policy document is richer in content with regards to planning implications, it is however completely lacking in the area of building material policies and could also benefit from more specific architectural design policies.

Conclusively, while the level of government involvement in protecting buildings from flooding is so far highly commendable in the UK and US; in Nigeria, climate adaptation regulations in building codes are inadequate and much work needs to be done in this area. There is need to review the current national building code to include policies directly linked to architecture, planning and use of building materials in high-risk flood zones.

### **2.3.6 Adaptive Capacity, Social Capital and Coping Strategies for Flood Disaster Risk Reduction**

Adaptive capacity is the property of a system that allows it to change its properties and behavior to extend its range of adaptation to existing and future climate conditions. Specifically, adaptive capacity is the ability to develop and implement effective adaptation strategies and respond to changing threats and stressors to reduce the likelihood and magnitude of negative outcomes<sup>117</sup>. Research has shown that the presence of strong social capital and the existence of coping strategies play an important role in increasing adaptation for flood disaster risk reduction<sup>57</sup>.

On the one hand, social capital is defined by the density of trust networks and useful relationships between people; and it is categorized in relation to the bonding (relationships with family members and relatives), bridging (relationships with neighbours and friends) and linking (relationships among people, communities and organisations structured differently in terms of societal power)<sup>35</sup>. Over the last decades, much attention has been paid to the role of social capital in promoting positive actions within and across disaster-affected communities. Social capital has received special attention in the context of developing country because of the assumption that strong social capital can supplement scarce resources, such as financial, human, natural or physical capital resources<sup>35</sup>. Much of the existing literature identifies the various ways in which social capital influences risk reduction, preparedness, response, and recovery cycles<sup>17, 77</sup>. Social capital provides information and assists indecision-making, including evacuation before hazards occur. Social capital in the form of mutual care and support helps provide physical, financial and emotional support during times of disaster<sup>35</sup>. In a post-disaster setting, social capital can be essential to give people access to information and recovery resources<sup>49</sup>. In general, positive associations have been found between the presence of social capital, and adaptive capacity to natural disasters.

On the other hand, coping strategies refers to the approaches people employ to successfully deal with a crisis<sup>118</sup>. In dealing with flood disaster, people have overtime developed their own strategies to avoid loss of lives and/or properties<sup>61</sup>. On one hand, studies have identified: appraisal-focused (adaptive cognitive), problem-focused (adaptive behavioural), and emotion-focused strategies. On the other hand, studies have also classified coping strategies as structural or non-structural and indigenous or modern<sup>116</sup>. Other researchers have argued that household responses to floods can be classified into pre- and post-flood strategies, with the former consisting of risk reduction and mitigation strategies adopted in the pre-flood period, and the latter refers to risk coping strategies to recover from disasters in post-disaster periods<sup>26</sup>. Therefore, coping strategies focus on the hazard event currently taking place and their benefits are often short term<sup>61</sup>.

Furthermore, common flood control measures in the built environment include raising land near buildings, constructing gutters to drain water from buildings, placing sandbags and rock bags in flooded areas, placing valuables on shelves and placing them in temporary shelters with neighbours and donating valuables and so on<sup>119</sup>. In addition, the practical measures that can be considered in coping with floods as suggested in literature<sup>21</sup> are moving vulnerable features, and those expensive to replace, above ground level, including electrical intakes, service meters, boilers, ovens and washing machines; install one-way valves in drain pipes to prevent backflow of flooding and sewage through service pipes, and create external drains to drain water from the property; and the use of more permeable materials.

Also, empirical research revealed that people rely on various indigenous strategies which are usually context specific in coping with floods. For example, it is noted that residents in the riverine floodplains of Teesta River in Bangladesh Households used diverse coping approaches, such as borrowing money, assets disposal, consumption reduction, temporary migration, and grants from external sources, to cope with floods<sup>26</sup>. Whereas, in Lagos Nigeria, residents of flood prone areas cope with flood risk by clearing their local environment and ensuring proper waste disposal practices; construction of drains in front of houses and outlets at the back of their houses to allow floodwater flow from their buildings, elevating buildings, constructing concrete walls, installing flood boards and the use of pumping machines to remove water from their buildings when it floods<sup>37</sup>.

However, in some other studies, the strategies ultimately employed usually consist of several factors, including socioeconomic factors, types of shock, severity of event, physical location, resilience, information on opportunities, and so on<sup>74</sup>. Consequently, the choice of coping strategy and its effectiveness may vary over time. In other words, flood risk does not only depend on the hazard, exposure and current level of vulnerability but also the capacity to recover from the flood's impact<sup>26</sup>. Traditional strategies, therefore contribute positively to improving the capacity of populations to adapt to flood risk, but in general, it is a complex process associated with other physical and socioeconomic variables.

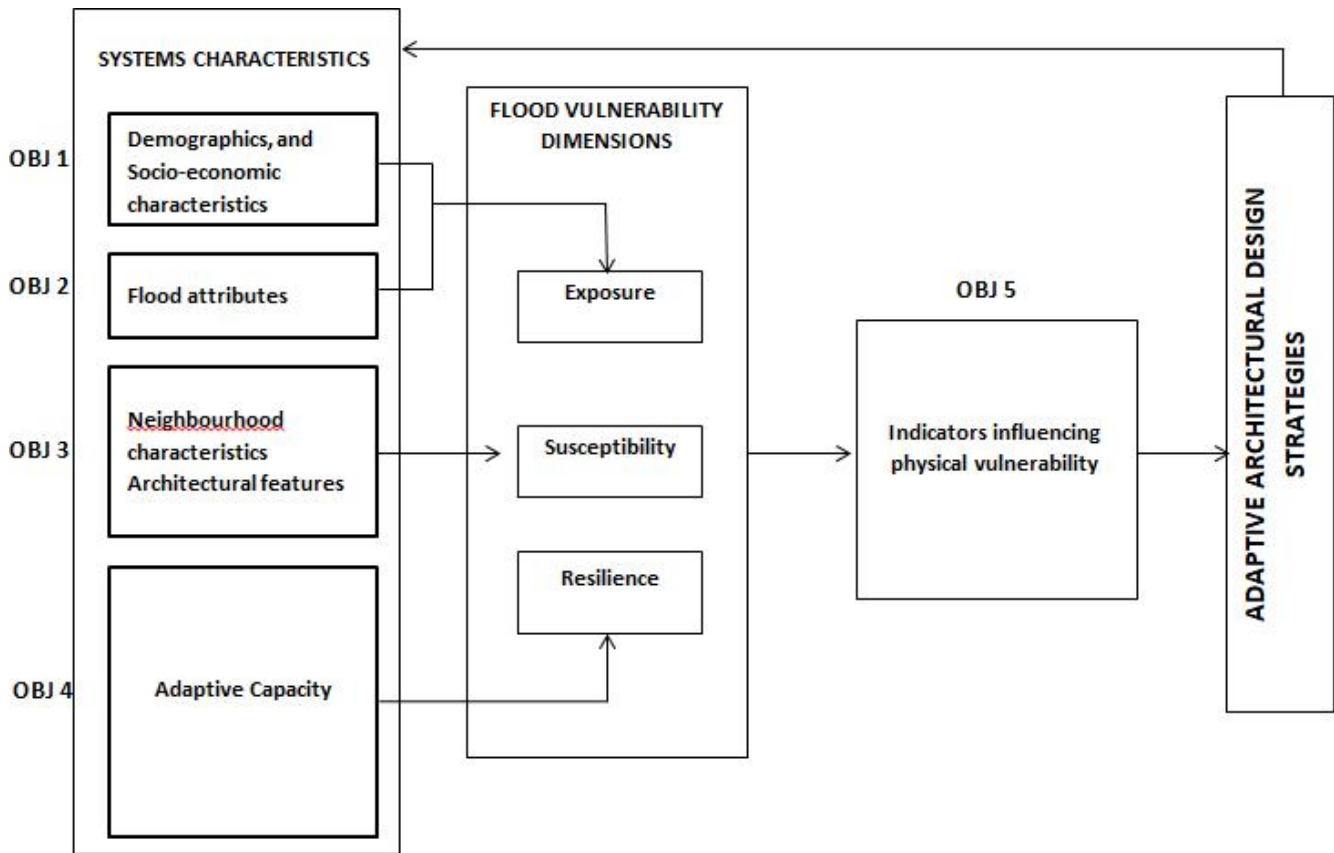
## 2.4 Conceptual Framework

A conceptual framework presents an integrated way of looking at a research problem. It is a visual representation or narrative of the key variables or constructs of a research and the supposed relationships between them<sup>59</sup>. It is argued that the entire methodology must agree with the variables, as well as their relationships and context. A conceptual framework therefore provides a logical structure of how to conduct the research as well as the variables that would explain the basic methodology for the research.

This study is based on the assumption that Assessment of Physical Vulnerability Indicators for Developing Adaptive Architectural Design Strategies in Flood-prone Residential Areas can be assessed by identifying the systems' characteristics that are capable of providing information regarding their level of exposure, susceptibility and resilience. This approach would leverage on vulnerability dimensions of exposure (*users at risk and flood attributes*); susceptibility (*likelihood of flood disaster based on neighborhood characteristics and architectural features of buildings*); and resilience (*pre-disaster preparedness, household coping capacity, and interventions in post disaster*) to develop a systemic analysis of most critical indicators influencing physical vulnerability to flood risk in the study area. In other words, the study identified a number of systems variables that influences flood risk exposure, susceptibility and resilience. An attempt has been made at integrating all these variables into a conceptual framework that explains the whole essence of the proposed research. The conceptual framework for

the study (Figure 2.3) has five key components reflecting the objectives of the study. The five components are: 1) the demographic and socio-economic characteristics of residents, 2) attributes of the flooding experienced, 3) neighborhood characteristics and architectural features of houses, 4) adaptive capacity of households, and 5) physical vulnerability indicators, which can be adapted for flood disaster risk reduction.

The key assumptions in the conceptual framework is that the identification of physical vulnerability indicators is a function of several factors such as the socio-demographic and economic characteristics of the residents; the attributes of the flooding experienced; neighborhood characteristics and architectural features of buildings; and the adaptive capacity of the households (all of which will determine the extent of exposure, susceptibility and resilience of houses and their occupants to flood risk). These assumptions are underpinned by the socio-ecological system, vulnerability and resilience theories as previously explained. Based on the proposed conceptual framework of this study, it is also assumed that the most effective adaptive architectural design strategies for flood-disaster risk reduction in the flood-prone residential areas of Kosofe are embedded within the most significant indicators influencing physical vulnerability in the area.



**Figure 2.3: Conceptual Framework**

Source: Researcher, 2023

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## 2.5 Summary of Gaps in Literature Reviewed

Literature search has revealed a dearth of researches in the area of physical vulnerability assessments and building adaptation strategies for flood disaster risk reduction, across countries, and also in Nigeria; although it is arguably a relatively new area of study. This section highlights gaps that were identified through the review of existing literature. Firstly, most of the literature on flood risk reduction has been mainly focused on urban resilience and adaptation planning. Very few researchers have investigated physical vulnerability indicators for the purpose of addressing flood disaster risk to houses located in flood-prone areas; and in the Nigerian context, search from literature revealed that no research was carried out to identify adaptive architectural design strategies for flood disaster risk reduction from the perspective of ‘risk’ by factoring vulnerability dimensions of exposure; susceptibility; and resilience.

Secondly, literature search on ‘physical flood vulnerability’ shows that diverse factors shape a systems’ proneness to flood damages; and the dynamic relationships and interdependence between these factors is highly contextual and location specific; for example, flood attributes experienced in a locality and the socio-economic characteristics of the residents determine the exposure of such systems. Also, existing policy frameworks; and physical environmental factors as reflected in the neighborhood and building characteristics, amongst other factors influence a building’s susceptibility to flood risks and its capacity for adaptation. In essence, identifying these factors is important in developing a framework for flood adaptation. However, no comprehensive literature was found specifically on built environment sub-systems, and factors that can provide information on the physical vulnerability of houses in Kosofe Lagos, Nigeria to flood risk.

Thirdly, the literature review into the existing policies on ‘flood adaptation’ and ‘resilience’ has shown that some of these policies are generic and does not directly address specific adverse effects of climate change in the built environment. Although the Lagos state government has made significant progress by enacting policies with more direct planning implications pertinent to its environmental challenges induced by climate change; for example, the Lagos State Climate Change Adaptation Strategy (LAS-CCAS). It is however deficient in the area of building material policies and could also benefit from more specific architectural design policies.

Lastly, it was identified that among the literature reviewed for this study, none have explicitly described the socio-ecological characteristics that influence vulnerability factors of exposure, susceptibility, and resilience of households in flood-prone areas to flood risk. These identified gaps necessitated the need to examine the most significant indicators for developing adaptive architectural design strategies to reduce flood risk to residential buildings in flood-prone areas in Kosofe Local government area of Lagos state. This study, therefore, was designed to fill the afore mentioned gaps by investigating the demographic and socio-economic characteristics of the study area, the attributes of the flooding experienced by residents, the neighbourhood and building characteristics, and adaptive capacity exhibited by households. The study also sought to fill the gap in the paucity of literature on physical vulnerability indicators for developing adaptive architectural design strategies in flood-prone residential areas of Lagos, Nigeria.

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## Chapter Three

### Methodology

#### 3.1 Research Design

##### 3.1.1 Philosophy

The study is focused on evaluating physical vulnerability indicators for developing adaptive architectural design strategies in flood-prone areas of Kosofe Local Government Area of Lagos State, Nigeria. In order to effectively answer the research questions outlined in chapter one of this study, the pragmatic philosophical stance was adopted based on its suitability for the research problem that is being addressed<sup>1</sup>. Pragmatism, which combines both positivist and interpretivist positions within the scope of a single research, is regarded as the root paradigm of the mixed methods<sup>2</sup>. The pragmatic approach is often developed based on the real world experiences and thus rejects reductionism<sup>1</sup>. Pragmatism as a research paradigm is a problem-oriented philosophy based on epistemology that employs multiple flexible approaches to solve a given research problem and provides freedom of choice for the researcher to choose the methods, techniques and procedures that best meet the needs and purposes of the research.

Based on the preceding discussion and in line with the nature of the research questions in this study, which would require practical interaction with residents of the study area and built environment professional, this research applied the pragmatism research philosophy, to firstly examine the socio-demographic characteristics of the residents, the neighbourhood and architectural contexts of the housing schemes that are being investigated; the attributes of the flooding experienced in the study area, and current adaptive capacity of the resident to flood risk; and secondly, to investigate the extent to which they influence physical flood vulnerability in the study area. The findings will help determine the factors that influence physical vulnerability to flood risk, so as to identify the most effective architectural design strategies for flood disaster risk reduction in the built environment of flood prone settlements.

### 3.1.2 Strategy

The research strategy for the study is the mixed-methods case study research (MMCSR). A mixed methods case study design is a research approach in which the quantitative and qualitative data collection, results, and integration are used to provide in-depth evidence for a case(s) or develop cases for comparative analysis”<sup>3</sup>.

### 3.1.3 Design

In the mixed-methods research approach, consideration was given to the design that best answers the research questions as well as to the degree of mixture of the qualitative and quantitative data in such a way that complements their strengths<sup>3</sup>. Therefore, as explained in mixed-methods research, and as illustrated in Figure 3.1, the proposed study will adopt the Cross-sectional Exploratory Sequential Design<sup>4</sup>. This design is ideal for developing appropriate quantitative instrument that will provide accurate measures within the study context<sup>5</sup>.

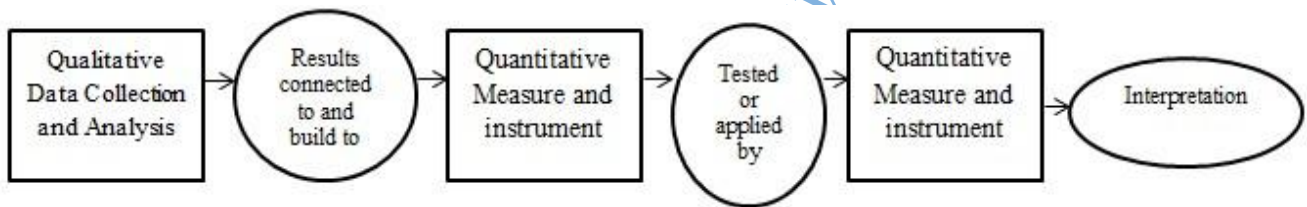


Figure 3.1: Cross-sectional Exploratory Sequential Mixed Methods Design<sup>4</sup>

Both case study and survey design strategies offer unique methodological advantages to address the complexity of the research problems and outlined research questions stated in chapter one of this thesis<sup>5</sup>. This is because they allow for the use of different data collection tools and methods to collect both qualitative and quantitative data required to address stated research questions<sup>4</sup>.

The Cross-sectional Exploratory Sequential Design has two distinct phases: the qualitative phase followed by the quantitative phase<sup>5</sup>. The first phase involves collecting qualitative exploratory data, analyzing the information, and using the findings to develop a quantitative instrument well adapted to the sample under study. As stated, the proposed study began with a qualitative exploration through interviews with selected homeowners in the study area to assess what construct should be measured to best understand physical flood

vulnerability in the study areas. From this exploration, a questionnaire was developed, which was thereafter tested with a sample in a pilot study.

### **3.2 Population of the Study**

The research population for the study comprises two distinct cohorts.

#### **3.2.1 Households in the Flood-prone areas of Kosofe, Lagos state**

The first cohort consists of households in the flood-prone areas of Kosofe Local Government Area of Lagos State, precisely, households living within Owode-Ajegunle, Agboyi and Oworonshoki. The housing schemes investigated are privately-owned residential buildings located within 30m to 70m from the existing river channel. These buildings represent the most vulnerable, vulnerable and less vulnerable buildings<sup>6</sup>.

#### **3.2.2 Expert**

The second cohorts are the experts who have an understanding, expertise, and experience on flood vulnerability in Nigeria. The experts include university professors/lecturers, employees of the Lagos state Ministry of Physical planning and urban development, university post-graduate researchers, and other relevant organizations.

### **3.3 Sample and Sampling Techniques**

A sample is the subset of the population selected, on which the research instruments are administered<sup>1</sup>. A total of 2309 privately-owned residential buildings located within 30m to 70m from the river channel/lagoon have been identified for the study (Table 3.1). A sample was chosen in such a way that it represents the total number of households identified in the study area so as to ensure full coverage. The study adopted the systematic random sampling technique which typically involves the following steps: calculate the sampling interval (the number of observations in the population divided by the number of observations needed for the sample); select a random start between 1 and sampling interval; repeatedly add sampling interval to select subsequent households.

### 3.3.1 Sample Size Determination

#### 3.3.1.1 Sample Size of Households

In estimating the sample size „n“ for the households, the Yamane formula was used with an assumed margin of error of +/- 5% “N” size by giving equal probability to all households. Using the Yamane formula: ( $n = \frac{N}{(1 + N \times e^2)}$ ).

$$n = \frac{2309}{(1 + 2309 \times 0.05^2)} = 341$$

Where, n = Sample size, N = Population size, and e = Margin of error = 0.05 (95% confidence).

An effective sample size of 341 households was derived for the study. In order to accommodate non-response, the adjusted value was derived using a non-response rate of 10%. The final minimum sample size for the buildings is 379 households.

$$\begin{aligned} \text{Final sample size} &= \frac{\text{Effective sample size}}{(1 - 0.1)} \\ n_0 &= \frac{341}{(1 - 0.1)} = 379 \end{aligned}$$

As described previously under sampling technique, the numbers of households surveyed within each area (Owode/Ajegunle, Agboyi and Oworonshoki) was selected using systematic sampling method, based on a random starting point, but with a fixed sampling interval. The sampling interval for each area is six, calculated by dividing the population size of 2,309 households by the desired sample size of 341 units. The sample size within each area was obtained by dividing the total number of households within each area by the sampling interval. This resulted to 385 households, increasing the sample size by six units. One copy of the questionnaire was administered to one respondent/representative of each household selected. This means that in all, a total of 385 households were sampled.

**Table 3.1: The sample sizes derived for each selected area**

Area Under Study	HOUSING STOCK (Meters)			*No. of Households	Sample sizes (Households)	*(Residents)
	Less than 30 (m)	30 – 50 (m)	50 – 70 (m)			
Owode-Ajegunle	325	211	222	758	126	3790
Agboyi	344	232	216	792	132	3960
Oworonshoki	309	253	197	759	127	3795
<b>TOTAL</b>				<b>2309</b>	<b>385</b>	<b>11, 545</b>

Source: Google Earth Mapping

### 3.3.2 Sample Size for Experts

The snowball sampling technique which is a non-probability sampling method where new units are recruited by other units to form part of the sample was used to filter out experts with the requisite skill and experience on flood vulnerability in Nigeria. A total of 35 experts were used for the selection of the indicators with the most relevance on physical flood vulnerability in Nigeria.

### 3.4 Description of the Research Instrument(s)

The data collection instruments used in the research is structured interview (focused group discussions), expert opinion survey form, and structured questionnaire.

#### 3.4.1 Focused Group Discussions (FGDs)

In the first phase of the exploratory sequential design for this study as previously explained, qualitative data were generated via focus group discussions with six (6) home-owners in the study area. The discussions were carried out in the month of July and August 2021. The focus group discussions in the study area were carried out in three groups within Owode-Ajegunle, Agboyi and Oworonshoki, with the assistance of the Landlord Associations in the various areas.

Using the research objectives as a guide, the key areas of discussions with the two (2) representatives of the landlord association of each area under study were on the perceived socio-economic and demographic

characteristics of each community under study; flood risks, occurrences and exposure; perceived environmental characteristics and architectural design features of most existing buildings in the study areas; as well as coping and adaptation capacity at the household level (Appendix A for details of the questions asked in the FDG).

This helped in defining indicators for which the identified factors would be measured, and to provide variables for the study. The sequencing of the topics discussed was carefully considered to ensure that they were easy and impersonal questions at the beginning until communication was established. Questions were kept short, simple but concise. Themes on the variables were identified and used in addition to information sourced from literature in developing a questionnaire for data gathering from the residents of the study area.

**Table 3.2: Themes derived from the Focus Group Discussions with home-owners**

Focus Group Discussion Topics	Considered Themes		
	Group 1	Group 2	Group 3
Existence of social ties.	Considerable existence	Considerable existence	Considerable existence
Availability of social activities and infrastructure.	Low social activities, and lack of social infrastructure	Moderate social activities, but lack of social infrastructure	Low social activities, and lack of social infrastructure
Government presence and external support in crisis situation.	Very poor	Very poor	Very poor
Business activities within the area.	Medium and retail	Low and retail	Medium and retail
Economic status of residents within the area.	Mixed income status (low, medium and high)	Mostly low and medium income status	Mixed income status (low, medium and high)
Cost of living in the area compared with other parts of the city.	Relatively low cost of living	low cost of living	Relatively low cost of living

SOCIO-ECONOMIC CHARACTERISTICS

HAZARD ATTRIBUTES	Rainfall pattern.	Frequent in the rainy seasons	Frequent in the rainy seasons	Frequent in the rainy seasons
	Implication of continued housing developments in the flood prone areas.	High impact	High impact	High impact
	Frequency of flooding in the area	Very frequent	Very frequent	Very frequent
	Effectiveness of existing flood risk management strategies at the property level	Very poor	Very poor	Very poor
NEIGHBOURHOOD CHARACTERISTICS	Adequacy of services and infrastructures within the area	Poor	Poor	Poor
	Functionality of drainages facilities within the area	Very poor	Very poor	Very poor
	Performance of houses in reducing flood risk.	Very poor	Very poor	Very poor
ADAPTATION STRATEGIES	Existence of pre-disaster flood adaptation	Not sure	Not sure	Not sure
	Existence of household coping capacity during disaster	Fair	Fair	Fair
	Intervention during flood events and in post-disaster	Fair	Fair	Fair
	Disposition towards building adaptation for flood risk reduction	Open minded	Open minded	Open minded

### 3.4.2 Expert Opinion Survey

Expert opinion survey form were used in selecting variables with the most relevance on physical flood vulnerability in Nigeria from a list of 37 potential physical flood vulnerability indicators identified in literature<sup>7, 8, 9, 10, 11</sup>. Using the equal (no) weight approach and direct additive aggregation method, consideration was given to (i) flood attributes that induce flood damage (ii) adaptive building design characteristics (iii) probability to be exposed under certain socio-environmental neighbourhood conditions (iv) relevance of selected variables with respect to flood risk. Table 3.3 shows a range of potential flood vulnerability variables, clusters, scale and category used in the expert opinion survey. The experts are required to rate the indicators on a 7-point scale from 1 to 7, using the scale of relevance. Where, 1= Insignificant, 2= Low relevance, 3= Moderate relevance, 4= Moderate to high relevance, 5= High relevance, 6= High to Very high relevance, and 7= Very high relevance (See Appendix 5).

**Table 3.3: Physical Flood Vulnerability Variables, Clusters, Scale and Category**

S/N	Vulnerability variables	Clusters	Scale	category
1.	Flood water depth	Flood attributes (A)	Ordinal	1= Insignificant,
2.	Flood duration			2= Low relevance, 3= Moderate
3.	Flood water Velocity			relevance, 4= Moderate to high
4.	Water sedimentation			relevance, 5= High relevance
5.	Flood return period			6= High to Very high relevance
6.	Frequency of flood experience			7= Very high relevance
7.	Construction type and material	Architectural characteristics (C)	Ordinal	1= Insignificant,
8.	Quality of the building			2= Low relevance, 3= Moderate
9.	Number of floors			relevance, 4= Moderate to high
10.	Presence of basement			relevance, 5= High relevance
11.	Height of the building			6= High to Very high relevance
12.	Exterior paving material			7= Very high relevance
13.	Interior finishes			
14.	Age of building			
15.	Type/Use of building			

16.	Building size			
17.	Lev. of Maintenance/condition			
18.	Height of opening from ground			
19.	Stilts/ Building elevation			
20.	Position of electrical sockets			
21.	Roof design/materials			
<hr/>				
22.	Site topography			
23.	Heavy rainfall			
24.	Dist. from the coasts/ river			
25.	Surrounding vegetation			
26.	Drainage system	Neighbourhood	Ordinal	Ditto
27.	Proximity to major road	characteristics		
28.	Education/ literacy level	(E)		
29.	Income			
30.	Unemployment rate			
31.	Land use			
<hr/>				
32.	Dam and storage capacity			
33.	Awareness/ preparedness			
34.	Warning system	Adaptive capacity	Ordinal	Ditto
35.	Household coping capacity	(A)		
36.	Emergency service			
37.	Flood insurance			
<hr/>				

### 3.4.3 Questionnaire Design

The questionnaire for the homeowners consists of close-ended questions divided into four (4) sections. Section A consists of questions on the demographic and socio-economic characteristics of resident respondents. Section B included questions on the neighborhood characteristics and architectural design features of the existing housing stock in the selected study areas. Section C focused on assessing the attributes of the flooding experienced in the study area; while section D included questions on adaptive capacity, and influence of specific indicators on physical flood vulnerability in the study area.

### 3.4.4 Identification, Specification and Operationalization of Variables

**Table 3.4: Identification, Specification and Operationalization of Variables**

S/No	Description	Code Assigned	Range of Values	Scale	Categories
<i>Objective 1: Demographic characteristics of residents of the flood prone areas of Kosofe Local Government Area of Lagos State, Nigeria</i>					
1.	Gender of Respondents	GEN	1 – 2	Nominal	1= Male, 2=Female
2.	Nationality	NAT	1 – 2	Nominal	1= Nigerian 2= Foreigner
3.	Ethnicity	ETH	1 – 5	Nominal	1= Yoruba 2= Hausa/ Fulani 3= Ibo 4= Ijaw 5= Others (specify)
4.	Age bracket	AGE	1 – 5	Interval	1= 18-30 2=31- 43 3= 44- 56 4= 57-65 5=66 Above
5.	Marital status	MAR	1 – 4	Nominal	1= Single 2= Married 3= Divorced 4= Widow/Widower
6.	Religious inclination	REL	1 – 3	Nominal	1= Christian 2= Islam 3= other
7.	Highest Level of Education	EDU	1 – 4	Nominal	1= No formal education 2= Primary education 3=Secondary education 4= Tertiary education
8.	Employment status	EMP	1 – 6	Nominal	1= Unemployed 2= Self-employed within the area 3= Self-employed outside the area 4= Employee of private sector organization 5= Government employee 6= Retiree
9.	Number of people in the household	NPL	1 – 3	Interval	1= 1 – 2 persons 2= 3 – 4persons 3= 5 – Above
10.	Number of Physically challenged persons in the house	PCP	1- 4	Nominal	1= None 2= 1 – 2 3= 3 – 4 4= 5 – Above
11.	Number of cars in the household	NCR	1 – 4	Interval	1= None 2= 1 – 2 3= 3 – 4 4= 5 – Above
12.	Duration of residency	DUR	1 – 4	Interval	1= 1 - 5years 2= 6 - 10years 3= 11 - 15years 4= 16years +
13.	Occupancy Status of the Respondents	OSR	1 – 3	Nominal	1= Official residence 2=Tenant 3= Owner occupied
14.	Reasons for living in the neighbourhood	RLN	1 – 5	Nominal	1= Job transfer 2= Personal residence 3= official residence 4= to live with spouse 5= cheap accommodation
15.	Close friends and relatives live in my neighbourhood	CFN	1 – 5	Ordinal	1= Strongly disagree 2= Disagree 3= Not sure 4= Agree 5= Strongly agree
16.	Close relationships with my neighbours	CRN	1 – 5	Ordinal	Ditto
17.	Mutual trust amongst	MTR	1 – 5	Ordinal	Ditto

18.	the residents Presence of ethnic segregation amongst neighbours	PES	1 – 5	Ordinal	Ditto
19.	Presence of adequate religious activities	PAR	1 – 5	Ordinal	Ditto
20.	Presence of welfare and socio-cultural activities	PWS	1 – 5	Ordinal	Ditto
21.	Presence of cultural activities	PCA	1 – 5	Ordinal	Ditto
22.	Presence of government and external support in crisis situation	GPS	1 – 5	Ordinal	Ditto
23.	Source of family income	SFI	1 – 3	Nominal	1= Single source 2= Multiple sources 3= None
24.	Range of Family Income	RFI	1 – 5	Nominal	1= N18,000-49,000 2= N50,000-99,000 3=N100,000-299,000 4= N300,000-499,000 5= N500K+
25.	Financial services/ security	FSS	1 – 5	Nominal	1= Stable income 2= Thrift 3= loans 4= Insurance 5= Personal Savings

*Objective 2: Attributes of the flooding experienced in the study area;*

1.	Cause of flood experienced	CFD	1 – 5	Nominal	1= Intense Rainfall 2= River overflow 3= Poor Urban Design 4= Urbanization 5= Others (Dam Related)
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*Factors influencing flood occurrences in the study area*

2.	Site Topography	STP	1 – 5	Ordinal	1= Strongly disagree 2= Disagree 3= Not sure 4= Agree 5= Strongly agree
3.	Absence of Vegetation	ABV	1 – 5	Ordinal	Ditto
4.	Nature of soil	NOS	1 – 5	Ordinal	Ditto
5.	Poor channelization	PCH	1 – 5	Ordinal	Ditto
6.	Clogged drainages	CLD	1 – 5	Ordinal	Ditto
7.	Violation of planning regulation	VPR	1 – 5	Ordinal	Ditto
8.	Failure to heed flood risk warning	FHW	1 – 5	Ordinal	Ditto

9.	Building on flood plains	BFP	1 – 5	Ordinal		Ditto
10.	Time flooding occurs after intense rainfall starts	TFO	1 – 3	Nominal	1= 0-3 hrs. 2= 4- 9 hrs. 3= 10 hrs. & above	
11.	Flood pattern experienced	FPE	1 – 3	Nominal	1= Street flooding 2= compound flooding 3= Neighbourhood flooding	
12.	Building flood damage pattern experienced	BFD	1 – 3	Nominal	1= water penetration damage, 2= chemical damage (pollution and contamination), 3= structural damage	
13.	Depth of flood	DPT	1 – 3	Nominal	1= less than 300mm 2= 300-600 mm 3= 600+	

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*Impact of the flooding experienced in the study area*

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14.	Loss of lives	LOL	1 – 5	Ordinal	1= never 2= rarely 3= sometimes 4= very often 5= always	
15.	Displacement of people	DOP	1 – 5	Ordinal		Ditto
16.	Disruption of power supply	DPS	1 – 5	Ordinal		Ditto
17.	Disruption of communication	DOC	1 – 5	Ordinal		Ditto
18.	Interruption of businesses within the area	IBA	1 – 5	Ordinal		Ditto
19.	Traffic disruption	TRD	1 – 5	Ordinal		Ditto
20.	Destruction of infrastructure	DIF	1 – 5	Ordinal		Ditto
21.	Building collapse	BUC	1 – 5	Ordinal		Ditto
22.	Damages to building and contents	DBC	1 – 5	Ordinal		Ditto
23.	Damage to livestock	DTL	1 – 5	Ordinal		Ditto
24.	Erosion/ destruction of harvest	EDH	1 – 5	Ordinal		Ditto
25.	Blocked kitchen sink	BKS	1 – 5	Ordinal		Ditto
26.	Difficulty flushing	DIF	1 – 5	Ordinal		Ditto
27.	Blocked bathroom floor drain	BBF	1 – 5	Ordinal		Ditto
28.	Septic tank overflow	STO	1 – 5	Ordinal		Ditto

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*Objective 3: Neighborhood characteristics and Architectural design features of the existing housing stock in flood prone areas of Kosofe Local Government Area of Lagos State, Nigeria;*

1.	Availability of natural recreational areas.	NRA	1 – 5	Ordinal	1= Strongly disagree 2= Disagree 3= Not sure 4= Agree 5= Strongly agree
2.	Availability of adequate health care facility	HOS	1 – 5	Ordinal	Ditto
3.	Availability of adequate educational facilities	EDF	1 – 5	Ordinal	Ditto
4.	Availability of adequate stormwater drainage facility	SDF	1 – 5	Ordinal	Ditto
5.	Availability of adequate domestic waste disposal facilities	WAS	1 – 5	Ordinal	Ditto
6.	Availability of adequate water supply	AWS	1 – 5	Ordinal	Ditto
7.	Availability of adequate power supply	APS	1 – 5	Ordinal	Ditto
8.	Availability of good roads and streets networks	RSN	1 – 5	Ordinal	Ditto
9.	Availability of Space for social and religious activities	SSR	1 – 5	Ordinal	Ditto
10.	Availability of shopping facilities	SHF	1 – 5	Ordinal	Ditto
11.	Availability of Pedestrian walkways	PES	1 – 5	Ordinal	Ditto
12.	Availability of floodwall/ barrier along the river channel	FBR	1 – 5	Ordinal	Ditto
13.	Availability of flood retention ponds/ gardens	FRP	1 – 5	Ordinal	Ditto
14.	Availability of flood warning systems	FWS	1 – 5	Ordinal	Ditto
15.	Building Condition	BCN	1 – 5	Ordinal	1= Very poor t 2= Poor 3= Fair 4= Very good 5= Excellent
16.	Proximity of House to water body	PRX	1 – 3	Nominal	1= less than 30m 2= 30 – 50m 3= 50 -70m

17.	House type	TYP	1 – 5	Nominal	1= Single Bungalow 2= Semi-detached Bungalow 3= block of flats 4= Terrace row housing 5= Massionate / Duplex
18.	Number of bedrooms in the house	NBR	1 – 5	Nominal	1=1room 2=2rooms 3=3rooms 4=4rooms 5=5rooms+
19.	Ground floor height	HGR	1 – 4	Nominal	1= 150mm 2= 300 3= 450 mm 4= above 600mm
20.	Walling materials	WMR	1 – 5	Nominal	1= Bricks 2= Stone 3= Sandcrete Blocks 4= Stabilized Laterite 5= Concrete
21.	Roofing design	ROD	1 – 5	Nominal	1= Concrete with garden 2= Concrete without roof garden 3= mono pitch 4= double pitch 5= hip roof
22.	External door material	EDM	1 – 2	Nominal	1= Solid hardwood 2= Steel
23.	Internal doors material	IDM	1 – 2	Nominal	1= Solid hardwood 2= PVC
24.	Window material	WIM	1 – 5	Nominal	1= Wood 2= vinyl 3= Aluminum 4= Fiberglass 5= composite
25.	Interior floor finishes	IFF	1 – 6	Nominal	1= Tiles 2= Cement and sand screed 3= Terrazzo finish 4= Marble 5= Carpet and rugs 6= Wood
26.	Exterior floor finish	EFF	1 – 4	Nominal	1= paved stone 2= concrete flooring 3= Cement and sand screed 4= sand
27.	Wall finishes	WLF	1 – 3	Nominal	1= Tiles 2= Cement plaster 3= Paint
28.	Kitchen cabinet	CAB	1 – 3	Nominal	1= Wood 2= Steel 3= PVC
29.	Position of electric sockets	PES	1 – 2	Ordinal	1= Low Level 2= High Level
30.	Position of Phone socket	PPS	1 – 2	Ordinal	1= Low Level 2= High Level
31.	Position of meters	PMT	1 – 2	Ordinal	1= Low Level 2= High Level

*Objective 4: Adaptive coping strategies currently used in managing flood risks to the building;*

***Flood disaster Preparedness***

1.	Source of information on flood risk awareness	SIF	1 – 3	Nominal	1= previous flood experience 2= official information 3= Environmental signals
2.	I am aware of risks attributed to flooding	ARF	1 – 5	Ordinal	1= Strongly disagree 2= Disagree 3= Not sure 4= Agree 5= Strongly agree

3.	Levels of flood preparedness	LFP	1 – 4	Ordinal	1= Not prepared at all 2= Not very prepared 3= Slightly prepared 4= Very well-prepared
4.	Practice of preparatory measures	PPM	1 – 3	Ordinal	1= Never 2= Sometimes 3= Always
<i>Household coping capacity during Household coping capacity during flood disaster</i>					
5.	Use of drainage systems	UDS	1 – 5	Ordinal	1= Strongly Disagree 2= Disagree 3= Not Ditto Sure 4= Agree 5= Strongly Agree
6.	Periodic maintenance of drainages	PMD	1 – 5	Ordinal	Ditto
7.	Exterior paving with permeable materials	EPM	1 – 5	Ordinal	Ditto
8.	Rain garden to reduce run-off	RGR	1 – 5	Ordinal	Ditto
9.	Trees planting to reduce run-off	TWR	1 – 5	Ordinal	Ditto
10.	Rainwater harvesting system to reduce run-off	RHR	1 – 5	Ordinal	Ditto
11.	Roof garden to reduce run off	RFR	1 – 5	Ordinal	Ditto
12.	Raised building ground floor	RDF	1 – 5	Ordinal	Ditto
13.	Location of living accommodation on first floor	LIV	1 – 5	Ordinal	Ditto
14.	Raised electrical services above flood line	ELC	1 – 5	Ordinal	Ditto
15.	Use of flood barriers across external doorway	FBR	1 – 5	Ordinal	Ditto
16.	Anti-flooding devices are fixed to sewage systems	AFD	1 – 5	Ordinal	Ditto
17.	Use of non-return valve in bathrooms	NRV	1 – 5	Ordinal	Ditto
18.	Standby pump	PUM	1 – 5	Ordinal	Ditto
19.	Use of flood alarm system	FAS	1 – 5	Ordinal	Ditto

*Post flood disaster intervention*

20.	Source of Intervention in post disaster	SIP	1 – 5	Nominal	1= Government support 2= Insurance 3= Support from family/friends 4= prayers 5= Borrowing
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*Objective 5: Extent to which Socio-economic, Physical Environmental characteristics and Adaptive capacity Influence Physical Flood vulnerability in the study area.*

*Objective 5b: Most significant indicator influencing physical flood vulnerability in the study Area*

1.	Flood water depth	FWD	1 – 5	Ordinal	1= Insignificant Influence 2=Little Influence 3= Not sure 4=Significant Influence 5= Very Significant Influence
2.	Flood duration	FLD	1 – 5	Ordinal	Ditto
3.	Flood water Velocity	FWV	1 – 5	Ordinal	Ditto
4.	Construction type and material	CTM	1 – 5	Ordinal	Ditto
5.	Quality of the building	QTB	1 – 5	Ordinal	Ditto
6.	Stilts/Elevated buildings	ELV	1 – 5	Ordinal	Ditto
7.	Site topography	STP	1 – 5	Ordinal	Ditto
8.	Building distance from river	BDR	1 – 5	Ordinal	Ditto
9.	Presence of sur. vegetation	PSV	1 – 5	Ordinal	Ditto
10.	Drainage system	DRS	1 – 5	Ordinal	Ditto
11.	Low income	LIN	1 – 5	Ordinal	Ditto
12.	land use	LNU	1 – 5	Ordinal	Ditto
13.	Dam and storage capacity	DSC	1 – 5	Ordinal	Ditto
14.	Existence of household coping capacity	EHC	1 – 5	Ordinal	Ditto

### 3.5 Validity of the Research Instrument

Validity indicates how sound the research has been conducted, both in the design and the methods employed. It shows that the findings in the research rightly represent the phenomenon that is studied in the research, and that it measures what it claims to be measuring. In order to ensure validity in this current study, construct validity, internal validity and external validity were considered.

Construct validity deals with how well a given measurement scale is measuring the theoretical construct that it is expected to measure, the constructs or concepts investigated have been transferred into measurable variables in the data collection instruments and how well the variables in the research have been adequately operationalized. To achieve this in the research, the data was subjected to factor analyses and all the constructs investigated had been adequately operationalized into measurable variables as shown in Table 3.4. Internal validity refers to the extent to which observations are consistent and can be generalized from one person to another and from one time to another. It also measures the extent to which variables used in a research truly test the situation being investigated and the extent to which the results obtained reflect the situation investigated. In view of these, the following steps were taken to achieve internal validity in the proposed research: adoption of mixed-method research design, the use of different data collection instruments and tools and subsection of the numeric data to factor and regression analyses.

External validity is concerned with the generalizability of results from a sample for the entire study population, which is known as population validity and for other group of people, organizations, contexts, or time (i.e. ecological validity). In this study, external validity was achieved firstly, by drawing a sample from the right population that is residents of the flood prone areas of Kosofe LGA, Lagos State and built environment experts who have the understanding, expertise, and experience on flood vulnerability in Nigeria. Secondly was by selecting a sample that is representative of the various sub-groups that have all the characteristics of the target population.

### 3.6 Reliability of the Research Instrument

Reliability assesses the procedure used in collecting data for a study, to ascertain quality, consistency and relevance; and how the research can be replicated to produce the same results every time. For mixed methods research, the legitimation step is proposed, which involves assessing the trustworthiness of both qualitative and quantitative data and subsequent interpretation<sup>1, 2</sup>.

Therefore, in this study, the rigour of the research that would verify its validity and reliability, as well as the credibility and relevance of the methods were obtained majorly by pre-testing the questionnaire for the residents of the flood-prone areas of the study area and subjecting the ordinal data to reliability test using the Cronbach's Alpha reliability coefficient test. The designed questionnaire was used for an external pilot study involving 72 residents of Irawo, a neighbourhood that is constantly subjected to periodic flooding in kosofe LG area of Lagos state. This represented about 20% of the estimated sample size. The test set out to measure if all variables were measuring the same thing. The ordinal data obtained on all the variables of each of the research objectives were subjected to reliability test using the Cronbach Alpha reliability coefficient test. The test results showed high Cronbach's Alpha of 0.710, 0.759, and 0.847 on the Attributes of the flooding experienced (Objective 2); neighbourhood characteristics and architectural features (Objective 3); and Adaptive Capacity (Objective 4), respectively. The values obtained were higher than the recommended of 0.70 averages on such tests. Result of these tests is shown in Table 3.5.

**Table 3.5: Reliability by Objectives (Ordinal Variables)**

Objectives	Cronbach's Alpha	No of items
Objective 1	-	-
Objective 2	0.710	8
Objective 3	0.847	16
Objective 4	-	-
Objective 5	0.759	21

**Source: Researcher's Result via SPSS Version 23, (2023)**

### 3.7 Method of Data Collection

Due to the nature of the research approach (mixed-methods case study research) of the study, the qualitative data was collected from literature review and interviews, complimented with observation and photographic materials; while the quantitative data was collected by means of well-structured questionnaires were administered by the researcher and trained field assistants. Table 3.6 below shows the phases in the data collection process.

**Table 3.6: Phases in Data Collection Process for Mixed-methods Research**

Qualitative Data Collection	Phases in the process of research	Quantitative Data Collection
<ul style="list-style-type: none"> <li>• Purposive sampling strategies</li> <li>• Small number of participants and sites</li> </ul>	Sampling	<ul style="list-style-type: none"> <li>• Random sampling</li> <li>• Adequate size to reduce sampling error and provide sufficient power</li> </ul>
<ul style="list-style-type: none"> <li>• From individual providing access to sites</li> <li>• Individuals</li> </ul>	Permissions	<ul style="list-style-type: none"> <li>• From individual providing access to sites</li> <li>• Individuals</li> </ul>
<ul style="list-style-type: none"> <li>• Open-ended interviews</li> <li>• Expert opinion surveys</li> <li>• Photographic materials (Field pictures and Google earth Images)</li> </ul>	Data sources	<ul style="list-style-type: none"> <li>• Instruments (Questionnaires)</li> </ul>
<ul style="list-style-type: none"> <li>• Interview protocols</li> </ul>	Recording the data	<ul style="list-style-type: none"> <li>• Instruments with scores that are reliable and valid</li> </ul>
<ul style="list-style-type: none"> <li>• Attending to field issues</li> <li>• Attending to ethical issues</li> </ul>	Administering data collection	<ul style="list-style-type: none"> <li>• Standardization of procedures</li> <li>• Attending to ethical issues.</li> </ul>

Source: <sup>3</sup>

### 3.8 Data Characteristics, Sources and Analyses by Objectives

#### Objective 1

*To assess the demographic and socio-economic characteristics of residents of the flood prone areas of Kosofe Local Government Area of Lagos State, Nigeria;*

**Data Characteristics:** The data for Objective 1 are nominal and ordinal, as well as quantitative in nature. The variables are as stated in Table 3.4.

**Data Source:** The data for this objective will be sourced from questionnaire administered to the residents of the selected flood-prone areas of Kosofe Local Government Area of Lagos State, Nigeria (see Appendix 3).

**Data Analysis:** The quantitative data obtained will be analysed using frequency distribution, cumulative percentages, charts and descriptive summary.

#### Objective 2

*To examine the Attributes of the flooding experienced in the study area;*

**Data Characteristics:** The data for Objective 2 are nominal and ordinal, as well as quantitative in nature. The variables are as stated in Table 3.4.

**Data Source:** The data for this objective will be sourced from questionnaire administered to the residents of the selected flood-prone areas of Kosofe Local Government Area of Lagos State, Nigeria (see Appendix 3).

**Data Analysis:** The quantitative data obtained will be analysed using Charts, frequency distribution, cumulative percentages, Mean, Std. Deviation, factor analysis, and Relative Importance Index Analysis.

#### Objective 3

*To assess neighbourhood characteristics and Architectural design features of the existing housing stock in flood prone areas of Kosofe Local Government Area of Lagos State, Nigeria;*

**Data Characteristics:** The data for Objective 3 are nominal and ordinal, as well as quantitative in nature. The variables are as stated in Table 3.4.

**Data Source:** The data for this objective will be sourced from questionnaire administered to the residents of the selected flood-prone areas of Kosofe Local Government Area of Lagos State, Nigeria (see Appendix 3).

**Data Analysis:** The quantitative data obtained will be analysed using Mean, Std. Deviation, factor analysis, charts, frequency distribution and cumulative percentages.

#### **Objective 4**

*To investigate the adaptive coping strategies currently used in managing flood risks in the study area.*

**Data Characteristics:** The data for Objective 4 are quantitative in nature. The variables are as stated in Table 3.4.

**Data Source:** The data for this objective will be sourced using questionnaire administered to the residents of the selected areas for this study (see Appendix 3).

**Data Analysis:** The data obtained will be analysed using frequency, cumulative percentages, charts, Mean and Standard deviation.

#### **Objective 5**

*To investigate the extent to which socio-economic, environmental/physical characteristics and current adaptive capacity influence the physical flood vulnerability in the study area.*

**Data Characteristic:** The data for Objective 5 are ordinal, as well as quantitative in nature. The variables are as stated in Appendix 5 and Table 3.4.

**Data Source:** Literature review, Pilot surveys, questionnaires, field observations and expert opinion survey were useful sources of relevant indicators, (See Appendix 3 and 5).

**Data Analysis:** Relative Importance Index (RII), Linear Regression, and Analysis of variance (ANOVA).

### 3.9 Ethical Approval

Ethical consideration is how to authenticate the collection of data in order to prevent falsification and fabrication, minimize error and promote knowledge and truth as well as to guard against the infringement of human rights in the course of the research. As this research involves interaction with human population both at homes and work places, it is important to establish trust with participants, where rights were respected. Therefore, full consent was obtained from participants of the research, using consent forms, and privacy of the participants would not be violated in the administration of the questionnaires and interview sessions. In reporting the findings, the highest levels of confidentiality and anonymity were maintained as no information provided by any participant would be linked to him/her. The research process was clearly stated to respondents, providing the aim and objectives, so that responses obtained would be as true as possible without external influences. The views of participants will be respected, and the data was carefully stored to avoid access by unauthorized persons.

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**Table 3.7: Summary of Research Design/ Strategy**

<b>Objectives</b>	<b>Type of Data</b>	<b>Nature of Data</b>	<b>Types of Analyses</b>
<b>Objective 1</b> <i>To assess the demographic and socio-economic characteristics of residents of the flood prone areas of Kosofe Local Government Area of Lagos State, Nigeria;</i>	Quantitative	Nominal, ordinal	Descriptive statistics such as frequency distribution and cumulative percentages
<b>Objective 2</b> <i>To examine the Attributes of the flooding experienced in the study area;</i>	Quantitative	Nominal, ordinal,	Charts, frequency distribution, cumulative percentages, Mean, Std. Deviation, factor analysis, and Relative Importance Index Analysis.
<b>Objective 3</b> <i>To assess neighbourhood characteristics and Architectural design features of the existing housing stock in flood prone areas of Kosofe Local Government Area of Lagos State, Nigeria;</i>	Quantitative	Nominal, ordinal	Mean, Std. Deviation, factor analysis, charts, frequency distribution and cumulative percentages.
<b>Objective 4</b> <i>To investigate the adaptive coping strategies currently used in managing flood risks in the study area;</i>	Quantitative	Ordinal	Frequency, cumulative percentages, charts, Mean and Standard deviation.

**Objective 5**

Quantitative

Ordinal

Relative Importance Index (RII), Linear Regression, and Analysis of variance (ANOVA).

*To investigate the extent to which the socio-economic, environmental/physical characteristics and current adaptive capacity influence physical flood vulnerability in the study area.*

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## Endnotes

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## Chapter Four

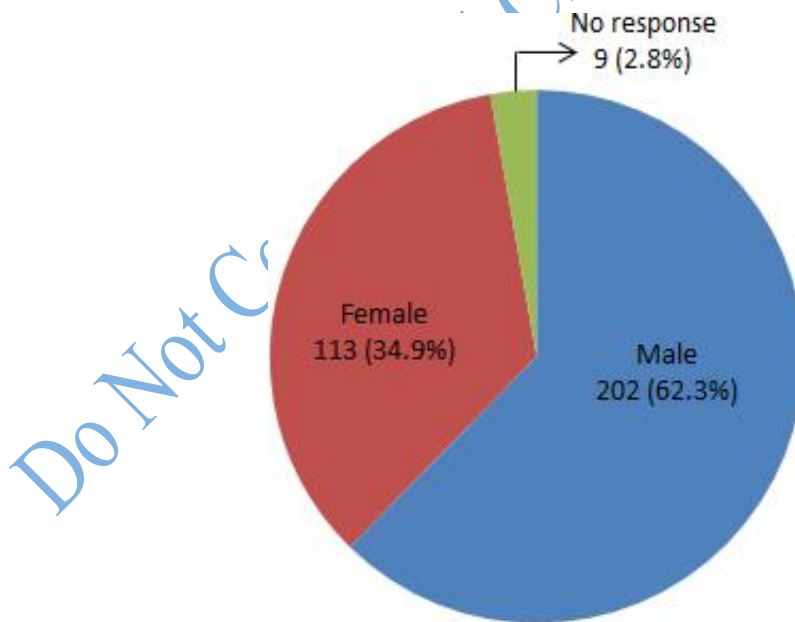
### Results and Discussion of Findings

#### 4.1 Demographic Data Analysis

This section begins the presentation of the result of the data collected and analyzed. A total of 385 household were surveyed through the administration of one copy of the questionnaire to each house. Out of these, 341 questionnaires were returned, of which 17 were voided due to incomplete, vague or wrongful entry of responses. Thus, a total of 324 copies of the questionnaires were included in the analyses. This represented an acceptable 84.15% of the 385 sample size for the survey. The demographic and socio-economic characteristics of residents of the flood-prone areas of Kosofe are presented in the following sections.

#### Demographic Characteristics of Residents of Flood-prone areas of Kosofe.

Figure 4.1 shows that 202 (62.3%) of the respondents were male, 113 (34.9%) were female, while 9 (2.8%) of respondents did not indicate their gender. This shows that more than one-half of the respondents were male.



**Figure 4.1: Gender of the Respondents**  
Source: Researcher's Result via SPSS Version 23, (2023)

The result also shows that a high majority (96%) of respondents are of Nigerian nationality, coming from over 50 tribes of the nation. Very few (3.4%) of the respondents are of other nationalities, comprising around 0.92% from china, 0.31% from Cameroun, and 2.2% from Benin Republic. However, 0.62% of the respondents did not indicate their nationality. It was further observed that majority of the respondents (60.8%) are tenants comprising of residents from Nigeria, Cameroon and Benin Republic; while (38.3%) live in their own house, the remaining 0.9% are Chinese who have lived in service apartments provided by their work organization for official use for a period of between 6 and 10 years.

The third demographic characteristic studied was age of the residents in the study area. It can be seen from the result in Table 4.1 that, majority of the respondents are between the ages of 31 years and 43 years (28.1%), followed by those between 18 years and 30 years (26.9%); 44 years and 56 years (19.1%); 57 years and 69 years (12.7%); and above 70 years (12%) respectively.

**Table 4.1: Age Distribution and Education status of the Respondents**

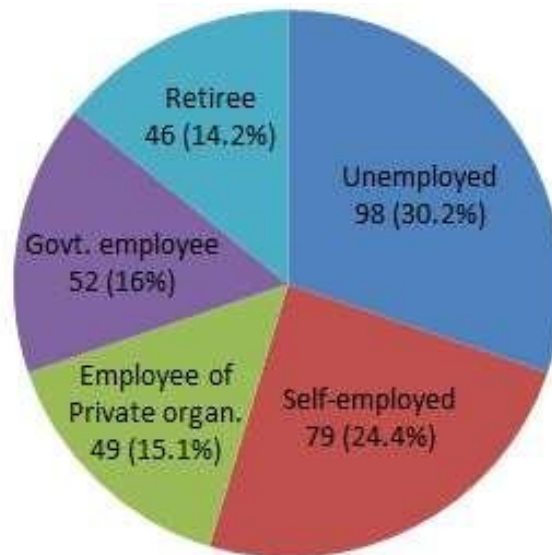
<b>Age Grouping</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
18-30	87	26.9	26.9
31-43	91	28.1	54.9
44-56	62	19.1	74.1
57-65	41	12.7	86.7
66- above	39	12.0	98.8
No Response	4	1.2	<b>100.0</b>
<b>Total</b>	<b>324</b>	<b>100.0</b>	

<b>Highest Level of Education attained</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percentage</b>
Primary education	54	16.7	16.7
Secondary education	69	21.3	38.0
Tertiary education	201	62.0	<b>100.0</b>
<b>Total</b>	<b>324</b>	<b>100.0</b>	

**Source: Researcher's Result via SPSS Version 23, (2023)**

It can also be observed in Table 4.1 that the employable age range of between age 18 years and 56 years had the predominant combined proportion of 74.1%, while those at the retirement age range of 66 years and above constitute 12% of the sample. Specifically, 14.2% of the participants in the survey were found to be retirees. Furthermore, the employment status of the respondents was also investigated in this study, and the results showed that 55.5% of the respondents were employed; comprising self-employed persons (24.4%), employees of private sector organizations (15.1%), and government employees (16%); while around 30.2% of the respondents were unemployed.



**Figure 4.2: Employment Status of the Respondents**  
**Source: Researcher's Result via SPSS Version 23, (2023)**

Concerning the marital status of the respondents, the result shows that a larger number (44.1%) of the respondents were married, another 33% claimed that they were single persons living alone; 10.5% of them were widowed persons; and 6.5% are divorced or separated persons; while 5.9% of respondents did not indicate their marital status. In addition, the result shows that 57.1% of the respondents identified with the Christian religion, while 40.7% identified with the Islamic religion.

Further, the result in Table 4.1 shows the highest level of educational attainment of the respondents in the survey. Results reveal that most respondents (62%) in the survey reported having had tertiary education, 21.3%

had secondary education, 16.7% had primary education, and no respondent was reported as not having any level of formal education.

## **4.2 Presentation of Research Questions and Data**

### **Research Question One**

*What are the demographic and socio-economic characteristics of residents in the flood prone areas of Kosofe Local Government Area of Lagos State?*

The three questions on the socio-economic characteristics were the social capital, the household composition, and the livelihood patterns of residents of the study area.

### **Social Capital**

The factors used to examine the social capital of the respondents were the socio-demographic ties, socio-demographic diversity, and existence of external support in the study area. Socio-demographic ties were investigated by examining the frequency of available family ties in the study area; relationships and mutual trust among neighbours. In addition, the socio-demographic diversity was assessed by the extent of ethnic segregation, shared interests and religious beliefs, and availability of socio-cultural activities; while the external support was also investigated by examining the presence of government and external support. The data on these variables were obtained from the questionnaires administered to the respondents in the study area. The data were collected via questionnaire using a 5-point Likert type scale, where the respondents were asked to indicate the extent of agreement or disagreement with the questions relating to the afore mentioned variables. The scale of measurement used are Strongly Disagree = 1; Disagree = 2; Not Sure = 3; Agree = 4; and Strongly Agree = 5 (See Appendix 3). The result on available family ties in the study area is presented in Table 4.2.

The result in Table 4.2 shows that around 34.9% of the respondents agreed that they had close friends and relatives living within the estates, 33% of respondents disagreed to this factor, while 31.1% of the respondents were not sure of this.

**Table 4.2: Social Capital of the Respondents**

<b>Having close friends and relatives living in the area</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Strongly disagree	49	15.1	15.1
Disagree	58	17.9	33.0
Not sure	104	32.1	65.1
Agree	83	25.6	90.7
Strongly Agree	30	9.3	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Relationship with Neighbours</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Strongly disagree	22	6.8	6.8
Disagree	29	9.0	15.7
Not sure	17	5.2	21.0
Agree	182	56.2	77.2
Strongly Agree	74	22.8	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Mutual Trust amongst Residents</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Strongly disagree	56	17.3	17.3
Disagree	104	32.1	49.4
Not sure	87	26.9	76.2
Agree	22	6.8	83.0
Strongly Agree	51	15.7	98.8
No Response	4	1.2	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Perceived ethnic segregation</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Strongly disagree	219	67.6	67.6
Disagree	34	10.5	78.1
Not sure	14	4.3	82.4
Agree	30	9.3	91.7
Strongly Agree	27	8.3	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Religious Activities in the Study Area</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Strongly disagree	1	.3	.3
Disagree	5	1.5	1.9
Not sure	2	.6	2.5
Agree	99	30.6	33.0
Strongly Agree	217	67.0	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	

<b>Socio-Cultural Activities</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Strongly disagree	25	7.7	7.7
Disagree	42	13.0	20.7
Not sure	23	7.0	27.7
Agree	135	41.7	69.4
Strongly Agree	99	30.6	<b>100.0</b>
<b>Total</b>	<b>324</b>	<b>100.0</b>	

<b>Welfare facilities and Socio-Cultural Activities</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Strongly disagree	8	2.5	2.5
Disagree	131	40.4	42.9
Not sure	42	13.0	55.9
Agree	34	10.5	66.4
Strongly Agree	109	33.6	<b>100.0</b>
<b>Total</b>	<b>324</b>	<b>100.0</b>	

**Source: Researcher's Result via SPSS Version 23, (2023)**

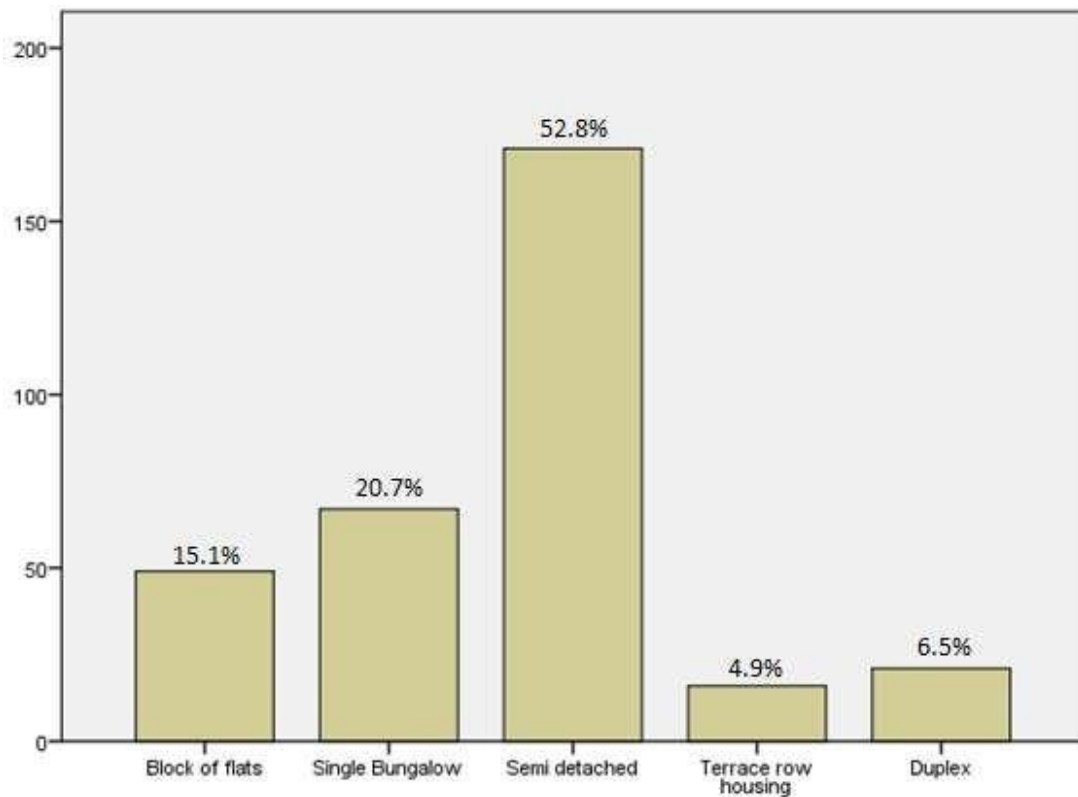
The result in Table 4.2 indicates the level of neighbourhood ties among residents. This result reveals that 79% of the respondents agreed that they had close relationships with their neighbours, while 15.8% disagreed, and 5.2% of the respondents were not sure of this. In spite of the high level of close relationship reported among neighbors, results as shown in Table 4.2 indicate that mutual trust amongst the residents was low. Also, Table 4.2 reveals that 16.9% of the respondents agreed that there was mutual trust amongst residents in the area; 49.4% disagreed; while 26.9% of the respondents were not sure of this. Such low level of trust amongst neighbors was suspected to be as a result of the diversity of tribes (about 50) living within the study area. However, it is clear that a few of the respondents perceived ethnic segregation amongst neighbors despite the low level of trust amongst neighbors.

The result in Table 4.2 also shows that around 78.1% of the respondents disagreed to the presence of ethnic segregation amongst neighbors, with only 17.6% saying there was ethnic segregation, and around 4.3% of the respondents were not sure. Similarly, the result in Table 4.2 shows that majority of the respondents (97.6%) agree to the presence of religious activities in the area; very few of the respondents (0.6%) were not sure of this, while 1.8% disagreed with the availability of religious activities in the study area. Despite the proportion of residents who reported a high level of religious activities, the survey on socio-cultural activities showed a similar view.

On the presence of socio-cultural activities within the study area, the result in Table 4.2 reveals that about 72.3% of the respondents agreed to the availability of social activities within the study area; 20.7% disagreed, while 7% were not sure. Similarly, it was observed from the result in Table 4.2 that there is a close tie between those who agreed (44.1%) and disagreed (42.9%) to government presence and external support within the area.

### **Household Composition of the Residents**

This factor was examined through the study of house types, occupancy status of the respondents, household sizes, and duration of residency in the study area; Figure 4.3 shows the frequency distribution of the different house types within the areas. The result in Figure 4.3 shows that the predominant housing types within the study area are the semi-detached apartment. The semi-detached housing types showed the highest frequency, with a total of around 52.8%. This is followed by the single bungalow which accounted for 20.7%; the block of flats accounted for 15.1% of the housing types, while the duplex housing type contributes around 6.5% of the sample. The terrace row housing type was the lowest accounting for around 4.9% of the houses included in the survey.



**Figure 4.3: Frequency of House Types in the area**  
**Source: Researcher's Result via SPSS Version 23, (2023)**

This highest proportion of semi-detached appearing in the areas sampled correspond with the survey result of occupancy status of the residents as shown in Table 4.3, which shows that around 60.8% were tenants living in rented apartments. However, only 38.3% of the respondent households were found to be families living by themselves; while 0.9% of the respondents were Chinese expatriate living in a service apartment provided by their work organization. This occupancy characteristic was also reflected in the number of people living in the households.

**Table 4.3: Household Composition**

Occupancy status	Frequency	Percentage	Cumulative percent
Official Resident	3	.9	.9
Tenant	197	60.8	61.7
Owner Occupied	124	38.3	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
Number of people in the Household	Frequency	Percentage	Cumulative percent
1-2	67	20.7	20.7
3-4	191	59.0	79.6
5 and above	66	20.4	100.0

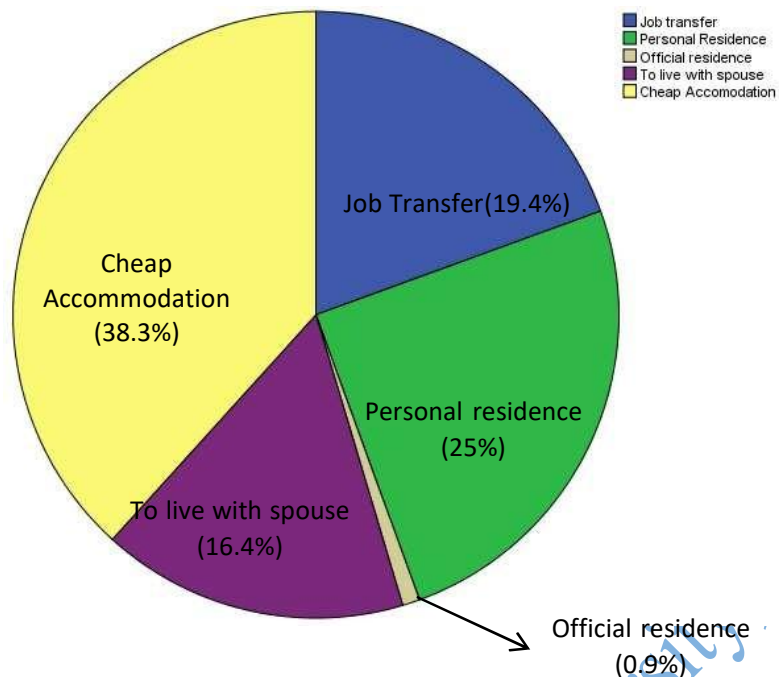
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Duration of Residency in the area</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
1-5	32	9.9	9.9
6-10	75	23.1	33.0
11-15	64	19.8	52.8
16 and above	153	47.2	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	

**Source: Researcher's Result via SPSS Version 23, (2023)**

Furthermore, as revealed by the result in Table 4.3, the household sizes of between three people and four people had the highest rate of 59%. A household size of one and two people was 20.7%; whereas a larger household size of five people and above was the lowest at 20.4%. However, only 2.8% of residents are physically challenged, while 62.7% of the households sampled are without cars.

Further investigation was carried out on the duration of residence of the respondents within the areas, and the result is shown in Table 4.3. The result on duration of residence as shown in Table 4.3 reveals that the longest staying respondents in the areas (47.2%) are those who had lived there for more than 16 years. This is followed by respondents who had lived in the areas between 6 years and 10 years (23.1%), while about 19.8% of the sample had lived in the area for between 11 years and 15 years, and the lowest proportion of 9.9% having lived in the areas for less than 5 years.

The reasons given by the respondents for living in the area as presented in Figure 4.4 shows that majority (38.3%) live in the area because of the cost of housing.



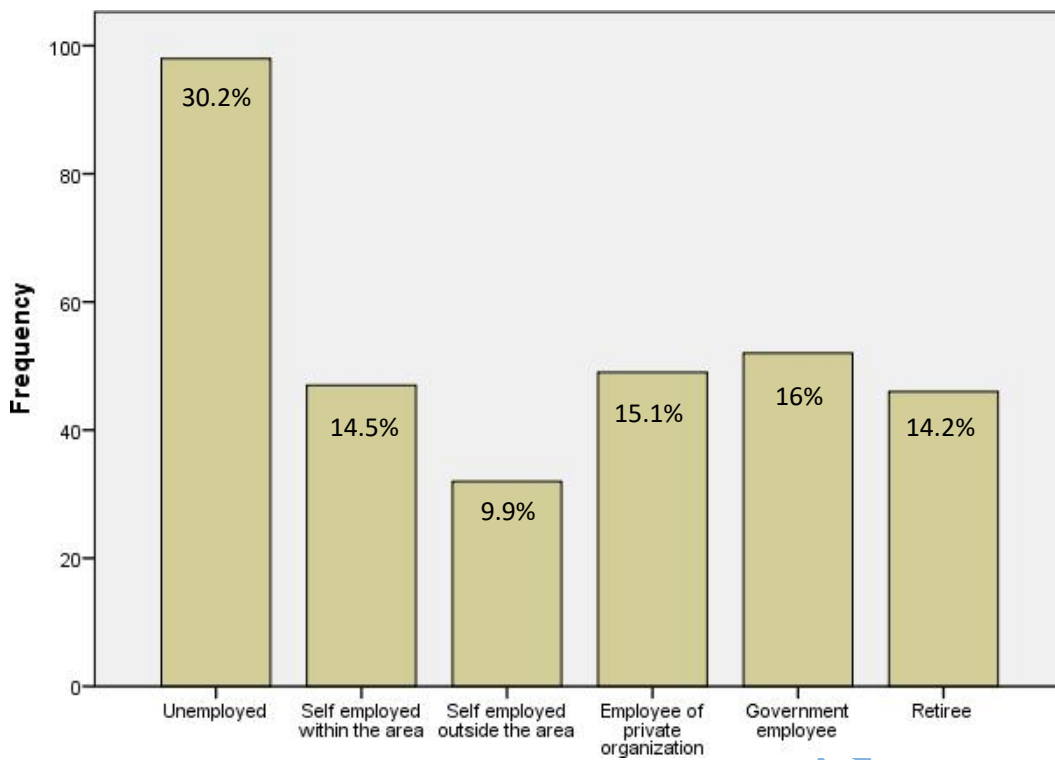
**Figure 4.4: Reasons for living in the areas**  
**Source: Researcher's Result via SPSS Version 23, (2023)**

This is followed by those who have their personal residences within the area. The result further reveals that the other reasons for living in the area included job transfer and to live with spouse who accounted for 19.4% and 16.4% respectively. However, the least indicated reason for taking up residency in the area is that it is an official residence (0.9%).

### **Livelihood Pattern**

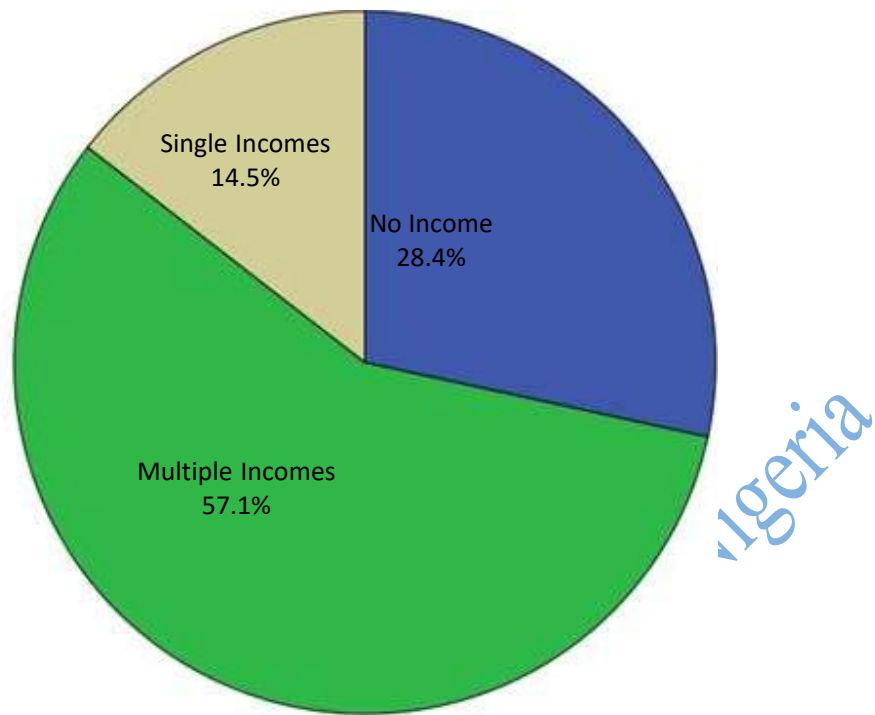
The third set of variables used to assess socio-economic characteristics of residents in the study areas is related to the livelihood pattern of residents, which is an indicator of resilience. To help determine the pattern of livelihoods of the residents, their employment pattern, income patterns and financial services available within the study areas were assessed. Figure 4.5 shows the result of the employment status of the respondents in the household survey.

From the result in Figure 4.5 it can be seen that the unemployed formed the highest proportion of the respondents (30.2%). This is followed by the self-employed who accounted for 24.4% of the respondents. 14.5% of the self-employed operate their businesses within the area, while 9.9% are self-employed outside the area. Also, 16% of the respondents were in government employments.



**Figure 4.5: Employment status of Respondents**  
**Source: Researcher's Result via SPSS Version 23, (2023)**

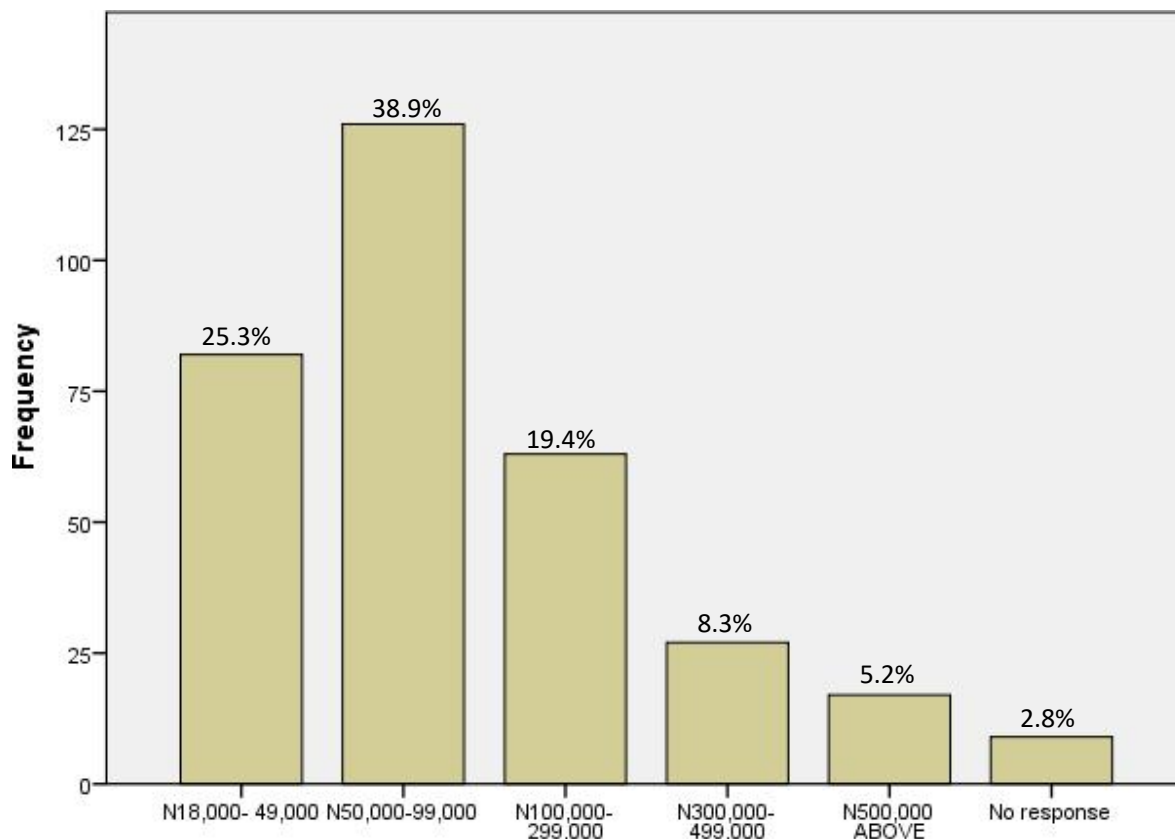
Employees of private sector organization formed 15.1% of the sample population, while only 14.5% of the respondents reported being unemployed, and 14.2% of the respondents were retirees. To further investigate employment pattern of the respondents, the survey assessed the number of streams of income within the household. Figure 4.6 shows the result of the survey on number of streams of income within the household where respondents were drawn from.



**Figure 4.6: Number of Streams of Income in a Household**  
**Source: Researcher's Result via SPSS Version 23, (2023)**

Results in Figure 4.6 revealed that around 57.1% of the respondents claimed to have multiple streams of income, while 14.5% of the respondents claimed that they have a single source of income. However, 28.4% of the respondents reported having no streams of income. In addition to the various numbers of streams of income of the household, the monthly cumulative income range of employed members of the household was investigated. The result of the monthly income is represented in Figure 4.7.

The result presented in Figure 4.7 shows that the highest percentage (64.2%) of the households represented had a total family income of below N99, 000. This is followed by the income group of between N100, 000.00 and N299, 000.00, which constituted 19.4% of the respondents. A very low percentage (8.3%) of the household representative indicated earning between N300, 000.00 and N499, 000, while 5.2% of the respondents earned above N500, 000.



**Figure 4.7: Range of Monthly Household Income Source: Researcher's Result via SPSS Version 23, (2023)**

Regarding the availability of Security for contingencies, the result of financial services available to the respondents is shown in Table 4.4. From the result in Table 4.4, majority of the respondents (47.2%) indicated that they rely on their participation in Thrifts (Ajo); while 25.9% of the respondents rely on personal savings, and 17.6% rely on Stable income. However, a lower value of 7.1% and 2.2% of the respondents rely on availability of loans and insurance cover respectively.

**Table 4.4: Financial Services available for contingencies**

Available Financial Services	Frequency	Percentage	Cumulative percent
Stable income	57	17.6	17.6
Participation in Thrifts (Ajo)	153	47.2	64.8
Availability of loans	23	7.1	71.9
Availability of insurance cover	7	2.2	74.1
Personal Savings	84	25.9	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	

**Source: Researcher's Result via SPSS Version 23, (2023)**

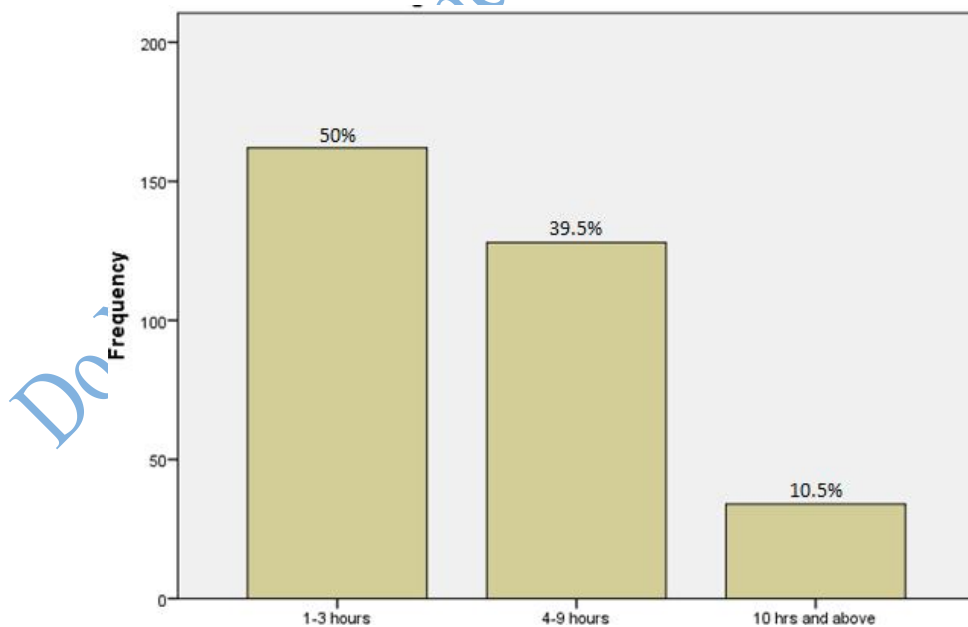
## Research Question Two

*What are the attributes of the flooding experienced in the flood prone areas of Kosofe Local Government Area of Lagos State?*

The survey on flood attributes sought to examine the patterns, causes, and impact of the flooding experienced in the study area. The data used for this objective are nominal and ordinal in nature; and the information were derived from section C of the questionnaires (Appendix 3) administered to the respondents living within the study areas.

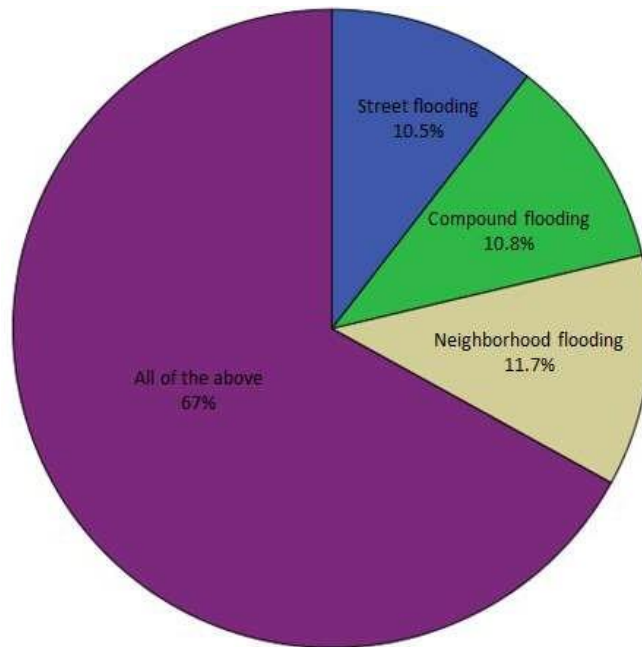
### Patterns of the Flooding Experienced

There are 4 variables used to assess the pattern of the flooding experienced in the study areas. They include: time flooding occurs after intense rainfall starts, flooding experienced, building flood damage pattern experienced and flood depth. Figure 4.8 shows time flooding occurs after high-intensity rainfall starts. The result in Figure 4.8 shows that majority of the respondents (50%) in the survey agree that flooding starts within the first three hours (1-3 hrs.) after the start of an intensity rain, while 39.5% percent and 10.5% of the respondents indicated that most flooding starts within (4- 9 hrs.) and (10 hrs. above) respectively.



**Figure 4.8: Time flooding occurs after intense rain starts**  
**Source: Researcher's Result via SPSS Version 23, (2023)**

On the flooding experienced by residents of the study area, results in Figure 4.9 shows that most of the respondents (67%) reported to have experienced Neighbourhood flooding, street flooding and compound flooding. However, 11.7% of the respondents claimed to have experienced neighbourhood flooding alone, while 10.8% and 10.5% of the respondents respectively indicated having experienced compound flooding and street flooding alone.



**Figure 4.9: Flooding experienced in the study area**  
**Source: Researcher’s Result via SPSS Version 23, (2023)**

Table 4.5 shows the building damage pattern experienced and flood depth. Regarding the building flood damage pattern experienced in the study area, results as shown in Table 4.5 shows that water penetration damages (55.9%) were reported to be more frequent. This is followed by structural damages which accounted for 44.1% of the flood damages experienced in the study area. Also, majority of the respondents (46%) consider the depth of the flood experienced to be between 300mm and 600mm, while 39.5% claimed it to be above 750mm. However, 14.5% of the respondent noted that the flood depth is less than 300mm.

**Table 4.5: Building flood damage and Flood depth experienced in the study areas**

Flood damage pattern	Frequency	Percentage	Cumulative percent
Water penetration damage	181	55.9	55.9
Structural damage	143	44.1	<b>100.0</b>
Total	324	<b>100.0</b>	

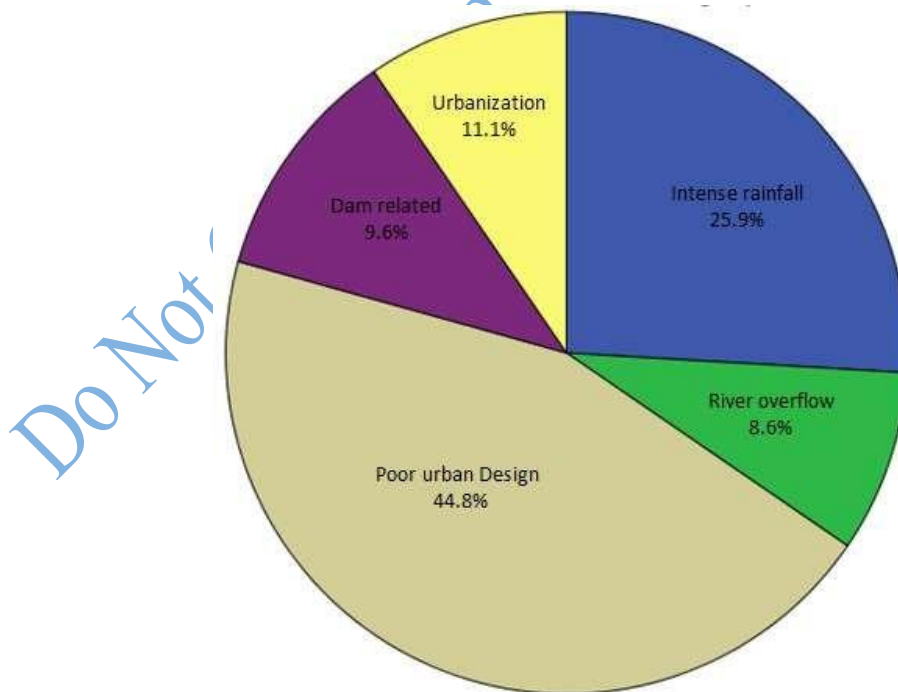
  

Depth of flood	Frequency	Percentage	Cumulative percent
Less than 300mm	47	14.5	14.5
300-600mm	149	46.0	60.5
750mm +	128	39.5	<b>100.0</b>
Total	324	<b>100.0</b>	

Source: Researcher's Result via SPSS Version 23, (2023)

### Causes of Flooding Experienced and its Influencing Factors

Findings from the survey as shown in Figure 4.10 suggest resident's perception of the causes of flooding experience in the study areas. Majority of the respondents (44.8%) attributed the cause to poor urban design, while 25.9% of the respondents signified intense rainfall. Others attributed the cause to urbanization (11.1%), occasional release of water from the dam or failure (11.1%), and river overflow (8.6%).



**Figure 4.10: Causes of flooding experienced in the study areas**  
Source: Researcher's Result via SPSS Version 23, (2023)

## Factors Influencing Occurrence of floods in the study area

8 variables were used to evaluate the factors influencing occurrence of flood events in the study area, the result in Table 4.6 shows that the mean of the most influential factor being clogged drainages which is 4.94. This is followed by poor channelization (4.77), building on flood plains (3.87), violation of planning regulation (3.81), nature of soil (3.46). The mean of the three least factors influencing flood occurrences in the study area are the absence of vegetation (3.31), failure to heed flood risk warning (2.75) and site topography (2.70).

**Table 4.6: Factors Influencing Occurrence of floods in the study area**

Factors Influencing flood occurrences	Mean	Std.	
		Deviation	Ranking
Clogged drainages	4.94	.235	1
Poor channelization	4.77	.603	2
Building on flood plains	3.87	1.179	3
Violation of planning regulation	3.81	1.077	4
Nature of soil	3.46	1.186	5
Absence of Vegetation	3.31	1.404	6
Failure to heed flood risk warning	2.75	1.443	7
Site Topography	2.70	1.201	8

**Source: Researcher's Result via SPSS Version 23, (2023)**

In order to better understand how the residents understood and interpreted the factors influencing flood occurrences in their areas, the 8 variables used to assess this were subjected to factor analysis. The suitability of the survey data for factor analysis was investigated by conducting the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and the Bartlett's Test of Sphericity. The KMO test produced 0.856, while the Bartlett's Test of Sphericity was significant at 0.000 (See Appendix 6) hence the data were subjected to factor analysis. Using the Principal Component Analysis (PCA) extraction method, two main dimensions (components) were extracted as shown in Table 4.7. The Table shows the result of the total variance accounted for by the two dimensions that have eigenvalue of 1 and above to be around 90%.

**Table 4.7: Total Variance Explained**

Component	Initial Eigenvalues			Extraction Sums of Squared			Rotation Sums of Squared		
	Total	Loadings		Total	Loadings		Total	Loadings	
		% of Variance	Cumulative %		% of Variance	Cumulative %		% of Variance	Cumulative %
1	6.140	76.745	76.745	6.140	76.745	76.745	4.607	57.582	57.582
2	1.085	13.562	90.307	1.085	13.562	90.307	2.618	32.725	90.307
3	.318	3.970	94.276						
4	.167	2.083	96.359						
5	.130	1.623	97.983						
6	.084	1.052	99.035						
7	.053	.658	99.694						
8	.025	.306	100.000						

Extraction Method: Principal Component Analysis.

**Source: Researcher's Result via SPSS Version 23, (2023)**

Table 4.8 shows the summary of the names, factor loadings, Eigenvalue and percentage of variance for each of the two dimensions (components) identified. The original Table of the factor loadings on each of the dimensions is presented in Appendix 6.

**Table 4.8: Presentation of Result of Factor Analysis**

Dimensions of the factors influencing flood occurrences in the study area	Factor Loadings	Eigen value	% of Variance	Cum %
<b>Dimension 1: Non-structural</b>		4.607	57.582	57.582
Site Topography	.909			
Absence of Vegetation	.914			
Nature of Soil	.855			
Violation of Planning regulation	.779			
Failure to heed flood risk warning	.960			
Building on flood plain	.735			
<b>Dimension 2: Structural</b>		2.618	32.725	90.307
Poor Channelization	.844			
Clogged drainages	.913			

90% of Variance accounted for.

**Source: Researcher's Result via SPSS Version 23, (2023)**

Examination of the result in Table 4.8 reveals that the first dimension is site topography, absence of vegetation, nature of soil, violation of planning regulation, failure to heed flood risk warning, and building on flood plain. This dimension accounts for around 57.6% of the variance in the 8 variables included in the analysis. It has 6 of the 8 variables loaded on it and hence it is the dimension with the highest contribution to understanding the factors influencing flood occurrences in the study areas. The second dimension is poor channelization and clogged drainages. This second dimension accounts for around 32.7% of the variance in the 8 variables, and has two variables loaded on it.

### Impact of the flooding experienced in the study areas

The data on this information were derived from questionnaires (Appendix 3) administered to the respondents living within the study areas. The impact of the flooding experienced in the study areas were investigated using 15 variables. The variables were evaluated using descriptive statistics and exploratory factor analysis. The scale of measurement used was the 5-point Likert-type scale of never=1; rarely=2; sometimes =3; very often=4; always=5. The result of the descriptive analysis of the impacts of the flooding experienced is presented in Table 4.9.

**Table 4.9: Impact of flooding in the study area**

Impacts	Mean	Std. Deviation	Ranking	Level of Impact
Disruption of businesses within the area	4.45	.730	1	SIGNIFICANT
Displacement of people	4.43	.728	2	
Traffic disruption	4.24	.797	3	
Erosion/ destruction of harvest	4.04	.903	4	
Disruption of power supply	3.99	.973	5	MODERATE
Disruption of communication	3.97	1.026	6	
Damages to building and contents	3.86	.893	7	
Damages to livestock	3.57	1.166	8	
Loss of lives	3.06	.975	9	
Destruction of infrastructure	3.01	1.090	10	
Building collapse	2.72	1.064	11	LITTLE
Difficulty flushing	2.61	1.174	12	
Blocked bathroom floor drain	2.59	1.215	13	
Blocked kitchen sink	2.52	1.176	14	
Septic tank overflow	2.46	1.471	15	

Source: Researcher's Result via SPSS Version 23, (2023)

From the result in table 4.9, it is evident that 4 of the impacts have mean scores of between 4.45 and 4.04, and are ranked 1 to 4. These impacts can be considered as the most significant impact of flooding experienced by residents of the study areas. The second set of 6 impacts have mean scores of 3.99 – 3.01, and are ranked from 5 to 10. These can be seen as the moderate impacts of flooding. The last 5 impacts ranked from 11 to 15 have mean scores of between 2.72 and 2.46, and can be considered to be the least impact of flooding on the residents of the study area. A further examination of the result reveals that the top three most significant impact of flooding to residents of the study areas are disruption of businesses within the area with mean score of 4.45, displacement of people (4.43), and traffic disruption (4.24). In contrast, the three least important impacts considered by the residents of the study areas are blocked bathroom floor drain, blocked kitchen sink, and septic tank overflow, which all emerged with mean scores of 2.59, 2.52 and 2.46 respectively.

### **Relative Importance Index Analysis**

The data were further analyzed using the Relative Importance Index (RII). The RII is measured for each of the variables and ranked accordingly. The RII was calculated by using the equation  $RII = \frac{\sum w}{N}$  Where,  $w =$  weight (1, 2...4),  $A =$  highest weight, and  $N =$  number of responses. Five important levels of the relative index values are high (H) ( $0.8 \leq RI \leq 1$ ), high-medium (H-M) ( $0.6 \leq RI \leq 0.8$ ), medium (M) ( $0.4 \leq RI \leq 0.6$ ), medium-low (M-L) ( $0.2 \leq RI \leq 0.4$ ), and low (L) ( $0 \leq RI \leq 0.2$ ). Generally, RII values close to 1 are considered to be of high importance and vice versa. The results are presented in Table 4.10.

From the result presented in Table 4.10, out of the 15 impacts investigated, 4 of them have high level of importance based on residents' perception of the impact of the flooding experienced in the study areas. 6 impacts have high-medium importance, while other 5 impacts have medium importance. As stated in Table 4.10, the highest ranking impact of flooding is interruption of businesses within the area (0.871). This is followed by displacement of people (0.886), traffic disruption (0.848), and erosion (0.809). This seems to support the result of the descriptive statistics analysis, which shows these four factors as the top most

significant impact of flooding from the residents' perspective. The lowest ranking factor of the 15 impacts is septic tank overflow (0.492). It is evident that no impact was ranked low.

**Table 4.10: Relative Importance Index Ranking Results**

<b>Impact of flooding</b>	<b>Relative Index</b>	<b>Overall ranking</b>	<b>Importance level</b>
Interruption of businesses within the area	0.871	1	High
Displacement of people	0.886	2	High
Traffic disruption	0.848	3	High
Erosion/ destruction of harvest	0.809	4	High
Disruption of power supply	0.799	5	High-medium
Disruption of communication	0.794	6	High-medium
Damages to building and contents	0.772	7	High-medium
Damages to livestock	0.727	8	High-medium
Loss of lives	0.612	9	High-medium
Destruction of infrastructure	0.601	10	High-medium
Building collapse	0.544	11	medium
Difficulty flushing	0.522	12	medium
Blocked bathroom floor drain	0.517	13	medium
Blocked kitchen sink	0.497	14	medium
Septic tank overflow	0.492	15	medium

**Source: Researcher's Result via SPSS Version 23, (2023)**

### **Research Question Three**

*What are the neighbourhood characteristics and architectural design features of the existing housing schemes in the flood prone areas of Kosofe Local Government Area of Lagos State?*

The study identified 14 variables to assess the neighbourhood characteristics of the study areas. The variables were evaluated using descriptive statistics and exploratory factor analysis. The internal consistency of the 14 variables was ascertained using Cronbach alpha reliability test. A value of 0.929, greater than the acceptable value of 0.70, was obtained. In the survey the respondents were asked to indicate the level of agreement with the

availability of the variables on a 5-point Likert-type scale. The result of the descriptive analysis of the neighbourhood characteristics are presented in Table 4.11.

**Table 4.11: Available Neighbourhood characteristics in the study area**

Available Neighbourhood Characteristics	Mean	Deviation	Ranking
Space for social and religious activities	3.32	1.343	1
Educational facilities	3.27	1.609	2
Shopping Facilities	3.19	1.360	3
Power Supply	3.05	1.276	4
Health Center	3.02	1.531	5
Pedestrian Walkways	2.77	1.530	6
Good Roads and Streets Networks	2.59	1.308	7
Floodwall/ Barrier Along the River Channel	2.31	.850	8
Flood Retention Ponds/ Gardens	2.22	.737	9
Flood Warning Systems	2.17	.682	10
Domestic Waste Disposal Facilities	1.67	1.073	11
Adequate Stormwater Drainage Facility	1.60	.937	12
Portable water Supply	1.54	.792	13
Natural Recreational Areas	1.54	.915	13

**Source: Researcher's Result via SPSS Version 23, (2023)**

For the 14 variables used to assess the availability of specific neighbourhood characteristics, the result in Table 4.11 shows that the mean of the most available feature being space for social and religious activities is 3.32; followed by availability of educational facilities (3.27); shopping facilities (3.19). The mean of the three least available neighbourhood features were adequate stormwater drainage facilities (1.60), portable water supply (1.54) and natural recreational areas (1.54). The result in Table 4.11, therefore suggests that the most available neighbourhood characteristic in the study areas is space for social and religious activities, while the least are Water supply and natural recreational areas.

To develop a better understanding of how the residents understood and interpreted the neighbourhood characteristics of the study area, the 14 variables used to assess this were subjected to factor analysis. However, prior to carrying out this analysis the suitability of the survey data for factor analysis was investigated by

conducting the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and the Bartlett's Test of Sphericity. The KMO test produced 0.925, which is above the acceptable value of 0.6, while the Bartlett's Test of Sphericity was significant at 0.000 (See Appendix 7) hence the data were subjected to factor analysis. Using the extraction method involving principal component analysis (PCA) and a Varimax with Kaiser Normalization rotation method; two main dimensions (components) were extracted as shown in Table 4.12.

**Table 4.12: Total Variance Explained**

Component	Initial Eigenvalues			Extraction Sums of Squared			Rotation Sums of Squared		
	Total	Loadings		Total	Loadings		Total	Loadings	
		% of Variance	Cumulative %		% of Variance	Cumulative %		% of Variance	Cumulative %
1	11.286	80.616	80.616	11.286	80.616	80.616	7.222	51.589	51.589
2	1.394	9.954	90.571	1.394	9.954	90.571	5.457	38.982	90.571
3	.508	3.626	94.197						
4	.276	1.970	96.167						
5	.152	1.085	97.251						
6	.084	.597	97.848						
7	.068	.486	98.334						
8	.053	.379	98.713						
9	.045	.321	99.034						
10	.043	.310	99.344						
11	.033	.236	99.580						
12	.023	.161	99.741						
13	.020	.140	99.881						
14	.017	.119	100.000						

Extraction Method: Principal Component Analysis.

**Source: Researcher's Result via SPSS Version 23, (2023)**

Table 4.13 shows the summary of the names, factor loadings, Eigenvalue and percentage of variance for each of the two dimensions (components) identified. The original Table of the factor loadings on each of the dimensions is presented in Appendix 7. Examination of the result in Table 4.13 reveals that the first dimension is availability of natural recreational areas, adequate stormwater drainage facility, adequate domestic waste

disposal facilities, adequate water supply, good roads and streets networks, floodwall/ barrier along the river channel, flood retention ponds/ gardens, and flood warning systems.

**Table 4.13: Presentation of Result of Factor Analysis**

<b>Dimensions of the Neighbourhood characteristics of the study areas</b>	<b>Factor Loadings</b>	<b>Eigen value</b>	<b>% of Variance</b>	<b>Cum %</b>
<b>Dimension 1: Spatial pattern</b>		7.222	51.589	51.589
Natural recreational areas	.936			
Adequate stormwater drainage facility	.921			
Adequate domestic waste disposal facilities	.914			
Adequate water supply	.904			
Good roads and streets networks	.741			
Floodwall/ barrier along the river channel	.836			
Flood retention ponds/ gardens	.771			
Flood warning systems	.745			
<b>Dimension 2: Physical infrastructural development</b>		5.457	38.982	90.571
Health care facility	.654			
Educational facilities	.949			
Adequate power supply	.780			
Space for social and religious activities	.875			
Shopping facilities	.879			
Pedestrian walkways	.720			

90.57% of Variance accounted for.

**Source: Researcher's Result via SPSS Version 23, (2023)**

This dimension accounts for 52% of the variance in the 14 variables included in the analysis. It has 8 of the 14 variables loaded on it and hence it is the dimension with the highest contribution to understanding the neighbourhood characteristics in all the study areas put together. This second dimension accounts for around 39% of the variance in the 14 variables, and has 6 variables loaded on it (availability of health care facility, educational facilities, adequate power supply, space for social and religious activities, shopping facilities, and pedestrian walkways).

## Architectural design features of the housing stock in the flood prone areas of Kosofe

In order to assess the architectural design features of buildings in the study areas, the study identified 17 variables (Proximity to water bodies, House type, Number of bedrooms in the house, Building Condition, Ground floor height, Walling materials, Roofing design, External door material, Internal doors material, Window material, Interior floor finishes, Exterior floor finish, Wall finishes, Kitchen cabinet, Position of electric sockets, Position of Phone socket, and Position of meters) which residents were asked to evaluate. As shown in Figure 4.3 above, results shows that the predominant housing types within the areas are semi-detached houses which accounted for 52.8% of the entire house types in the study areas. Furthermore, results of the descriptive statistics reveal that 36.4% of the buildings are located within 30meters from the existing river body, while 35.8% and 27.8% are situated within 31-50meters and 51-70meters respectively.

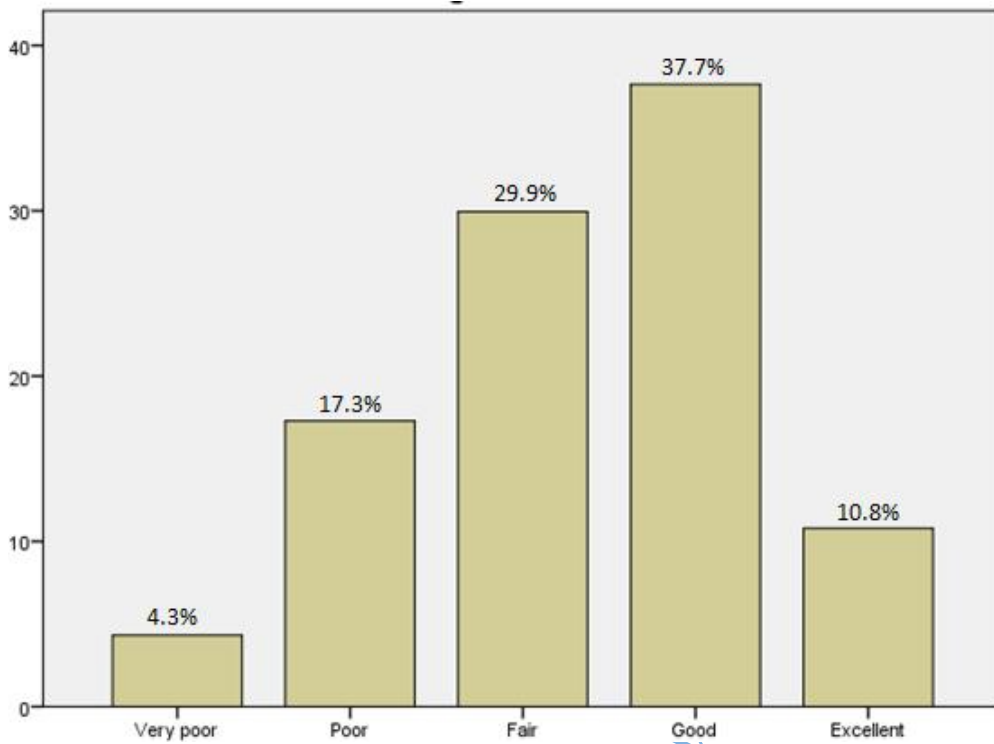
4.14 is a display of the result of descriptive statistics (frequency and cumulative percentage) of the number of bedrooms in the house. A glance at the results showed that the three bedroom house design was the most common type in the areas surveyed.

**Table 4.14: Number of Bedrooms in the house**

Number of Bedrooms	Frequency	Percentage	Cumulative percent
1	59	18.2	18.2
2	55	17.0	35.2
3	182	56.2	91.4
4	28	8.6	100.0
5 above	0	0	
<b>Total</b>	<b>324</b>	<b>100.0</b>	

**Source: Researcher's Result via SPSS Version 23, (2023)**

From the result in Table 4.14 it can be deduced that the highest proportion (56.2%) of the respondents indicated that the most common housing design in the study areas are the 3 bedrooms, followed by the 1 bedroom and 2 bedrooms designs which accounted for 18.2% and 17% respectively. The least indicated housing design type by the respondents was the 4 bedroom design which accounted for 8.6% of the survey. Unfortunately, very few of the buildings are in excellent condition as revealed in Figure 4.11.



**Figure 4.11: Condition of the Buildings in the Study Areas**  
**Source: Researcher's Result via SPSS Version 23, (2023)**

Regarding the conditions of the buildings in the areas under survey, the result reveals that majority of the respondents (37.7%) consider their buildings to be in good condition, while 29.9% and 21.6% of the respondents claimed that their buildings are in fair and poor conditions respectively. However, a relatively low percentage of the respondents (10.8%) indicated that their buildings are in excellent conditions. Further, the result in Table 4.15 shows the ground floor height of the buildings in the study areas.

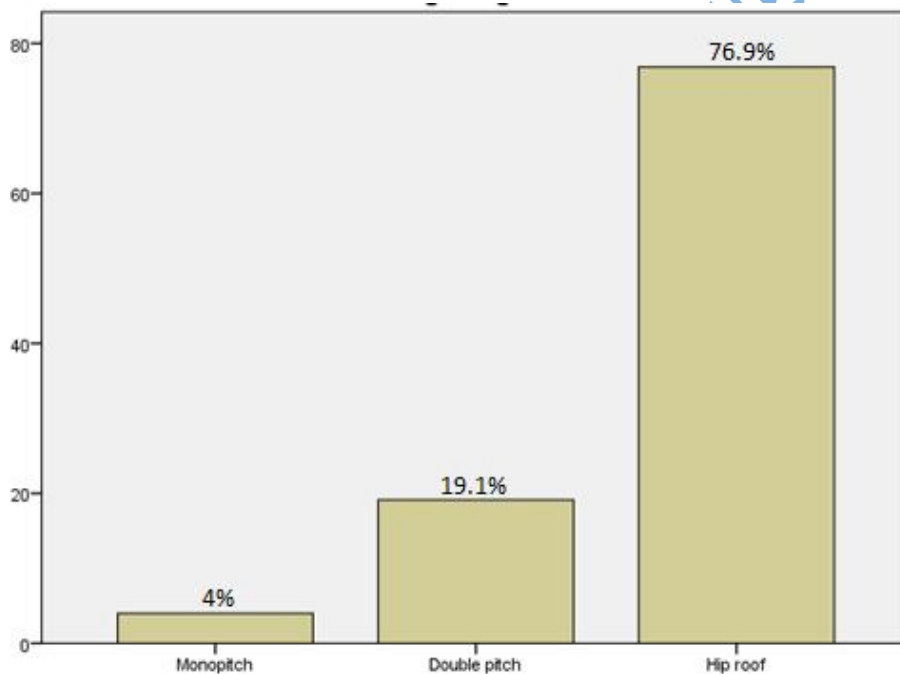
Majority of the respondents (64.5%) claimed that their houses are 300mm higher than the natural ground floor level (NGL), followed by respondents (19.8%) who claimed that their houses were 600mm above NGL. However, 14.5% of the respondents agree that their houses are 150mm above NGL, while a very few respondents (1.2%) claimed that their building height is 450mm above the ground floor level.

**Table 4.15: Ground Floor height of the Buildings in the Study Area**

Floor Height	Frequency	Percentage	Cumulative percent
150mm	47	14.5	14.5
300 mm	209	64.5	79.0
450mm	4	1.2	80.2
above 600mm	64	19.8	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	

Source: Researcher's Result via SPSS Version 23, (2023)

Figure 4.12, although the predominant roof design was the Hip roof which accounted for 76.9%, followed by the double pitch and Mono-pitch which accounted for 19.1% and 4% respectively. It was observed that there not concrete roofs in the study areas.



**Figure 4.12: Roof Designs in the study area**

Source: Researcher's Result via SPSS Version 23, (2023)

Furthermore, on the choice of wall materials, 91.6% of the respondents claimed that their homes were made of sandcrete blocks, while the remaining 8.4% indicated that brick was used for the walls. Also, majority of the walls were finished with cement mortar and paint (See Table 4.16). Regarding the choice of door materials as shown in table 4.16; on one hand, results show that majority of the respondents (95.4%) in the survey reported having a steel external door, while the remaining 4.6% of the respondent have solid hard wood external doors.

**Table 4.16: Building Material**

<b>Wall material</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Sandcrete block	297	91.6	91.6
Bricks	27	8.4	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Wall finishes</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Ceramic tiles	21	6.5	6.5
Cement plaster	178	54.9	61.4
Paint	125	38.6	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>External Door Material</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Solid hardwood	15	4.6	4.6
Steel	309	95.4	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Internal Door Material</b>			
Solid hardwood	317	97.8	97.8
PVC	7	2.2	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Window material</b>			
Aluminum	293	90.4	90.4
Wood	31	9.6	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Kitchen cabinet</b>			
Wood	321	99.1	99.1
No response	3	.9	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	

**Source: Researcher's Result via SPSS Version 23, (2023)**

On the other hand, 97.8% indicated having a solid hardwood internal door, while a few of the respondents (2.2%) have a PVC internal door. Furthermore, results on the choice of window material indicate that majority of the respondents' claim that their windows are made of Aluminium, only 9.6% of the buildings used wood. However, majority of the respondents reported that their kitchen cabinets were made with wood.

Examination of the data in Table 4.17 reveals the choice of interior floor, exterior floor finishes and the material used for the kitchen cabinets. The result shows that majority (58.3%) of the interior floor areas of building in the study areas are finished with tiles. 21.3% had also noted that their floors were finished with cement and sand screed, while 10.5% and 9% claimed that their floors were finished with terrazzo and carpet/rugs respectively. However, very few of the respondents (0.9%) in the survey reported that their interior floor area was finished with Marble. Similarly, based on results in Table 4.26, majority (40.7%) of the compounds in the study area were finished with cement and sand screed. This followed by concrete flooring, which accounted for 26.5%.

**Table 4.17: Finishes**

<b>Interior floor finishes</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Ceramic Tiles	189	58.3	58.3
Cement and sand screed	69	21.3	79.6
Terrazzo	34	10.5	90.1
Marble	3	.9	91.0
Carpet and rugs	29	9.0	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Exterior floor finishes</b>			
Pave stone	33	10.2	10.2
Concrete	86	26.5	36.7
Cement and sand screed	132	40.7	77.5
Sand	73	22.5	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	

**Source: Researcher's Result via SPSS Version 23, (2023)**

This is followed by compounds (26.5%) finished with concrete. However, 22.5% of the respondents claimed that their compound was filled with sand while 10.2% of the respondent had their compound finished with paving stone. Regarding the position of electric sockets, majority of the buildings in the areas surveyed have low level electrical sockets. Table 4.18 shows the position of electric sockets and meters in the buildings existing in the study area. On one hand, results reveal that 81.2% of the buildings have low-level sockets, 13.6% had mid-level while 5.2% had high-level sockets. On the other hand, majority of the buildings (94.8%) had low-level phone sockets, while a very few (5.2%) have mid-level phone sockets. However, when the respondents in

the survey were asked on the position of meters, majority (78.1%) reported that their buildings had high-level meter, while 21.9% of the respondents claimed that electrical meters were positioned at mid-level on the walls.

**Table 4.18: Position of sockets and meters**

<b>Position of electric sockets</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cumulative percent</b>
Low-level	263	81.2	81.2
Mid-level	44	13.6	94.8
High-level	17	5.2	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Position of Phone socket</b>			
Low-level	307	94.8	94.8
Mid-level	17	5.2	100.0
High-level	0	0	
<b>Total</b>	<b>324</b>	<b>100.0</b>	
<b>Position of meters</b>			
Low-level	0	0	13.3
Mid-level	71	21.9	35.2
High-level	253	78.1	100.0
<b>Total</b>	<b>324</b>	<b>100.0</b>	

**Source: Researcher's Result via SPSS Version 23, (2023)**

#### **Research Question Four**

*What is the adaptive capacity of households in the study area to flood risk?*

As described in literature, adaptive capacity can be measured by assessing pre-disaster level of adaptation; coping capacity (resources, characteristics and conditions) during disaster; and intervention during the event and in post-disaster. Therefore, in order to address the objective, the survey sought to know resident's level of awareness of flood risk and their preparedness in pre-disaster; the household coping strategies used during severe flooding; and the intervention during and after the floods. The data on this information for the selected areas were derived from section D of the questionnaires administered to residents of the study areas.

## Pre-disaster flood risk awareness and Preparedness of Residents

In order to investigate flood risk awareness among residents of the study area, respondents were asked to indicate on a 5 point likert type scale ranging from 1= Strongly Disagree to 5= Strongly Agree their awareness of the risks attributed to flooding; and the source of information on awareness. The result in Table 4.19 shows that majority (70.4%) of the respondents are aware of the risks attributed to flooding. This is followed by 17.6% of the respondents who claimed not to be aware. The remaining proportions of respondents (12%) indicated that they are not sure of the risks attributed to flooding. Also, Table 4.19 shows the results on the source of information on flood risk awareness.

**Table 4.19: Flood risk awareness in the study areas**

Awareness of risk attributed to flooding	Frequency	Percentage	Cum. percent
Strongly disagree	16	4.9	4.9
Disagree	41	12.7	17.6
Not sure	39	12.0	29.6
Agree	128	39.5	69.1
Strongly agree	100	30.9	<b>100.0</b>
Total	324	<b>100.0</b>	
<b>Source of information on awareness</b>			
Previous flood experiences	249	76.9	76.9
Official information	14	4.3	81.2
Environmental signal	61	18.8	100.0
Total	324	100.0	

**Source: Researcher's Result via SPSS Version 23, (2023)**

The results as shown in Table 4.19 reveal that majority of the respondents (76.9%) learnt from previous flood experiences, while 18.8% of respondents reported that they got the awareness from environmental signals. However, a few of the respondents ascribe their awareness to government official information. To develop a better understanding of the relationship between flood risk awareness and previous flood experiences, a chi-square test was carried out on the two variables. Results are presented in Table 4.20. The result of the chi-square test confirmed a significant relationship between flood risk awareness and past flood experience ( $\chi^2 = 218.602$ ,  $P = 0.000$ ).

**Table 4.20: Chi-Square Tests**

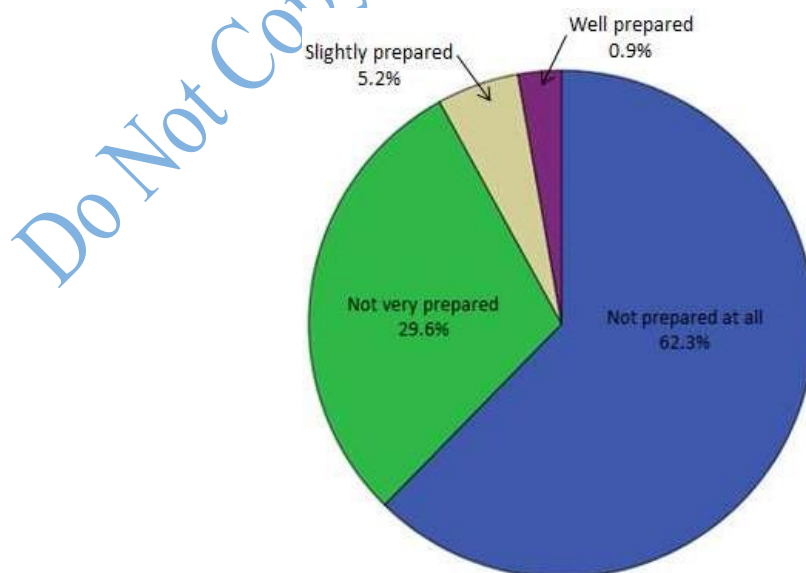
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	218.602 <sup>a</sup>	8	.000
Likelihood Ratio	238.140	8	.000
Linear-by-Linear Association	101.199	1	.000
N of Valid Cases	324		

a. 5 cells (33.3%) have expected count less than 5. The minimum expected count is .69.

**Source: Researcher's Result via SPSS Version 23, (2023)**

However, despite the extent of flood risk awareness among residents, the results of the survey concerning the level of preparedness to face future flooding scenarios (Figure 4.14) reveal that majority (62.3%) of the respondents were 'not prepared at all', while 29.6% and 5.2% of the respondents claimed they were 'not very prepared' and 'slightly prepared' respectively. However, only 0.9% of the respondents reported that they were well-prepared to face future flood risks.

Furthermore, the respondents were asked if they have engaged in any form of preparedness measures to mitigate flood risk. The results indicate that majority of the respondents (66.4%) have never practiced any form of preparedness measures, while the remaining portion of the respondents (33.6%) claimed to have practiced risk mitigation measures sometimes.



**Figure 4.13: Level of preparedness of Residents**  
**Source: Researcher's Result via SPSS Version 23, (2023)**

## Household adaptive coping capacity during flood disaster

The survey also investigated household coping strategies used in managing flood risk. Respondents were asked to indicate their level of agreement/disagreement with 15 statements describing various adaptive household coping strategies used at the property level. The questionnaire was based on a 5- point Likert type scale ranging from 1= Strongly Disagree to 5= Strongly Agree. The reliability of this scale of measurement for the 15 items was investigated using the Cronbach alpha reliability coefficient test and the result produced 0.847 (see Appendix 6), which is greater than the acceptable 0.70. Table 4.21 reveals the result of descriptive statistics (mean and standard deviation) of the 15 items investigated. According to Zaki and Ahmad (2017), five important levels used to interpret mean scores are Very high (V-H) (4.30-5.00), high (H) (3.50-4.20), moderate (M) (2.70- 3.49), low (L) (1.90-2.69), and Very low (V-L) (0-1.89). The results are presented in Table 4.30.

**Table 4.21: Household Coping Strategies**

Coping Strategies	Mean	Std. Deviation	Rank.	Interpret.
Rainwater harvesting system	3.15	1.463	1	Moderate
Use of drainage system	3.09	1.410	2	
Periodic maintenance of drainages	2.53	1.439	3	Low
Raised building ground floor	2.45	1.312	4	
Raised electrical services above flood line	2.14	1.335	5	
Exterior paving with permeable materials	2.00	1.107	6	
Rain garden to reduce run-off	1.91	1.119	7	
Tree planting to reduce run-off	1.89	1.110	8	
Roof garden to reduce run off	1.36	.480	9	Very Low
Standby pump	1.35	.973	10	
Location of living accommodation on first floor	1.26	.437	11	
Use of flood alarm systems	1.16	.368	12	
Use of flood barriers across external doorway	1.13	.333	13	
Anti-flooding devices are fixed to sewage systems	1.00	.000	14	
Use of non-return valve in bathrooms	1.00	.000	14	

**Source: Researcher's Result via SPSS Version 23, (2023)**

A glance at the table shows that the mean scores of the most prominent household coping strategy is the use of rainwater harvesting system to reduce run-off (3.15). However, this is followed by the use of drainage systems (3.09), periodic maintenance of drainages (2.53), raised building ground floor (2.45), raised electrical services above flood line (2.14), exterior paving with permeable materials (2.00), rain garden to reduce run-off (1.91), tree planting to reduce run-off (1.89), roof garden to reduce run off (1.36), use of standby pump (1.35), location of living accommodation on first floor (1.26), use of flood alarm systems (1.16), and use of flood barriers across external doorway (1.13). The lowest ranking household coping strategies are the use of anti-flooding devices on sewage systems (1.00) and non-return valve in bathrooms (1.00).

### **Intervention during and in post-disaster**

The last part of the fourth objective was to assess interventions residents receive during severe flooding events and in post-disaster. In collecting the data for this, the residents were asked to indicate in the questionnaire their perceptions on the extent to which interventions are provided through government support, insurance, support from family/friends, prayers and borrowing.

The questionnaire was based on a 5-point Likert-type scale ranging from 1= Strongly Disagree to 5= Strongly Agree. A total of 5 variables were used to assess interventions residents of the study areas receive during severe flooding events and in post-disaster.

**Table 4.22: Intervention during and in post-disaster**

<b>Intervention</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Cum. percent</b>
Government support	51	15.7	15.7
Insurance	0	0	15.7
Support from family and friends	69	21.3	37.0
Prayer	126	38.9	75.9
Borrowing/ thrift	78	24.1	<b>100.0</b>
<b>Total</b>	<b>324</b>	<b>100.0</b>	

**Source: Researcher's Result via SPSS Version 23, (2023)**

The result in Table 4.22 shows that prayer (38.9%) and borrowing/thrifts (24.1%) are the most common interventions residents of the study areas received during severe flooding events and in post-disaster. The result

also shows that the surveyed respondents received support from friends and families (21.3%) and the Lagos state government (15.7%) to alleviate the impact of flooding. However, none of the respondent acknowledged any form of flood insurance cover.

### Research Question Five

*What significant socio-economic; neighbourhood and architectural design features, and adaptive capacities have the most influence on physical flood vulnerability in the study area?*

### Variables Selection

Literatures and field survey was used for the preliminary variable selection, and expert opinion was used for the final selection. Using the equal (no) weight approach and direct additive aggregation method, consideration was given to (i) flood attributes that induce flood damage (ii) adaptive building design characteristics (iii) probability to be exposed under certain socio-environmental neighbourhood conditions (iv) relevance of selected variables with respect to flood risk. Table 4.23 shows a range of potential flood vulnerability variables, components, dimensions and clusters. Thereafter, an expert opinion survey form was designed containing all thirty seven (37) potential indicators. A total of 35 experts were used for the selection of the indicators with the most relevance on physical flood vulnerability in Nigeria. The respondents rated the indicators on a 7-point scale from 1 to 7, using the scale of relevance. Where, 1= Insignificant, 2= Low relevance, 3= Moderate relevance, 4= Moderate to high relevance, 5= High relevance, 6= High to Very high relevance, and 7= Very high relevance (See Appendix 5).

**Table 4.23: Physical flood vulnerability variables, components, and clusters**

Vulnerability variables	Components	Dimensions	Clusters
Flood water depth	Physical/Environmental	Exposure	
Flood duration	Ditto	Exposure	
Flood water Velocity	Ditto	Exposure	Flood
Water sedimentation	Ditto	Exposure	attributes
Flood return period	Ditto	Exposure	(A)

Frequency of flood experience	Ditto	Exposure	
Construction type and material	Architectural	Susceptibility	
Quality of the building	Ditto	Susceptibility	
Number of floors	Ditto	Susceptibility	
Presence of basement	Ditto	Susceptibility	
Height of the building	Ditto	Susceptibility	
Exterior paving material	Ditto	Susceptibility	Architectural
Interior finishes	Ditto	Susceptibility	characteristics
Age of building	Ditto	Susceptibility	(C)
Type/Use of building	Ditto	Susceptibility	
Building size	Ditto	Susceptibility	
Lev. of Maintenance/condition	Ditto	Susceptibility	
Height of opening from ground	Ditto	Susceptibility	
Stilts/ Building elevation	Ditto	Susceptibility	
Position of electrical sockets	Ditto	Susceptibility	
Roof design/materials	Ditto	Susceptibility	
Site topography	Physical/Environmental	Susceptibility	
Heavy rainfall	Ditto	Susceptibility	
Dist. from the coasts/ river	Ditto	Susceptibility	
Surrounding vegetation	Ditto	Susceptibility	
Drainage system	Ditto	Susceptibility	
Proximity to major road	Ditto	Susceptibility	Neighbourhood
Education/ literacy level	Social	Exposure	characteristics
Income	Economic	Exposure	(E)
Unemployment rate	Economic	Exposure	
Land use	Environmental/Economic	Exposure	
Dam and storage capacity	Physical/economic	Resilience	
Awareness/ preparedness	Social	Ditto	
Warning system	Social	Ditto	Adaptive
Household coping capacity	Physical/social	Ditto	capacity
Emergency service	Social	Ditto	(A)
Flood insurance	Economic	Ditto	

Table 4.24 shows the feedback from expert opinion survey on flood vulnerability indicators in Nigeria.

**Table 4.24: Feedback of Expert opinion on physical flood vulnerability indicators.**

		N= 35			
		Weighted Total ( $\Sigma w$ )	RII	Mean	Decision
<b>Flood vulnerability Indicators</b>					
<b>Socio-economic</b> (S)	Education/ literacy level	114	0.47	3.257	Rejected
	Low income	166	0.68	4.743	Selected
	Unemployment rate	91	0.37	2.600	Rejected
<b>Flood attributes</b> (A)	Flood water depth	215	0.88	6.143	Selected
	Flood duration	210	0.86	5.800	Selected
	Flood water velocity	203	0.83	6.000	Selected
	Water sedimentation	83	0.34	2.371	Rejected
	Flood return period	91	0.37	2.600	Rejected
	Frequency of flood experience	117	0.48	3.343	Rejected
<b>Architectural characteristics</b> (C)	Construction type and material	200	0.82	5.714	Selected
	Quality of the building	206	0.84	5.886	Selected
	Number of floors	73	0.30	2.086	Rejected
	Presence of basement	65	0.27	1.857	Rejected
	Height of the building	92	0.38	2.629	Rejected
	Exterior paving material	121	0.49	3.457	Rejected
	Interior finishes	101	0.41	2.886	Rejected
	Age of building	103	0.42	2.943	Rejected
	Type/Use of building	88	0.36	2.514	Rejected
	Building size	98	0.40	2.800	Rejected
	Level of Maintenance/condition	108	0.44	3.086	Rejected
	Height of opening from the ground	84	0.34	2.400	Rejected
	Stilts/ Building elevation	127	0.52	3.629	Selected

	Position of electrical sockets/fittings	104	0.42	2.971	Rejected
	Roof design/materials	95	0.39	2.714	Rejected
Neighbourhood characteristics (E)	Site topography	206	0.84	5.886	Selected
	Heavy rainfall pattern in the area	121	0.49	3.457	Rejected
	Building distance from the coasts/ river	203	0.83	5.800	Selected
	Absence of surrounding vegetation	181	0.74	5.171	Selected
	Drainage system	219	0.89	6.257	Selected
	Proximity to major road	118	0.48	3.371	Rejected
	land use	156	0.64	4.457	Selected
Adaptive capacity (A)	Dam and storage capacity	188	0.77	5.371	Selected
	Flood risk awareness/ preparedness	105	0.43	3.000	Rejected
	Warning system	107	0.44	3.057	Rejected
	Existence of household coping capacity	169	0.69	4.829	Selected
	Emergency service	98	0.40	2.800	Rejected
	Flood insurance	91	0.37	2.600	Rejected

**Source: Researcher's Result via SPSS Version 23, (2023)**

Among the expert respondents, 37% (13) are university professors/lecturers, 29% (10) are personnel of the Lagos state Ministry of physical planning and urban development, while university post-graduate researchers and experts from other relevant organizations represent 17% (6) each. The returned survey forms were analyzed using the Relative Importance Index (RII) method to determine the most important of the potential indicators. The formula adopted for RII being,  $RII = \frac{\sum w}{N}$  Where, w = score as assigned by each respondent on a scale (1, 2...7), A = highest score (7), and N = number of responses. Based on the RII of indicators, an RII weight of >0.50 is accepted, and indicators with an RII value below 0.50 are considered rejected, as shown in Table 4.24.

A total of 14 indicators were selected to be influential to physical flood vulnerability in the study area.

#### **Influence of selected indicators on the physical flood vulnerability in the study area.**

To examine the influence of the selected 14 indicators on the physical vulnerability of study area, the data used were derived from section D of the questionnaires (Appendix 3) administered to the residents of the study area.

The questionnaire was based on a 5-point Likert-type scale of 1 = Insignificant Influence, 2 = Little Influence, 3

= Not Sure, 4 = Significant Influence, and 5 = Very Significant Influence. In performing the analysis, Linear Regression was used in the data analysis and the analysis is at 95% confidence level (i.e.  $p \leq 0.05$ ). Physical flood vulnerability was the dependent variable, while the independent variables were (1) flood water depth (2) flood duration (3) flood water velocity (4) construction type and material (5) quality of building (6) Stilts/ Building elevation (7) site topography (8) building distance from the coasts/ river (9) absence of surrounding vegetation (10) drainage system (11) low income (12) land use (13) dam and storage capacity, and (14) existing household coping capacity. From the Analysis of variance (ANOVA) table (see Appendix 10), results shows a high significance F value = 428.257,  $p < 0.000$ . Also, the Model Summary (Appendix 11) shows that the model having  $R^2 = 0.975$  explained around 98% of variance in the influence of the selected indicators on Physical Flood vulnerability in the study area. The coefficients of the linear regression analysis are presented in Table 4.25.

**Table 4.25: Coefficients of the Linear Regression Analysis of flood vulnerability indicators**

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	1.909	.147		12.954	.000
Flood water depth	-.220	.059	-.360	-3.746	.000*
Flood duration	.157	.051	.266	3.060	.002*
Flood water Velocity	.016	.025	.029	.638	.524
Construction type and material	-.032	.024	-.060	-1.331	.184
Quality of the building	.122	.042	.258	2.915	.004*
Stilts/ Building elevation	.453	.033	.689	13.869	.000*
Site topography	.023	.033	.043	.699	.485
Building distance from river	.022	.053	.047	.417	.677
Absence of sur. vegetation	-.142	.026	-.272	-5.415	.000*
Drainage system	.101	.023	.205	4.429	.000*
Low income	.218	.038	.204	5.801	.000*
land use	-.027	.033	-.063	-.812	.417
Dam and storage capacity	.083	.053	.135	1.553	.122

Existence of household coping capacity	-0.154	0.039	-0.136	-3.976	.000*
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a. Dependent Variable: Physical flood vulnerability

**Source: Researcher's Result via SPSS Version 23, (2023)**

Result of the analysis reveals that of the 14 indicators investigated, eight have a P-value lower than 0.05; and as such have the most significant influence on physical flood vulnerability in the study area. As shown in the p-values in Table 4.25, the eight indicators that significantly influence physical flood vulnerability in the study area are: Flood water depth ( $p=0.000$ ) Stilts/ Building elevation ( $p=0.000$ ) Absence of surrounding vegetation ( $p=0.000$ ) Drainage system ( $p=0.000$ ) Low income ( $p=0.000$ ) Existence of household coping capacity ( $p=0.000$ ) Flood duration ( $p=0.02$ ) Quality of the building ( $p=0.04$ ).

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### 4.3 Discussion of Findings

#### Demographic Characteristics

The results of the demographic characteristics of the residents of the flood-prone areas of Kosofe, the local government area of Lagos State, show diversity in gender, ethnic representations, age structure, employment status, marital status, religion and educational attainment. First, the diversity of socio-demographic characteristics of the inhabitants supports previous studies that human societies have always been attracted to floodplains due to its physical geography and environmental conditions, which provide favorable conditions for agriculture, commerce, economic growth, cultural organization and human settlement<sup>1</sup>. Furthermore, the representation of demographic data seems consistent with the statement that the floodplains of Lagos State exert a strong attraction for migrants, whose population represents a culturally heterogeneous composition of numerous ethnic groups of different religious beliefs, gender, age, educational background, marital status and family size<sup>2, 3</sup>. Furthermore, previous related studies have also suggested that the floodplains of the city of Lagos have experienced rapid population influx over the past three decades, leading to an expansion of physical development<sup>4</sup>. However, the clustering of a socio-culturally heterogeneous population within the study area suggests a significant level of exposure and vulnerability to increased climate risk. This spatial development model appears to support a recent United Nations report indicating that the greatest increase in urban vulnerability occurred in unplanned and informal settlements, where residents' ability to adapt to climate change is limited<sup>5</sup>.

The results of the present study also seem to confirm that the category of people moving to floodplains is mainly made up of people of working age; suggesting that residents may not be economically vulnerable as more people can work to recoup economic losses<sup>6</sup>. However, the results of the survey data also showed that 30.2% of residents were unemployed, suggesting some degree of economic vulnerability given the limited financial resources of these residents. Studies have shown that income affects vulnerability to disasters as it affects an individual's ability to prepare, cope and recover<sup>7</sup>. Further analysis of the occupational pattern showed that 14.5% of residents in the area are self-employed, suggesting that when the environment is flooded, income and

livelihoods would suffer. This finding corroborates previous studies that found that flood events have a negative impact on local employment<sup>8</sup>. Moreover, despite the large proportion of inactive residents, the result continues to show that a higher percentage of residents living with their families are married. This therefore simply implies that the majority of respondents have dependents, which invariably increases the number of vulnerable populations. This statement is consistent with previous studies suggesting that the presence of large numbers of dependent populations makes the community more vulnerable to flood risk<sup>6</sup>.

Regarding the level of education of the residents surveyed, the result showed that 38% of respondents did not have a college degree. This is important because the level and quality of education of a population are very indicative of its vulnerability. A more educated population has the knowledge to mitigate flood damage and implement viable solutions for reasonable post-disaster reconstruction; while low-educated households are more likely to be at risk of flooding and less prepared for flooding<sup>9</sup>. In addition to these demographics, the religious beliefs of the inhabitants of the sample were Christianity and Islam. However, those of the Christian faith made up a higher percentage (57.1%) of the respondents.

### **Socio-economic characteristics**

Three issues bordering on the socio-economic characteristics of the inhabitants of the study area were identified and brought forward for further discussion (*social capital, household composition and patterns of existence*).

#### ***Social Capital***

The results of the current social capital survey of the study area demonstrated the existence of relatively strong socio-demographic ties, as reflected in the bonding network model, which is characterized by close family ties and strong neighborly relationships. However, there appears to be little mutual trust among the inhabitants of the study area. Furthermore, the results seem to confirm the existence of a strong socio-demographic diversity, as reflected by the connection network model, including a good mix of ethnic groups, low perception of ethnic segregation, high levels of religious and socio-culture within the research area. However, feedback from residents on the presence of government and external support in the area showed a below average pattern of connectivity networks,

as only 44.1% of the respondents agree to the assertion. 42.9% did not agree with government presence and outside support within the area.

A look at the summary of local government statistics of Lagos State shows the presence of police stations, primary health care centers and primary schools in the Kosofe local government area<sup>1</sup>. However, there was a lack of facilities such as libraries, youth centers, secondary schools and hospitals. Additionally, further analysis of the results revealed that residents reported low levels of support from government, friends and family in crisis situations. The diversity of ethnic origins and the lack of adequate support when needed may therefore explain the high level of distrust among residents, as evidenced by the result. Based on the results of current research, it can be stated that the value of social capital appears to be slightly above average in the region. This notion is supported by evidence showing a good bonding pattern (*close family ties, strong relationship with neighbors, but lack of mutual trust*); very good bridging pattern (*good ethnic mix, low ethnic segregation, high level of religious and socio-cultural activities*) in the study area; and below average linkage pattern (*inadequate government presence and external support*) in the area. Therefore, this finding suggests that flood-prone areas of Kosofe are socially vulnerable due to limited social resilience from lack of adequate social structures, institutions, and organizations to foster trust and cooperation among residents. This finding appears to be in line with the study indicating that high social capital reduces community vulnerability, and should be a measure of their social vulnerability or resilience<sup>10</sup>. Therefore, disaster management plans should enhance a community's ability to understand and rely on social capital for risk mitigation.

### ***Household Composition***

Regarding the household composition of residents, house types, occupancy status, household size and length of stay in the study area were considered. Analysis of the results showed some degree of variation in housing typology within the study area, for example, there are apartment buildings, semi-detached houses, individual bungalows, duplexes and townhouses. However, the predominant housing type in the study area is semi-detached houses. This finding appears to support the OECD report that semi-detached houses are common in most cities, although some countries report housing mix, with each type of main dwelling (semi-detached or

multi-family, detached) accounting for less than 20% of the shares<sup>11</sup>. By definition, a semi-detached house refers to two dwellings that share at least one wall; and is designed to accommodate more than one household in the same building. Each housing unit has a separate entrance and access. Previous studies have shown that semi-detached houses offer sufficient privacy and save significantly on total construction costs compared to single-family houses<sup>12</sup>. These features make the semi-detached house a popular rental home. The outcome of the survey seems to correspond with the occupancy status of the households in the study area, from which it emerges that approximately 60.8% of residents live in rented accommodation. A UN Habitat report indicated that millions of people living in African cities are renters<sup>13</sup>.

On the one hand, rented housing is known to provide a sort of permanent residence for rural residents and migrants in urban centres<sup>13</sup>. On the other hand, it suffers from limited investment by individual owners and is often seen as an exploitative, low quality and temporary place where the poorest citizens live<sup>14</sup>. Furthermore, research shows that these types of homes usually exist outside formal laws and regulations<sup>15</sup>. Therefore, the high concentration of populations at risk, combined with poor housing conditions in informal settlements, make these areas more exposed and more vulnerable to the impacts of climate change. This finding therefore suggests that weak housing rights, combined with limited access to quality housing, may be the cause of the growing concentration of residents in the flood-prone areas.

Furthermore, data from the present study show that most households have between 3 and 4 occupants. This finding is in line with statistics on the number of bedrooms in homes, which showed that three-bedroom designs were the most common housing type. Furthermore, very few of the population are physically disabled, while most households do not own a car. Baseline measurement of the study area showed that residents depend on the use of motorcycles for commuting. Regardless, a higher proportion of respondents have lived in the study areas for more than 16 years. Thus, this means that most households in the study area have experienced flooding while living in the study area at various points in the past. This finding has a positive impact on vulnerability, as recent study has explained that increased exposure to past flooding increases vulnerability<sup>16</sup>. Furthermore, the outcome of the results on the reason for living in the study area assumes that the majority of residents are

limited by financial resources. Similar studies conducted in other parts of Nigeria found that people in flood-prone areas stayed due to cultural-ethnic affinities, lack of other places to live, local ties based on family background, and cheaper houses to rent<sup>17</sup>. However, in Lagos State, studies have shown that land scarcity and high rental costs in most parts of the city have led to an exodus to vulnerable areas<sup>18</sup>. The claim is backed up by similar related studies, stating that the majority of people in Kosofe Municipality, Lagos State cannot afford housing in high income areas<sup>19</sup>. It can be concluded that financing is a decisive indicator for the choice of place of residence

The result of the survey also shows that the majorities of the inhabitants of the study area are between 31 and 43 years old; and are married and live with their families. Observations from past study suggest that the financial constraints imposed by starting a family are a particularly important factor for people aged 35 and over<sup>20</sup>. The characteristics of households in the study area therefore indicate that there are different types of dwellings in the study area and that the majority of residents are tenants living in semi-detached houses with their families. These residents have experienced flooding before; however, continued to live in flood-prone areas due to the availability of cheap housing compared to other parts of the city.

### ***Livelihood Pattern***

Survey results of the livelihoods of study area residents revealed diversity in employment patterns. As already mentioned, 30.2% of respondents were unemployed. Overall, however, 55.5% of residents surveyed are either self-employed, employed by a private agency, or government employed. The highest proportion of employed respondents own businesses in the region. Therefore, the income of residents with businesses in the area will be negatively affected by flood hazard. This finding supports the claim that the income of flood-prone households is strongly influenced by the characteristics of the floods<sup>21</sup>. Some studies also show that the self-employed run a higher risk of poverty<sup>22</sup>. This assumes that in addition to the area's high unemployment, most families are at risk of poverty.

Furthermore, the IFRC report explained that a resilient community offers economic opportunities, a wide range of employment opportunities, income and financial services to recover from a crisis situation<sup>23</sup>. It can therefore invariably be concluded that the economic vulnerability of a community has a strong relationship with the income of the residents. For example, people with multiple income streams are less vulnerable to flooding. Although the results of the number of income streams per household in the study area showed that majority of respondents (57.1%) have multiple sources of income; however, the household income distribution results showed that 64.2% of households earned less than NGN 99,000, while 27.7% earned between NGN 100,000 and NGN 299,000, and 13.5% earned between NGN 300,000 and NGN 500,000.

On one hand, the World Bank \$3.20 poverty line family income indicator for low-medium countries like Nigeria per month stands at NGN 89, 814. On the other hand, the Anker estimated monthly living income value which covers cost of basic but decent standard of living for a rural family in Nigeria is NGN 138,678<sup>24</sup>.

This implies that the household income of the majority of respondents is below the living wage. The results hint at economic inequality in the study area and also support the argument that residents of flood-prone areas are mostly low-income people who lack the economic ability to access housing in appropriate places, as previous research has shown<sup>13</sup>.

In the current context of appalling economic disparities between residents of the study area, there seems to be a general consensus that the most important financial services available for emergencies are participation in savings (collective money savings venture) and personal savings. Additionally, studies argued that the personal savings behaviors of low-income city dwellers serve as a buffer for individuals and households during times of shock or stress; but when savings are taken collectively, they can make a significant contribution to long-term collective vulnerability reduction.

### **Pattern of Flooding Experienced in the Flood-prone areas of Kosofe**

The survey result shows that flooding starts 1-3 hours after heavy rains. Flooding is observed to become more intense within 4 to 9 hours after heavy rains. This finding corroborates previous studies showing that flooding in Lagos is mainly due to short-duration, high-intensity rainfall or long-duration, low-intensity rainfall caused by

climate change<sup>18</sup>. The survey also shows that the neighborhood, streets and grounds will be flooded during this time (see Figure 4.14). The outcome of these results suggests that there is a slow rate of storm water runoff in the study area, which many studies attribute to the state of the drainage systems (insufficient and often clogged with silt and solid waste), and increasing impervious areas due to land use change and land cover modification<sup>25</sup>. Also, in addition to the obvious flash/pluvial flooding in the study area; other studies have linked the recurrent flood occurrences in Kosofe in part to river flooding caused by the release of water from the Oyan Dam upstream into the Ogun River<sup>26</sup>. For example, river flooding is said to have devastated these areas in 2010; resulting in "widespread loss and damage" and displacing several thousand residents from their homes. Furthermore, the results of the resident survey indicate that the majority of floods are more than 300 mm deep; implying that low-elevated buildings in the study area are subjected to severe damage from hydrostatic forces. Similarly, the results of the present study show that the most obvious pattern of flood damage suffered by households in the study area is water penetration damage (see Figure 4.15). This appears to support previous studies that suggested that flood damage to building structures was primarily due to a slow increase in flood depth rather than high flow velocity<sup>27</sup>.

Damage from water penetration is also associated with mold growth, contamination, cracks and slabs settlements, and damage to building services, contents and equipment<sup>28</sup>. All of this has negative impact on the structure of the building and on the health and well-being of the building users. The results of the flood pattern observed in the study area indicate that the settlement is prone to pluvial flooding from excessive runoff and slow fluvial flooding of the adjoining Ogun and Agboyi rivers.



**Figure 4.14: Street flooding 30minutes after heavy rainfall in the Oworonsoki area.**  
Source: Researcher's Field Survey, (2023)



**Figure 4.15: Water penetration damage to building in the Ajegunle area.**  
Source: Researcher's Field Survey, (2023)

## **Causes of Flooding Experienced in the Flood-prone areas of Kosofe**

Feedback on the cause of the floods shows that a majority (44.8%) of respondents linked the recurrent flood episodes experienced in the flood-prone area to poor urban planning, followed by 25.9% of respondents who ascribed it to intense rains. This finding seems to be supported by past studies linking perennial flooding of Lagos city to anthropogenic factors, including land-use change and land-cover modification<sup>29</sup>. For example, the development of illegal structures on or across drainage channels, land reclamation or encroachment, poor physical planning, inadequate drainage channels, blockage of canals and drains, collapsed dams and nature of terrain were the primary causes of flooding in most part of the city. As examined in Literature, floodplains are natural flood reservoirs; therefore, forcing floodplains to be flood-free by changing its use for urban development purposes compromises the ecological function of the area and contributes to increasing exposure to risk. Yet, previous studies indicate that enforcement of physical planning regulations in informal settlements in Lagos city remains a challenge as housing continues to expand into floodplains<sup>18</sup>. This implies that intrusion into the floodplain areas of Kosofe through anthropogenic activities and urbanization significantly influences the spatial characteristics and indirectly increases residents' exposure to flood risk. These findings support the claim that disturbances in the natural hydrological and hydraulic functions of floodplains often lead to increased vulnerability to flooding. Thus, designing for flood risk reduction in flood prone areas becomes even more complex due to the many social, physical and environmental variables involved. However, the influential role of risk-informed urban design is to reconcile these variables within the design process. Thus, understanding the factors influencing flood occurrences will facilitate decision-making on integrating the most appropriate adaptation strategies into urban planning.

## **Factors Influencing Flood Occurrences in the Flood-prone areas of Kosofe**

The two key dimensions identified in this study as factors that influence the occurrence of floods in the study area. are (i) site topography, lack of vegetation, soil conditions, violation of planning regulations, failure to comply with flood warnings and development of flood plains (ii) poor channelization and clogged drainages. These dimensions explain local residents' perception of the factors influencing the occurrence of floods in the

study area. This implies that these two dimensions are the properties of the study areas that have a significant impact on flood events as perceived by residents of the study area. This outcome indicates that the factors influencing flood occurrences in flood-prone areas are related to the physical and socio-economic characteristics of the area. Linking this result to studies in a similar context carried out in Awka, Nigeria, it was found out that the factors influencing the occurrence of floods are rainfall, soil, drainage density, distance from the drain, height, slope, and land-use/land cover<sup>17</sup>. Also, another related study identified narrow river channels and construction of housing units and other developments along floodplains as contributing significantly to flood occurrence in Lagos city<sup>25</sup>. However, a similar study in Uyo, Nigeria, showed that rainfall and roads without good drainage channel exact significant influence on flooding<sup>19</sup>. However, the outcomes of this finding indicate that the influence of the considered factors varies according to the socio-ecological characteristics of the area.

These variations could be due to differences in climate, socio-economic trends, built systems and infrastructure endowments, legal and policy frameworks, political conditions and hydrological processes. Regardless, continuous anthropogenic influences through urban development in the flood-prone areas explain the reason for the high exposure to flood risk (see Figure 4.16). Yet, consideration for flood disaster risk reduction is rarely considered in the development of such settlement<sup>30</sup>. The implication of this result on flood disaster risk reduction in flood prone areas is that urban design can be linked with flood risk adaptation by identifying the role of green infrastructure in creating a more 'permeable landscape' that provides for water absorption and storage; habitat connectivity; recreational access; and the requirements of emergency response. This idea is encapsulated into eight distinctive features appropriate for a resilient urban design planning: (i) increase the multi-functionality of each site to provide more recreational opportunities, ecology and disaster prevention. (ii) improve flexibility of spatial processes to eliminate the stormwater, (iii) create facilities to promote interactions between ecological and social factors, (iv) increase the number of functions a facility can serve so as to ensure the normal operation of certain function in disasters, (v) improve the intelligence of public services to enable communities to advance or save more time in response to disasters (vi) emphasize the humanity of public services (vii) use a dynamic management approach that can adjust to different environmental change factors,

and (viii) make diversified parties participate in the management and form a feedback mechanism with cooperative mode<sup>31</sup>.

Therefore, relating the findings of the current study with studies on resilient urban floodplain settlements, it is observed that the flood-prone areas of Kosofe currently lacks features of flood adaptation in its urban design planning. This implies that the study area is exposed and vulnerable to flood risk and associated impact.



**Figure 4.16: Development sprawling into the floodplains, Alapere area.**  
Source: Researcher's Field Survey (2023)

#### **Impact of Flooding in the Flood-prone areas of Kosofe**

The last issue among the flood attributes experienced in the study area is the impact of flooding as perceived by residents. First, the result shows that flooding has had an impact on the socio-economic and physical fabric of the study area. Of all the possible impacts evaluated, the relative importance index results show that none of the effects scored low. Analysis of survey data shows that the main impacts of flooding in the study area are: disruption of businesses in the area, displacement of people, disruption of traffic and erosion/destruction of

crops. The result simply implies that the most significant impacts of flooding on residents of the study area are the economic losses caused by flood impact (see Figure 4.17).

These results seem to support an earlier study suggesting the main impacts of floods are related to tangible flood damage<sup>27</sup>. In addition, the results show that high to moderate impacts are associated with disruptions to electricity and communications, damage to buildings and contents, loss of life and livestock, and destruction of infrastructure. The results suggest that these impacts are the indirect and intangible consequence of the floods. However, the average impacts revealed by the survey results are those perceived at the household level. They include: building collapse, difficulty draining, clogged bathroom floor drain, blocked sink, septic tank overflow.

This finding is consistent with literatures on flood impact assessment, which appears to agree that losses from flooding have a variety of overwhelming socio-economic and physical impacts<sup>18</sup>. Past studies indicate that flooding affect the economic lives of people, the environment as well as animals and people<sup>17</sup>. This implies that the vulnerability of the communities to natural hazards is affected by both their physical and social exposure.



**Figure 4.17: Street flooding affecting businesses in the study area, Kosofe area.  
Source: Researcher's Field Survey (2023)**

## **Neighbourhood Characteristics of the Flood-prone areas of Kosofe**

Findings from the study shows that the predominant neighbourhood features in the study area are: spaces for social and religious activities, educational facilities, shopping facilities, power supply, and primary health centres. However, the neighbourhood lacks adequate domestic waste disposal facilities, stormwater drainage facility, portable water supply, and natural recreational areas. Furthermore, results of the factor analysis of resident's perception of the Neighbourhood characteristics of the study areas are discussed in the next section.

### **Dimensions of the Neighbourhood Characteristics in the Study areas**

From the result, two main dimensions of the neighborhood characteristics of the study areas were identified. The first dimension includes the natural recreation areas, the rainwater drainage system, the household waste disposal systems, the water supply, the road and road network, the flood wall/barrier along the river channel, the flood ponds/gardens and flood warning systems. The second dimension includes health facilities, educational facilities, energy supply, space for social and religious activities, commercial facilities and pedestrian paths. The implication of this is that residents of the study area perceive attributes in the first dimension (*natural recreational areas, rainwater drainage facilities, household waste disposal facilities, drinking water supply, road and street network, flood wall/barrier along the river channel, flood retention ponds/gardens and flood warning systems*) more important in explaining the physical characteristics of the neighborhood than the attributes in the second dimension.

On the one hand, the first dimension mainly represents attributes of the spatial configuration of the neighborhood. The sustainability of a neighborhood's development is significantly dependent on physical development plans, which typically include appropriate land allocation, development control, provision of facilities, services and public goods, conservation, protection and conservation of resources, among others<sup>32</sup>. Spatial planning is an important tool to advance the proactive and preventive adaptation of human settlements to threats caused or exacerbated by climate change. The influential role of spatial planning in mitigating flood risk is well documented in literature<sup>33, 34</sup>. Based on empirical studies, it is argued that the use of flow delay, detention, retention and infiltration techniques through natural recreational areas and flood retention ponds/

gardens allow greater control over the quantity and quality of water drained, preventing flood areas from affecting water supply systems existing downstream<sup>35</sup>. However, in Lagos City, increasing change in land-use and natural land cover modification due to urban physical development in the flood-prone areas increases the chance of flooding; and thus heightens exposure and susceptibility of residents to flood risk<sup>36</sup>. Also, the presence of potholes/bad roads, poor drainage systems and poor waste disposal systems have been said to further aggravated the incidence of flooding in the region of Kosofe in Lagos State<sup>37</sup>. Other related studies have also confirmed the absence of flood warning systems and the absence of flood walls/barriers along the river channel, as major contributors to the increased risk of flooding<sup>18</sup>.

On the other hand, the second dimension includes public amenities to support the residents of the study area. The high expansion rate of physical development caused by the construction of housing and public amenities leads to an increase in impervious area. Studies have shown that the development of impermeable surfaces affects water resources and the hydrological cycle; thereby reducing urban surface runoff rates and peak discharges, evaporation, and increasing pollution in runoff, reducing absorption of rainfall and the inevitable decrease in groundwater recharge<sup>38</sup>. This is reflected in the continuing flooding in the study area.

It is clear from the result of this current study that residents considered spatial pattern to be more influential and should therefore be given due consideration when planning flood disaster risk reduction. Past studies seem to support this claim, arguing that disaster risk reduction efforts in high risk areas should consider land use through appropriate land use allocation<sup>39</sup>. In this way, exposure to and susceptibility to flood disasters can be minimized or even prevented. In a similar study, using a case study to identify neighborhood characteristics of resilient urban communities around the world, two performance dimensions influential in addressing all kinds of natural and man-made disasters were identified. The dimensions were: 1) spatial pattern of traffic roads, residential buildings, activity sites and landscaping, and 2) the environmental components such as infrastructure for living and recreation, municipal public utilities, municipal network, information and communication in urban community. The authors however noted that specific strategies and measures for disaster risk reduction are embedded in these dimensions. Table 4.26 shows a comparison of dimensions of neighbourhood characteristic

in the studies discussed. Inferences from the case studies suggest that the spaces and spatial patterns illustrated in the characteristics of multifunctionality and flexibility have as much effect on flood management as the neighborhood-level approach. Additionally, the interactive and diverse components of communities that span both spaces and facilities can help build an inclusive and green community that provides diverse opportunities in a changing climate. This means that given variations in climate patterns and increasing flood projections, disaster-prone areas such as urbanized floodplains are expected to change and adapt in different ways to reduce flood risk, prepare for possible floods and recover from the floods as quickly as possible.

**Table 4.26: Comparison of Dimensions of Neighbourhood Characteristics Evaluation**

S/N	Dimensions of the Neighbourhood characteristics of the study areas	Performance dimensions of resilient urban communities by Case studies <sup>31</sup>
1	Natural recreational areas, adequate stormwater drainage facility, adequate domestic waste disposal facilities, adequate water supply, good roads and streets networks, floodwall/ barrier along the river channel, flood retention ponds/ gardens, flood warning systems	Traffic roads, residential buildings, activity sites and landscaping,
2	Health care facility, educational facilities, adequate power supply, space for social and religious activities, shopping facilities, pedestrian walkways	Infrastructure for living and recreation, municipal public utilities, municipal network, information and communication

**Source: Researcher's Summary**

It can be concluded that the reduction of the risk of flooding in flood-prone neighborhoods lies in their ability to adapt. Adaptability in a neighborhood context aims to restore and maintain the functions of the natural circulatory system disrupted by urbanization<sup>38</sup>. Adaptability also enables a community to cope with negative impacts and to respond to changing climatic conditions over the long term, which includes financial resources as well as planning and design decisions. The following section illustrates the architectural features of the existing housing stock in the study area.

## Architectural Design Features of Buildings in the Study area

A total of 324 buildings, unevenly distributed between 30 meters and 70 meters from the Agboyi River, were evaluated for this study. The survey result shows that 118 buildings are located 30 meters near the Agboyi River, which are the most vulnerable buildings according to the standard criteria of the Land Use Ordinance (Building Plan) of 1986, which is still in effect today. Furthermore, 116 buildings are located between 30 meters and 50 meters from the river channel, representing the vulnerable; while 90 buildings are located between 50 and 70 meters from the Agboyi River, representing the least vulnerable. Vulnerable buildings are houses in low-lying areas near the river channel<sup>5</sup>. These results are consistent with past studies, stating that most of the buildings in the lower area of Kosofe do not respect the legal distance of 30 meters from the river floodplain (See Figure 4.18)<sup>37</sup>. Hence, it can be inferred that a key indicator of the extent of a building's susceptibility to flooding is its proximity to the river bed.

The result of the housing type surveys in the study area shows that the predominant housing types are semi-detached houses, which have neither flood walls nor raised foundations. Most of the buildings are fenced with sand concrete blocks. This means that buildings and their occupants are not only exposed but also very susceptible to flood damages. Based on Federal Emergency Management Agency (FEMA) and Associated Program on Flood Management (AFPM) standards for construction and renovation of buildings in flood-prone areas; Storey buildings fenced with flood walls are recommended as suitable construction methods in flood plains<sup>40</sup>. Additionally, there is disparity in the condition of buildings in the study area. Results show that a higher percentage of the buildings are in good condition (37.7%), this is followed by buildings which are in fair condition (29.9%). Very few of the buildings are in excellent condition (10.8%), while others are in poor condition (21.6%). However, this finding suggests that many of the buildings in the study area are ill-prepared to cope with a 100 year flood (which implies a flood event that has a 1% chance of occurring every year)<sup>41</sup>.



**Figure 4.18: Buildings in close proximity to River Agboyi**  
**Source: Researcher's Field Survey (2023)**

Additionally, respondents indicated that most houses are 300mm above natural ground floor level (NGL). However, this is below the standard average base height of 600mm above the estimated flood level<sup>42</sup>. The buildings are meant to withstand flooding to a depth of 600mm, after which water can enter the building to relieve pressure on the building structure. Furthermore, observations from empirical studies on Lagos State's vulnerability to flooding show that most of the city's floodplains are less than 5 meters above sea level<sup>43</sup>. This implies that the design and construction of most buildings in the study area did not take into account the current exposure of the study area. To substantiate this claim, past related studies confirmed that the structural and non-structural measures used to deal with the floods in the City of Lagos excluded requirements for the design and construction of resilient buildings<sup>44</sup>.

The results also show that different materials were used to build houses in the flood-prone areas of Kosofe. Based on the information in Table 4.19, all the houses were built with sand concrete blocks. This is however, not resilient as precast sand concrete blocks (mix ratio 1:8) have lower water absorption capacity and are prone to cracking; Therefore, FEMA has recommended the use of cement blocks, concrete, and compacted clay for construction in flood-prone areas. In addition, the survey results show extensive use of the traditional hipped roof for roofing (see Figure 4.19) and impermeable materials such as cement and sand screed and concrete for exterior flooring of the compounds ( see Figure 4.20).



**Figure 4.19: Buildings Features in the study area**  
**Source: Researcher's Field Survey, (2023)**



**Figure 4.20: Flooded compound in the study area**  
**Source: Researcher's Field Survey, (2023)**

While the pitched roof is a common feature of tropical architecture; recent studies however, had argued that structural flood mitigation measures could consider the use of green roofs to compensate for impervious areas of

the building for backflow water drainage<sup>35</sup>. However, the adoption of green roofs in the city of Lagos remains limited due to cost, technical challenges, lack of knowledge and constraints imposed by the interpretation of local town planning laws<sup>45</sup>. In addition, most of the interior floors of the houses in the study area are covered with ceramic tiles, while the walls have been covered with cement screed. Other prominent architectural features of buildings in the study area are the use of exterior steel doors, interior wood doors, aluminum windows, and wood kitchen cabinets; Low level sockets and high level meters.

Whereas, adaptation and resilience strategies to flooding at building level include elevation on plinths or raised foundations, and external protection of buildings to prevent water from entering, as well as measures such as transferring utilities and vulnerable elements to higher floor and implementation of Sustainable Urban Drainage Systems through permeable paving attenuation systems, filter drains, ponds, wetlands<sup>46, 47</sup>. The conclusions of the findings imply that unreliable measures have been taken to reduce the risk of flooding for homes in the Kosofe flood zone. The implication of knowledge about the architectural design features of houses in the study area supports empirical studies on the lack of knowledge in the practice of flood control or adaptation measures in flood prone houses in Nigeria<sup>48, 49</sup>. This may be attributed to different levels of vulnerability to flooding, the diversity and complexity of architecture and construction methods; all of this is important for understanding the adaptability of buildings to flooding. However, FEMA recommends that only highly qualified designers and engineers be hired to design and construct all types of buildings in flood-prone areas.

### **Pre-disaster Level of Adaptation**

Four specific issues are discussed in this section. The first issue is the level of awareness of the risks attributed to floods. The majority of respondents (70.4%) say they are aware of the risks. Second, the majority (76.9%) of the household representative attributes the source of information about their conscience to previous flood experiences. A chi-square test confirmed a significant relationship between flood risk awareness and past experience of flooding ( $\chi^2 = 218.602, P = 0.000$ ). The results of this survey are consistent with previous study which suggested that many residents of flood-prone areas are fully aware of the risks associated with living in the area<sup>50</sup>. Third, the results of the survey on the level of preparedness to deal with future flood risks show that

despite the high awareness of flood risks among residents of the study area, a very high percentage (91.9%) of respondents were "unprepared". Only 0.9% of respondents said they were well prepared for future flood risks. This result seems to be consistent with previous studies which asserted that very few homeowners in at risk areas adopt any mitigation measure despite the overwhelming public awareness of flood risk<sup>4</sup>. The fourth survey of the current study also shows that many respondents (66.4%) have never practiced any form of preparedness measures, while (33.6%) of respondents said they sometimes practice risk mitigation measures.

The implication of these results shows the docile attitude of the majority of the inhabitants of the study area to invest in mitigation; highlighting the challenges that policymakers face in encouraging residents of flood-prone areas to protect themselves against future floods and their associated impacts. For example, previous studies have shown that residents of flood prone areas in the city of Lagos have reacted passively to flood warnings and awareness campaigns over the years<sup>18</sup>. This was attributed to either a lack of knowledge of local residents on flood mitigation measures or due to local residents' perceptions that the flood warnings and awareness campaign were an attempt to evict them and acquire their land and the "lack of resources" and "reliance on government" to provide structural amenities<sup>44, 50</sup>. Others simply argue that flooding is regular and unavoidable, that the cost of moving is beyond their means, that as homeowners they were unable to leave their homes, or that past warnings had been in vain and the consequences of the flooding were not serious.

### **Household Coping Capacity during Flood Disaster**

Results of this survey shows that out of the 15 variables used to assess household coping strategies, 2 returned with a moderate mean score (3.15 -3.09), while 5 reported a low mean score (2.53- 1.91). The remaining 8 variables had very low mean scores (1.89-1.00). This implies that many households have a fairly low coping capacity. The result also shows that the most common coping strategies of households in the study area, as reported by respondents, are rainwater harvesting systems (3.15), the use of drainage (3.09) and regular maintenance of drainage systems (2.53). This finding appears to support previous studies that suggested that household coping strategies were not effective in many flood-prone areas of the city of Lagos<sup>26, 51</sup>. Studies have also shown that households in flood prone areas engage in various activities, usually dependent on their own

resources and income, to manage flood risk<sup>52</sup>. For example, residents use sandbags to protect properties, raise entrances to their buildings, fill depressions around property, clean their immediate surroundings and ensure proper waste disposal.

Nevertheless, the results of this current study suggest an important conclusion about flood mitigation strategies that differ from those proposed in previous research. Households in the study area use rainwater harvesting systems (RWH). The motivation for RWHS may be due to lack of potable water in the study area, as suggested by descriptive statistics of neighborhood characteristics. It is observed that most households in the study area meet their domestic water needs by purchasing water from outside the neighborhood or through rainwater. The existing wells are untreated, dirty and unfit for consumption. This inference is consistent with previous studies suggesting that low-income residential areas in the city of Lagos are more dependent on unimproved water resources and have little access to safe water supplies<sup>53</sup>. In particular, studies indicate that RWHs have several advantages as an effective alternative water supply solution and are useful for reducing flood risks in urban areas. However, the potential of RWH installation in flood risk reduction strongly depends on the amount of rainfall<sup>54</sup>. This implies that RWHs are more effective in mitigating flooding from small rainfall events; however, when combined with other building-based flood adaptation measures, there is greater potential to reduce flooding from heavy rainfall. Be that as it may, the result of the present study shows very minimal use of flood adaptation measures (*such as: tree planting, roof garden, backup pump, arrangement of first floor living spaces, use of flood warning systems and barriers against storm surges above the outside door, overflow devices on sewers and the use of non-return valves in bathrooms*) in many households in the study area.

According to some studies, the socio-economic characteristics of residents influence their capacity and ability to cope with flooding<sup>55</sup>. Thus, on the one hand, the low level of household coping capacity shown by most households in mitigating flood risks in the study area may thus be informed by the high rate of unemployment and low income among the residents. On the other hand, the low uptake of building-based adaptations suggests that residents have only a superficial understanding of the effectiveness of these adaptations, as previous research has shown.

## **Intervention During and in Post-Disaster**

Despite the low level of household coping capacity demonstrated by households in the study area, further analysis of the results (see survey table) shows that prayer is the most common intervention respondents (38.9%) receive during and after severe flooding. This is followed by loans/gifts for savings purposes (24.1%) and support from friends and family (21.3%). Government support appears to be insignificant, however, and none of those interviewed said they received any form of flood insurance cover. This finding therefore confirms the low level of adaptive capacity previously suspected in the households in this study.

## **Indicators Influencing Physical Flood vulnerability in the Flood-prone areas of Kosofe**

The result of the linear regression analysis shows that 8 indicators (*Flood water depth, Stilts/ Building elevation, presence of surrounding vegetation, Low income, Drainage system, Existence of household coping capacity, Flood duration, and Quality of the building*) out of the 14 variables investigated have a P-value lower than 0.05; and as such have the most significant influence on physical flood vulnerability in the study area. The eight indicators have vulnerability dimensions of exposure, susceptibility and resilience. The results presented in this study can be used to build resilience of flood-prone houses, and also to help policy and decision makers to develop appropriate adaptation strategies and policies required for flood disaster risk reduction in the built environment. The eight indicators are discussed in this section (see Figure 4.21).

### ***Socio-economic Characteristics- Low income***

Low income is one of the most important human factors of vulnerability<sup>56</sup>. Poverty has been identified as one of the critical indicators of vulnerability to physical flooding<sup>55</sup>. These statements are consistent with the findings of this study. The result of the regression analysis of the survey shows that "low income" is the most important socio-economic characteristic affecting exposure to flood risk in the study area. Regarding the link between flood risk and low income, a recent World Bank report estimated that more than 780 million people living on less than USD 5.50 per day are at high risk of flooding<sup>6</sup>. In other words, the data suggests that four out of ten people at risk from flooding globally live on low incomes. As indicated above, the results of the economic

characteristics of the inhabitants of the study area (see Figure 4.7) indicate that many of the families live on a low income.

The result of this current study represents an important contribution to understanding the significant link between physical vulnerability to flooding and low income. In terms of exposure, previous related research shows that low-income people are attracted to floodplains by cheap land and low-cost housing<sup>57</sup>. This statement is supported by the result of household characteristics of the current study area, which showed that most of the residents are tenants living in the area due to the availability of low-cost housing. This suggests that the concentration of poverty in flood-prone areas hint that low-income households accept flood risk to gain access to cheap housing.

Also in terms of susceptibility, most shelters for the poor are not of high quality as the materials put into these shelters are usually the cheapest available<sup>58</sup>. As a result, rental housing is flimsy, of poor quality and vulnerable to extreme flooding<sup>13</sup>. Extreme floods affect high, middle and low income people equally. Nevertheless, flood damage relative to household income is significantly higher in low-income families<sup>58</sup>. The inability to afford quality housing further amplifies the impact of floods and increases households' vulnerability to flood risk. In addition, low-income households tend to be less prepared for floods, have low coping capacity and have limited government support<sup>52</sup>. This is because most city governments do not encourage the development of informal settlements in flood-prone areas, preferring instead that residents evacuate the area.

Nonetheless, population continues to rise in at risk areas; and considering the long-lasting and devastating impacts of floods on livelihoods and wellbeing, policy actions and regulatory support in terms of investing substantial financial resources to strengthen disaster prevention and recovery capacity is most urgently needed in the hotspots where poverty and flood exposure coincide.

#### ***Flood Attributes- Flood Water Depth and Flood Duration***

Physical vulnerability depends on hazards<sup>59</sup>. In other words, the level of exposure and vulnerability to floods is strongly influenced by the characteristics of the floods. Therefore, understanding the type of flooding experienced is helpful in reducing the potential risk to buildings and residents. From the expert survey of this

study, three hazard attributes (flood depth, flood duration and flood speed) were classified as relevant indicators. However, the results of regression analysis on the extent to which hazard characteristics affect physical vulnerability to flooding in the study area showed that "flood depth" and "flood duration had the greatest influence. Physical vulnerability to flooding increases dramatically with increasing flood depth and duration<sup>43</sup>. On the one hand, the extent of flood damage varies with the depth of the flood. Indeed, increasing flood depths generally cause greater and more costly damage to buildings and residents. For example, a flood less than 0.5m deep will inundate sidewalks, streets and most land. However, buildings with ground level elevations at least 0.61 m (2 ft) above building flood level (BFL) should remain dry<sup>40</sup>. Nevertheless, the groundwater level of many houses in the study area is about 0.3 m; meaning that most households in the study area will likely stay indoors if the flood is less than 0.5m deep. Prior studies claim that a significant percentage of households in the city of Lagos stay indoors during floods. However, if the flood depth increases to 1 m, the ground floor of buildings is expected to be flooded, affecting power outlets, appliances and other equipment. At this point, an evacuation may be necessary. Similarly, with a flood depth of 1 to 3 m, low buildings are expected to be flooded by high water. Building occupants must be evacuated or moved to upper floors. This therefore implies that users of buildings, building elements, materials, finishes and service components are highly susceptible to the direct and indirect consequences of flooding.

On the other hand, flood duration is also another critical indicator influencing physical vulnerability. Prolonged flooding tends to increase damage to buildings. The longer the flood lasts, the greater the damage to the building. This is mainly because the structures of many properties are made of solid porous materials, such as brick, block and concrete. Nevertheless, in areas characterized by high flood depth and longer flood duration, an adaptation measure, raising habitable areas above the predicted flood level, could significantly reduce vulnerability<sup>60, 40</sup>.

#### ***Neighbourhood Characteristics- Absence of Surrounding Vegetation and Drainage Systems***

The physical characteristics of a neighborhood can reduce or increase the susceptibility of buildings and their occupants to the impacts of flooding. Indicators rated high and selected by the experts in this study regarding

neighbourhood characteristics are site topography, building distance from the coasts/ river, presence of surrounding vegetation, drainage system, and land use. However, only the absence of surrounding vegetation, and drainage system were ranked high by residents of the study area. Vegetation is influential in reducing the impact of climate change on the development of human society<sup>61</sup>. The study of Chen identified the presence of high ratio natural vegetation as one of the critical indicators that promote community resilience to flood risk in urbanized flood-plains<sup>62</sup>. However, it was deduced that floodplain areas which lacked vegetation are less tolerant of flooding, as there is less land functioning to convey and store floodwater and sediments and thus limits the capacity of the area to cope with flood risks<sup>63, 5</sup>. Also, removal of native vegetation has been linked to rising water tables and increased salinity, which reduces infiltration and inhibits crop growth<sup>64</sup>. It simply implies that land use practices and land cover change appear to play a crucial role in levels of physical exposure and vulnerability to flood risk. Similarly, previous studies have linked the increased physical vulnerability of floodplains to the siting of artificial drainage systems; resulting in a significant increase in runoff velocity and peak flows that exceed the capacity of existing drainage systems<sup>35</sup>. The introduction of impervious surfaces through physical development activities in flood plain areas often lead to changes in the natural course of drainage; and disturbances in the natural hydrological cycle<sup>65</sup>. As such, the volumes generated due to the impervious areas of the ground in these areas can exceed the capacity of storm water drainage system network. Conversely, green infrastructure strategy (GI) and sustainable urban drainage systems (SUDS) approach are capable of reducing the impact of urban development on floodplain ecosystem at the community and building scale<sup>35</sup>. For example, the introduction of pervious paving, trees, bioretention, and rainwater collection allows for on-site infiltration, which lessens the pressure on existing drainage systems<sup>5</sup>. In support, it is argued that innovation in drainage facilities, rainwater and sewage diversion, and management system may be implemented to reduce physical flood vulnerability in at risk areas<sup>62</sup>. Therefore, modern drainage systems may be designed to mimic natural water processes and complement natural vegetation so as to improve infiltration, attenuate flood risks and provide passive treatment for storm water run-off as close as possible to the source, thereby reducing

damages and expenditure on recovery. This implies that natural vegetation and drainage systems, if properly designed through spatial analysis, can help reduce the risk of flooding.

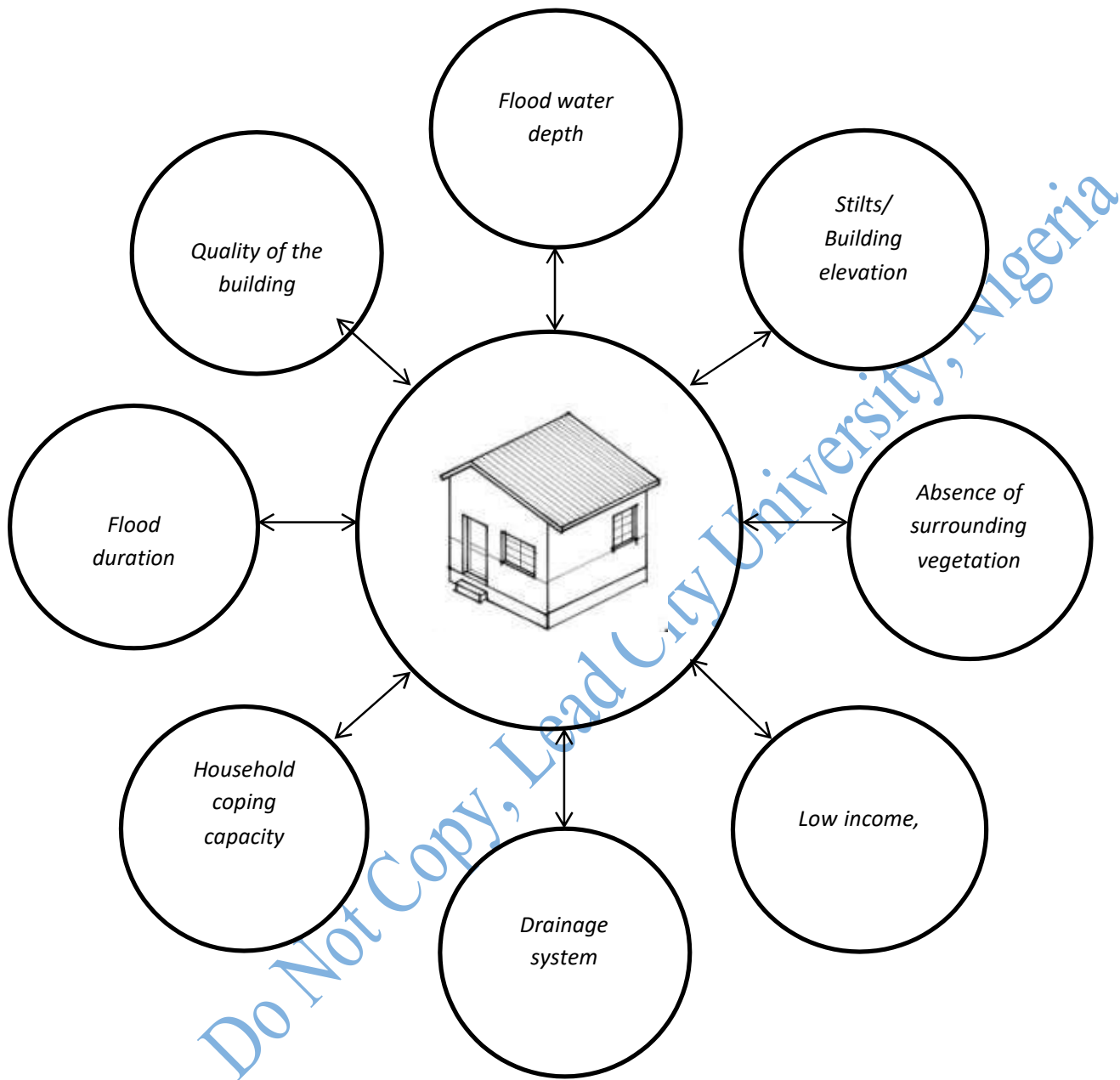


Figure 4.21: Indicators influencing Physical Flood vulnerability in flood-prone areas  
Source: Researcher's Result via SPSS Version 23, (2023)

### *Architectural Features- Stilts/ Building Elevation and Quality of the Building*

The result of the regression analysis in the present study shows that the critical indicators significantly influencing the flood susceptibility of households among architectural features are the use of piles or the height of buildings and the quality of construction. The structure of a building invariably serves as a predictor variable for assessing building quality and as a determinant of occupants' susceptibility and vulnerability to flooding<sup>28</sup>. This implies that the degree of susceptibility of buildings and their occupants to flood risks is closely related to the design and construction of buildings<sup>66</sup>. Fundamentally, the main architectural strategy for dealing with flood risk is the idea of avoiding flood-prone areas<sup>33</sup>. However, when this is not possible, resilient measures can be deliberately integrated into building design and construction to address the risk of flooding.

On the one hand, the results of the regression analysis, supported by the results on building characteristics and flooding attributes in the study area, indicate that low-rise buildings are more susceptible to damage from water infiltration because the ground floor level is lower than the flood level. On the other hand, these results appear to be further supported by ample empirical evidence suggesting that buildings raised on stilts above predicted flood water levels are effective flood adaptation measures useful for reducing household vulnerability to floods<sup>54, 63</sup>. During floods, elevated buildings on stilts are unaffected by fluctuations in the flood water level<sup>67</sup>. For example, in the Mekong Delta in Vietnam, stilt houses are a common form of vernacular architecture that has been used over the years to reduce the force of waves against the pavement during extreme flooding<sup>63</sup>. Therefore, this strategy can be applied to mitigate risks in flood prone areas. Based on recent research, new buildings in flood-prone areas can be designed with higher foundations such that the lowest story is above the base flood height (BFE) specified. Similarly, the lowest story of existing buildings can be raised on solid perimeter foundations, embankments, or an open foundation system so that the completed dwelling is above the expected flood stage. Therefore, raised buildings may have a low vulnerability to flooding compared to non-raised buildings.

In addition, the quality of a flood-prone building affects the extent of flood loss and damage<sup>68</sup>. In other words, the ability of buildings located in flood prone areas to remain functional during floods and to recover with

minimal damage is determined by the resilience of the structure. The resilience of homes depends both on the housing typology (layout organization) and on the quality of the building materials. Low-income settlements often develop organically and rapidly in floodplains, and as a result, lack of guidance or planning often results in settlements being extremely vulnerable to flood disasters. In terms of building materials, the materials used to build houses in low-income settlements are generally substandard and unprepared for recurring flooding. The results of the architectural characteristics of the houses in the present study show that water resistant materials, such as concrete blocks, fiber cement, durable or treated wood, PVC, bricks and clay tiles are rarely used on buildings in the study area. One of the main challenges regarding these building materials is maintaining a certain quality that allows them to withstand both structural loads and flooding.

However, access to quality building materials depends on income levels, and the current socio-economic level of low-income people living in flood-prone areas forces them to build with what they can afford (i.e. poor quality building materials, using less cement to save money or using inefficient compaction methods because they cannot afford to rent or buy equipment). This outcome is supported by past studies, which argued that the problem with increasing flood impacts on Nigeria's built environment is that many existing buildings are ill-suited and lack a defined coping strategy<sup>34</sup>. In other words, the way they were built increases their potential vulnerability to flood risk.

#### ***Adaptive Coping Capacity- Absence of Household Coping Capacity***

Also, different vulnerabilities exist in different systems based on the inherent responsiveness<sup>4</sup>. In this study, adaptive capacity was used to assess the ability of households in the study area to adequately respond to, cope with, and recover from flooding. Generally, adaptive capacity is reflected in the level of preparedness before a disaster, the capacity to adapt during a disaster and the response during and after a disaster. The results of the resident adaptive capacity survey in this study indicate a predominantly low level of pre-disaster coping, household coping capacity and external support in crisis situations. The findings indicate the existence of low-level adaptability in this area. Uncertainty about the type, extent, impact and frequency of future floods requires the development and establishment of a robust living and working environment<sup>5</sup>. For this reason, adequate flood

preparedness ensures that households are able to plan, prepare and respond appropriately to the impact<sup>69</sup>. This implies that disaster preparedness at the household level can help reduce flood damage and death, thereby helping to reduce physical vulnerability. Moreover, the ability to cope with flood-related disasters is generally inversely proportional to vulnerability. Although, coping strategies do not necessarily reduce vulnerability; however, understanding the reasons behind coping behaviors could also help reach those most at risk<sup>52</sup>. As such, the application of a certain set of coping strategies depends on the socio-economic circumstances of the resident.

**Table 4.27: Summary of Physical Vulnerability Indicators and Adaptation Options**

S/N	Vulnerability indicator	Adaptation strategies
<b>Exposure</b>		
1.	<i>Low income</i>	Promote resilient affordable housing schemes in urbanized flood-plain areas
2.	<i>Flood water depth</i>	Elevate buildings above flood level by raising the foundation or building on stilts or piers.
3.	<i>Flood duration</i>	Design for water flow by using permeable surfaces and landscaping, or by designing building with flood vents that allows water to flow through; Use flood-resilient material with minimum susceptibility during the flood ( <i>such as concrete bricks, stone and concrete blocks</i> ).
<b>Susceptibility</b>		
4.	<i>Absence of surrounding vegetation</i>	Plant native vegetation, create flood sinks, Use green roof
5.	<i>Drainage system</i>	Design modern drainage systems to mimic natural water processes and complement natural vegetation using green infrastructure (GI) strategy Provide passive treatment for storm water run-off as close as possible to the source using sustainable urban drainage systems (SUDS) strategy
6.	<i>Stilts/ Building elevation</i>	Higher foundation walls for new builds ( <i>design lowest floor level of new buildings to be above the indicated Base Flood Elevation (BFE)</i> ) Raise the lowest floor level of existing buildings on solid perimeter foundation walls ( <i>such that finished living space is located above the anticipated flood water level</i> )

7. *Quality of the building* Hiring qualified and experienced architects and building development professionals.  
Using high quality materials that can withstand both structural loads and flooding  
Creating a flood-resistant interior by using waterproof flooring and wall coverings

**Adaptive capacity**

8. *Household coping capacity* Installing flood barriers around the building, such as sandbags or metal panels  
Install flood warning systems, such as sensors or alarms.

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**Source: Researcher's Findings (2023)**

**Testing Hypotheses**

H<sub>0</sub>: There is no significant linear relationship (correlation) between factors (demographics and socio-economic characteristics; flood attributes experienced; Neighbourhood characteristics and architectural design features of buildings; and adaptive capacity exhibited by households in the area) and physical flood vulnerability of households.

**Null Hypothesis, (H<sub>0</sub>):** There is no significant linear relationship (correlation) between factors (demographics and socio-economic characteristics; flood attributes experienced; Neighbourhood characteristics and architectural design features of buildings; and adaptive capacity exhibited by households in the area) and physical flood vulnerability of households.

**Alternate Hypothesis, (H<sub>a</sub>):** There is significant linear relationship (correlation) between factors (demographics and socio-economic characteristics; flood attributes experienced; Neighbourhood characteristics and architectural design features of buildings; and adaptive capacity exhibited by households in the area) and physical flood vulnerability of households.

The hypothesis was tested using the linear regression analysis. From the Analysis of variance (ANOVA) table (see Appendix 10), results shows a high significance F value = 428.257, p < 0.000. Also, the Model Summary

(Appendix 11) shows that the model having  $R^2 = 0.975$  explained around 98% of variance in the influence of the selected indicators on Physical Flood vulnerability in the study area. The result suggests that there is a statistical significant linear relationship between a flood-prone areas' characteristics (demographics and socio-economic characteristics, flood attributes experienced, Neighbourhood characteristics and architectural design features of buildings, and adaptive capacity exhibited by households in the area), and their physical flood vulnerability; hence the null hypothesis ( $H_0$ ) is rejected, while the alternate hypothesis ( $H_a$ ) is accepted.

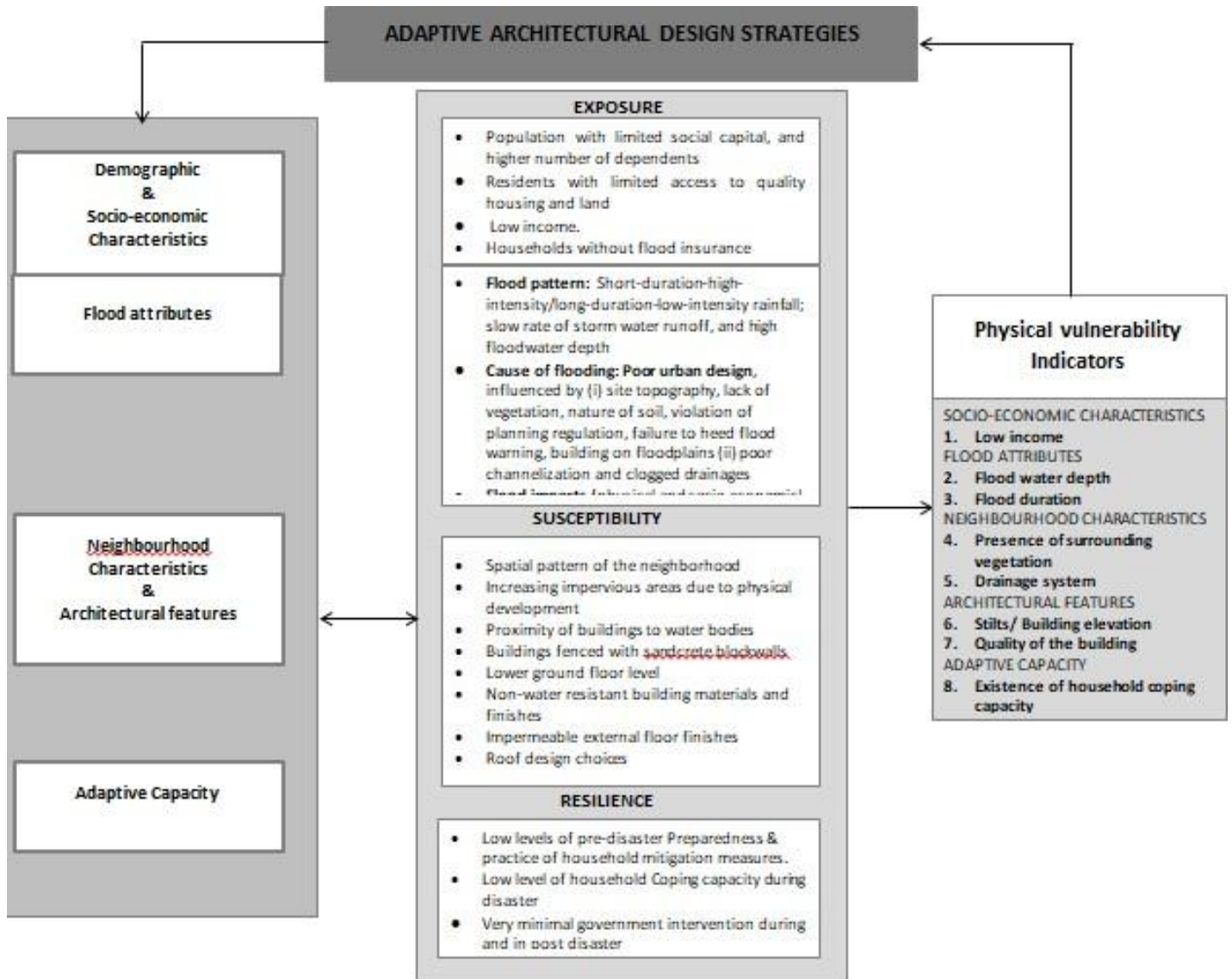
#### **4.4 Validation of the Conceptual Framework of the Study**

The conceptual framework, presented in Chapter Three of this thesis show the five key components of the research that were investigated, and how they relate with one another (see Figure 2.5). These five components formed the background for data collection and analyses. Recall that the conceptual framework of this study was developed prior to the survey. After the survey and data analysis it was important to validate the framework in light of findings of the research. Using the result of this research, a validated conceptual framework for developing adaptive architectural design strategies for flood disaster risk reduction in flood-prone residential areas is presented as shown in Figure 4.22.

Result of the data analysis showed the demographic characteristics of residents, as comprising individuals from different ethnic groups, of significant number of unemployed resident, of working-age population, and majority earning low-income monthly wages. Similarly, the socio-economic characteristics comprised of residents with relatively limited social capital, of long-staying tenants who have remained in the area due to availability of cheap land and housing, of households with dependents who have had past flood experiences.

The key issue investigated in the study was to assess physical vulnerability indicators for developing adaptive architectural design strategies for reducing flood disaster risks to houses in flood-prone areas. Attempt has been made to achieve this goal by considering the socio-economic, physical characteristics and resilience abilities of households in the flood-prone areas of Kosofe, Lagos, Nigeria, which influence physical vulnerability to flood risk. It is believed that the most relevant adaptive strategies for flood disaster risk reduction are embedded

within these physical vulnerability pathways. The study confirmed that the vulnerability of flood-prone residential buildings to flood risk is a function of exposure, susceptibility and resilience, as reflected in the socio-ecological characteristics of the neighborhood.



**Figure 4.22: Validation of Conceptual framework**  
Source: Researcher, (2023)

## Exposure

In terms of exposure, the analysis of the survey data identified the socio-economic characteristics and attributes of the flood experienced in the study area as follows:

### ***Demographic and Socio-economic Characteristics***

The study area comprises of populations with limited social capital, and higher number dependents; residents with limited access to quality housing and land; and households without flood insurance, majority of whom are low income earners.

### ***Flood Attributes***

The pattern of flooding experienced within the areas are pluvial and fluvial floods; typically, occurring within 1-3 hours after the start of an intense rainfall. It is compounded by the slow rate of storm water runoff. High floodwater depth above building flood level; and majorly water penetration damages.

The flooding is mainly caused by poor urban design and rainfall. The dimensions of factors influencing flood occurrences within the areas are (i) site topography, lack of vegetation, nature of soil, violation of planning regulation, failure to heed flood warning, building on floodplains (ii) poor channelization and clogged drainages

The most significant impact of flooding within the areas is linked to physical and socio-economic impact (majorly: disruption of businesses, displacement of people, traffic disruption, and erosion/ destruction of harvest).

These characteristics explain exposure of the study area to flood risk. Flood exposure, as earlier discussed in Chapter Two of this thesis, refers to the predisposition of a system to be disrupted by a flood event due to its location in the same area of influence. It is analyzed by delineating flood characteristics and aggregating the intersection population and/or built environment assets. Thus, the study proposed that these characteristics of exposure would be given consideration in developing a framework of indicators influencing physical flood vulnerability, and consequently adapts these vulnerability pathways for flood risk reduction. Furthermore, it was observed that one of the most important characteristics that influence susceptibility to flood risk are linked to the spatial pattern of the neighbourhood and the architecture of buildings in the study area.

### **Susceptibility**

In terms of susceptibility, analysis of the survey data identified the neighbourhood characteristics and the architectural features of buildings in the study area.

### ***Neighbourhood Characteristics***

Two dimensions of the neighbourhood characteristics were identified to influence susceptibility to flood risk: Spatial pattern (*Very limited natural recreational areas, inadequate and poorly maintained stormwater drainage systems, inadequate waste management facilities, lack of potable water supply, bad roads and streets networks, lack of floodwall/ barrier along the river channel, lack of flood retention ponds/ gardens, and flood warning systems*); and Increasing impervious areas due to physical development (*Infrastructure/ facilities such as health care facilities, educational facilities, social and religious activities, shopping facilities, and pedestrian walkways*).

### ***Architectural Features***

In terms of the architectural features, majority of the households surveyed live in close proximity to water bodies. The selected housing schemes can be characterized as mainly semi-detached houses without flood wall; buildings fenced with sandcrete blocks; buildings are in fair and poor condition; lower ground floor level (300mm) relative to floodwater depth (600mm). In terms of the choice of building materials, many of the buildings use sandcrete blocks; external steel door, interior wooden door, aluminium window and wooden kitchen cabinets. Furthermore, majority of the buildings are finished with ceramic floor tiles, walls finished with cement screed and painted. Also, the most common roof design is the traditional hip roof styles. The most common exterior floor finishes used are cement and sand screed, and concrete. Also, in terms of the positioning of electrical sockets, many of the buildings use low-level electrical sockets, and high level meters.

Based on the above characteristics, the susceptibility factor of vulnerability to flood risk is explained by likelihood of flood disaster based on neighborhood characteristics and architectural features of buildings in the study area. By definition, susceptibility implies the elements exposed within flood-prone area, which influence the probabilities of being harmed at times of hazardous floods. This study, therefore propose that first, specific strategies for disaster risk reduction in flood prone neighbourhoods are embedded within the dimensions of the (i) spatial pattern and (ii) physical development pattern. Thus, consideration should be given to design strategies that provide for water absorption and storage; neighbourhood interaction and connectivity; recreational access;

and requirements for emergency response. Secondly, the study proposes that building-based adaptation should be pursued through building elevation; dry-flood proofing; wet-flood proofing; and implementation of Sustainable Urban Drainage Systems.

### **Adaptive Capacity**

In terms of the adaptive capacity exhibited by residents and households in the study area, the analysis of the survey data identified pre-disaster preparedness, household coping capacity during disaster, and intervention during and in post disaster.

#### ***Pre-Disaster Preparedness***

Majority of the households appears to have a high level of flood risks awareness. Also, the main source of information on awareness is from previous flood experiences. In terms of the level of flood risk preparedness, majority of the households have low levels of preparedness. Similarly, many of the households rarely practice flood mitigation measures.

#### ***Household Coping Capacity during Flood Disaster***

Available household coping strategies are minimal usage of rainwater harvesting system, existing drainage systems, and periodic maintenance of drainages.

#### ***Intervention During and in Post-disaster***

The most common interventions received in during and in post flood disaster are prayer, borrowing/contribution in thrifts, and support from friends and families. Very minimal government support.

Adaptive capacity is the ability of a system to adjust to actual or expected climate impacts. The above described capacities exhibited by residents and households in the study area explain their resilience and adaptive capacity to flood risk. Hence, this study proposes that first; measures to enable buildings cope better during flood disaster should be planned and enforced in new and existing flood-prone buildings. Secondly, there is need to improve the understanding of households on the effectiveness of building adaptation measures in flood disaster mitigation.

## Physical Vulnerability Indicators

As discussed in literature, physical flood vulnerability is the extent to which buildings and other physical assets are susceptible to floods due to exposure, a perturbation, in conjunction with its ability (or inability) to cope, recover, or basically to adapt. Eight indicators were identified to have the most significant influence on physical vulnerability to flood risk in the study area. These indicators were derived from the existing vulnerability factors of exposure, susceptibility and adaptive capacity exhibited by residents and households in the study area as follows:

### Exposure

#### *Socio-economic Characteristics*

**Low Income:** poverty, monthly household income is below N99, 000; and high unemployment.

#### *Flood attributes experienced*

**Flood Water Depth:** 300-600mm inundation depth (whereas, building ground floor level is about 300mm above the natural ground level)

**Flood Duration:** Short-duration-high-intensity and long-duration-low-intensity rainfall

### Susceptibility

#### *Neighbourhood Characteristics*

**Absence of Surrounding Vegetation:** land use practices and land cover modification (physical development in flood plains; removal of native vegetation; less land functioning to convey and store floodwater and sediments)

**Drainage Systems:** implantation of artificial drainage systems; introduction of impervious surfaces through physical development activities.

#### *Architectural features*

**Stilts/ Building elevation:** non-elevated buildings on low foundation

**Quality of the building:** mal-adapted building structure; and use of non-water resilient building materials

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## Chapter Five

### Conclusion

#### 5.1 Summary of Findings

The thesis presented the assessment of physical vulnerability indicators for developing adaptive architectural design strategies in the flood-prone areas of Kosofe Local government area of Lagos state. The study sought to understand the factors of vulnerability (*based on the demographics and socio-economic characteristics of the residents; flood attributes experienced; Neighbourhood characteristics and architectural design features of buildings; and adaptive capacity*) which influence physical flood vulnerability, so as to identify options for adapting to the impact of flood disaster. The degree of exposure to flood risk was found to be a function of the socio-economic characteristics and hazard attributes experienced. Susceptibility to flood-risk was found to be a function of the neighborhood characteristics and architectural features of buildings. The adaptive capacity to respond appropriately to flood risk was found to be a function of the pre-disaster level of adaptation, household coping capacity exhibited during flood disaster, and external intervention during and in post flood disaster. From the analysis of data gathered for this research, the key findings of the research can be summarized as follows:

The demographic characteristics of residents of the flood-prone areas of Kosofe local government area of Lagos state show diversity in the gender, ethnic representation, age structure, employment status, marital status, religion, and education. 30.2% of the residents were unemployed and 38% had no tertiary education. 14.5% of residents own businesses within the study area. Communities in the study area, have a good mix of ethnic groups, low perception of ethnic segregation, high levels of religious and socio-cultural activities and a good bonding network model. However, there is a lack of government presence and external support within the area. Thus, the flood-prone areas are socially vulnerable due to the lack of adequate social structures, institutions and organizations to foster trust and cooperation among residents.

The socio-economic characteristics of residents reflected those of a predominantly low income residential neighbourhood. 30.2% of the respondents were unemployed, but 55.5% of them are either self-employed, employees of private organization or government employees. The highest proportion of the employed respondents own businesses within the study area. The income of residents with businesses in the area will be negatively impacted with increasing flood risk. Majority of the households earned below a NGN99, 000, while 27.7% earned between NGN 100,000 and NGN 299,000. Six out of ten residents at risk from flooding in the study area live on low incomes.

Also, majority of people living in the study area live in semi-detached houses. 60.8% of the residents live in rented accommodation. The majority of the inhabitants are between the ages of 35 and 43. Most households have between 3 and 4 occupants. The result attributed the concentration of low-income households within the area to the availability of cheap land and low-cost housing. Therefore, finance was a major consideration in the choice of residence for most people living in the area.

Flooding starts 1-3 hours after heavy rains and becomes more intense within 4-9 hours. There is a slow rate of stormwater runoff in the study area due to the state of the drainage systems and increasing impervious areas from land use changes and land cover modification. The study area lacks adequate facilities for waste disposal, storm water runoff and natural green areas. The majority of floods are more than 300 mm deep and the most obvious pattern of flood damage suffered by households is water penetration damages.

There are seven factors that influence the occurrence of floods in the flood-prone areas (*site topography, lack of vegetation, nature of soil, violation of planning regulation, failure to heed flood warning, and building on floodplains*). These factors are related to the physical and socio-economic characteristics of the neighborhood. The study area lacks flood-adaptive features in its urban planning. The main impacts of flooding in the study area are disruption of businesses, displacement of people, disruption of traffic and erosion/destruction of crops. Also, flooding has an indirect and intangible impact on the lives of residents. These impact increases the vulnerability of the communities to natural hazards.

Residents of the study area considered the spatial pattern of the neighbourhood very influential in assessing its characteristics. The neighbourhood characteristics reflect a limited availability of natural recreational areas, inadequate and poorly maintained stormwater drainage systems, inadequate waste management facilities, lack of potable water supply, bad roads and streets networks, lack of floodwall/ barrier along the river channel, lack of flood retention ponds/ gardens, and flood warning systems. It was also deduced that continuous physical development within the neighbourhood have led to an increase in impervious areas.

The 324 buildings that are vulnerable to flooding were examined in the flood-prone areas of Kosofe, Lagos. Most of the houses are semi-detached houses with neither flood walls nor raised foundations. Many of the buildings are ill-prepared to cope with a 100 year flood, due to its proximity to the river channel, quality, elevation and low foundation below the estimated flood level. The architectural characteristics of the housing schemes in the study area indicate that there are scant resilient measures taken to mitigate flood risk to houses. The majority of houses are built with sand concrete blocks. Most houses in the study area are 300mm above natural ground level.

The majority of survey respondents are aware of the risks of floods, but only 0.9% of them are well prepared for future flood risks. Many people in the study area have never practiced any form of preparedness, while 33.6% practice preparedness measures. Survey shows that many households in the study area have a fairly low adaptive capacity. The most common coping strategies of households in the study area are rainwater harvesting systems, the use of drainage and regular maintenance of drainage systems. The motivation for RWHS may be the lack of potable water in the area. Prayer is the most common intervention respondents receive during and after severe flooding. This is followed by loans/contribution for savings purposes (24.1%) and support from friends and family (21.3%). Government support appears to be insignificant. None of those interviewed said they received any form of flood insurance cover.

The outcome of the regression analysis highlighted that critical indicators influencing physical flood vulnerability in the flood-prone areas were *flood water depth, stilts/ building elevation, presence of surrounding*

*vegetation, low income, drainage system, existence of household coping capacity, flood duration, and quality of the building.* Thus, the study found out that the most robust adaptation options for flood disaster risk reduction is embedded within the identified physical vulnerability indicators.

## **5.2 Conclusion**

This study attempted to contribute to existing knowledge on flood disaster management by assessing critical physical flood vulnerability indicators in urbanized floodplain areas of Kosofe, in Lagos, Nigeria, which can be adapted to reduce flood risk to houses. To achieve this goal, the objectives were developed to assess the demographic and socio-economic characteristics of residents, as well as the hazard attributes; the neighbourhood characteristics and architectural design features of the housing scheme; and the adaptive capacity exhibited by households in the study area in pre-disaster, during and at post-flood disaster. Furthermore, the study examined the extent to which the above listed characteristics influence physical vulnerability to flood disaster risk.

The assessment of physical vulnerability indicators for developing adaptive architectural design strategies in the flood prone areas of Kosofe in Lagos, Nigeria has revealed that demographic and socio-economic characteristics can have a significant impact on exposure to flood risk. Areas with higher levels of poverty are often at greater risk of flooding due to inadequate infrastructure, lack of preparedness measures, and limited resources to recover from damages. Additionally, communities that are located in informal settlements or areas prone to flooding are more likely to experience flood-related hazards, and face additional barriers to accessing services and external support. Furthermore, age, income, and education levels can impact an individual's ability to prepare for and respond to floods. A predominantly working age population may not be economically vulnerable as more people can work to recoup economic losses during a flood, however lower-income households lack the financial resources to purchase insurance or evacuate to safer areas. Finally, individuals with lower levels of education may be less likely to understand the risks associated with floods or how to prepare for them. Similarly, it is obvious from the study that flood hazard attributes have a significant impact on exposure to flood risk. For instance, higher floodwater depth causes water penetration damages to houses, and

can make it difficult to evacuate or rescue individuals. Furthermore, the duration of the flood event can impact exposure levels, as longer flood events increase the likelihood of damage to homes and properties. Residents of the study area have experienced floods in the past, and are more likely to experience flood-related hazards in the future. This means that homes and properties in the flood-prone areas of Kosofe are at greater risk of damage or destruction in the event of a flood.

This study showed that Neighborhood characteristics of flood-prone settlements that influence vulnerability to flood hazards are embedded within its spatial pattern. Urbanized floodplain neighbourhoods that lack natural recreation areas, adequate drainage facilities, waste disposal systems, water supply, good road networks, flood wall/barrier, flood ponds/gardens and flood warning systems, are prone to rapid accumulation of water during a flood event, escalating the flood risk. Therefore, design solution at the neighborhood scale should focus on integrating flood risk adaptation into the spatial planning by creating adaptive multi-functional and flexible neighbourhood spaces that provides for water absorption and storage; neighbourhood interaction and connectivity; recreational access; and requirements for emergency response. Similarly, the Architectural features of the existing flood-prone houses, particularly its proximity to river channel, ground floor height, elevation, and quality in terms of the construction materials, impact susceptibility to flood risk. Low-elevated buildings experience higher risk. Also, buildings constructed using materials that are not water resistant are highly susceptible to flood-related damages. Inversely, houses with sufficient elevation above the flood level and flood-resistant features such as the installation of flood doors, sealants, and walls, would have greater resilience against future floods. Also, residential buildings with enhanced architectural features that utilize smart designs, green features, and eco-friendly materials to reduce runoff and floodwater accumulation, are highly resilient to future flood hazards. Overall, neighborhood characteristics and architectural features play a vital role in determining susceptibility to flood risk. Addressing the vulnerabilities inherent in these features through the implementation of adaptation measures such as flood-resistant architectural design, improvement to neighborhood infrastructure, and increase in community awareness and preparedness, can significantly reduce the damage caused by future flood events.

It is obvious from the outcome of this study that household adaptive capacity is an essential factor in developing effective flood adaptation strategies in flood-prone areas. Therefore, by improving the social capital of residents through inclusive designs, and integrating measures to enable new and existing buildings cope better during flood disaster, as well as encouraging investment in building adaptation measures; households are better positioned to deal with flood risks and are more likely to build resilience in the long run. The implications of household adaptive capacity on flood resilience are better at pre-disaster preparation for flood events, improved coping and financial resilience to flood risks, opportunity to learn from previous flood events, and taking steps to build resilience over time. Households with high adaptive capacity promote and reinforce their resilience, and these, in turn, contribute to the overall resilience of their neighborhood and communities.

### **5.3 Recommendations**

This research was carried out with the view to identifying the most robust adaptive architectural design strategies for disaster risk reduction in flood-prone residential neighbourhoods. Providing affordable flood resilient buildings in low income informal settlements will require a combination of approaches. Based on the findings the following recommendations are made:

1. Firstly, in order to achieve the goal of flood disaster risk reduction in flood-prone residential neighborhoods, the physical vulnerability indicators identified in this study should be given consideration in developing an adaptive architectural design framework to guide Architects and urban designers.
2. Involving and engaging the community in the design and implementation of flood-resilient buildings can help ensure that the solutions are tailored to their needs and local conditions. This can also help to build an understanding of the importance of flood resilience and the need for long-term solutions.
3. Building with locally available materials and techniques can help to reduce costs and increase the resilience of the buildings.

4. Implement integrated land use planning that takes into account flood risk zones and restricts or discourages development in high-risk areas.
5. Establish an effective early warning system that can provide timely and accurate information about potential flood events.
6. Develop and enforce building codes and standards that incorporate flood-resistant design principles. This includes requirements for flood-resistant foundations, elevated electrical systems, and flood-proofing measures for buildings located in flood-prone areas.
7. Implement nature-based solutions for flood management, such as restoring and preserving natural floodplains, creating retention ponds, and promoting sustainable drainage systems.
8. Implement nature-based solutions for flood management, such as restoring and preserving natural floodplains, creating retention ponds, and promoting sustainable drainage systems.
9. Government policies and incentives can encourage the adoption of flood-resilient building practices, such as building regulations that require flood-resistant materials and design features. Incentives such as tax breaks or subsidies can also make flood-resilient construction more affordable for low-income communities.

#### **5.4 Contribution to Knowledge**

The proposed study makes contributions to existing body of scientific knowledge in the areas of sustainable housing and disaster risk reduction in the built environment of flood-prone neighbourhood by:

- i. Developing a conceptual framework for assessing physical vulnerability indicators for achieving adaptive architectural design strategies in flood-prone residential neighbourhood in developing countries;
- ii. Identifying the specific socio-economic characteristics, hazard attributes, neighborhood characteristics, architectural design features and adaptive capacity that impact exposure, susceptibility and resilience to flood risk in flood-prone neighborhoods;

- iii. Improving understanding of the extent to which the factors of exposure, susceptibility and adaptive capacity exhibited by households in the study influence physical flood vulnerability;
- iv. Revealing the socio-economic characteristics, hazard attributes, neighborhood characteristics, architectural design features and adaptive capacity, that can inform adaptive architectural design measures for flood-disaster risk reduction;

### **5.5 Suggested Areas for further Research**

There are several areas for further research in architectural design strategies for flood disaster risk reduction in flood-prone residential neighborhoods. Some of these areas include:

1. Integration of green infrastructure in architectural design strategies for flood-prone residential neighborhoods.
2. Assessment of community needs and preferences for flood disaster risk reduction strategies in flood-prone residential neighborhoods.
3. Use of technology in architectural design strategies for flood disaster risk reduction.
4. Participatory design methods and community-based planning approaches in the development and implementation of architectural design strategies for flood disaster risk reduction.

These are just a few of the areas for further research in architectural design strategies for flood disaster risk reduction in flood-prone residential neighborhoods. It is important to continue to explore these and other areas to develop effective and sustainable design strategies that can help reduce the impact of flooding on communities.

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## Appendix 1

### Focus Group Discussion Guide with Home-Owners in the Study Area

#### Demographic and Socio-Economic Characteristics

1. What are your views about the people living in your area within the period you have lived here? (Age groups, tribe, Income level / financial status, level of education, increasing number, etc).
2. What are your experiences living within the area? (Housing condition, Family ties, friendliness, trust, assistance, safety, crime, noise, vehicular and human traffic etc).
3. What are your views about the living condition of residents in this area, compared to other residential areas in Lagos? (Source of income, employment pattern, Housing condition, etc).

#### Flood Risks, Occurrence and Exposure

1. How would you describe the rainfall pattern within the area?
2. What are your views about the flooding situation in your area? (frequency, pattern, impacts, etc)
3. What are your views about continued housing developments in the areas? (Land acquisition, land-use planning, land-cover modification, building development control etc)
4. What are your views about the effectiveness of current flood risk management efforts in preventing flood damages within the built environment (flood prevention and mitigation strategies, drainages and storm water channelization etc)

#### Environmental Characteristics and Architectural Design Features of Buildings in the Study Areas

1. How would you rate the condition of services and infrastructures provided in the area over the period of your residence? (Drainages, waste, sewage, water, power, playgrounds/recreation).
2. How would you describe the condition of drainage facilities in the area compared to the flooding situation experienced?
3. How would you describe the condition of the house you are living in, compared to the flooding situation experienced?

#### Coping and Adaptation Capacity at the Household Level

1. How have you been living with the flooding situation within the area?
2. How would you describe the effectiveness of your coping strategies in mitigating flood risk?
3. What changes would you consider making to improve the condition of your house's against flooding?

## Appendix II

### Focus Group Discussion Guide with Members of the Nigerian Institute of Architects (NIA)

Provisions in the Existing Building Codes, Regulations and Bye-Laws on Building Adaptation and Resilience to Flood Risk;

1. What are your views about the availability of the national building code, regulations and bye-laws in addressing issues related to flood risk reduction in the built environment across Nigeria?
2. How would you describe current provisions in the national building code, regulations and bye-laws on building development in flood-prone areas?
3. How would you describe current provisions in the national building code, regulations and bye-laws on building adaptation and resilience considering the possibility of more floods linked with climate change projections?
4. What are your views about possible review of the existing building policies in Nigeria to address modern building challenges; as it relates to flood risk reduction?

The Factors that Determine Effective Architectural Design Strategies for Enhancing Building Adaptability for Disaster Risk Reduction in the Flood Prone Areas of Kosofe

1. What are your views about the factors that will influence effective architectural design strategies for enhancing building adaptability for flood risk reduction in the study area? (Socio-economic characteristics of the occupants, Geographical location and neighborhood characteristics, Spatial planning and land-use activities, Building design and materials, Resilient measures and coping capacities, Building policy response on flood adaptation and resilience )

## Appendix III

**PhD Architecture Research Project  
Department of Architecture  
Lead City University Ibadan, Oyo- State Nigeria**

### **Questionnaire for Residents of the Flood-Prone Areas of Owode-Ajgunle, Agboyi and Oworonshoki Areas of Kosofe Local Government Area, Lagos-State**

Dear Resident,

This questionnaire is designed to obtain responses on issues relating to building adaptation strategies for reduced property damages and resilience to flood risk in the flood-prone areas of Kosofe. Particularly it is meant to examine the socio-demographic characteristics, neighbourhood and architectural design characteristics of houses in the area, attributes of flooding experienced as well as their adaptive capacity. It is solely for the purpose of gathering data for an on-going research. All information provided will be used confidentially and used purely for academic purposes. Thanks for providing true and accurate responses as much as possible.

#### **Researcher:**

Saudat Ajijola  
08106608653

#### **Section A: Demographic and Socio-Economic Characteristics of Residents of the Flood Prone Areas of Kosofe Local Government Area of Lagos State, Nigeria**

1. **Gender of Resident Respondents:** Male ( ) Female ( )
2. **Nationality:** Nigerian ( ) Foreigner ( )
3. **Duration of residency:** 1 - 5years ( ) 6 - 10years ( ) 11 - 15years ( ) 16years + ( )
4. **Ethnicity:** Yoruba ( ) Hausa/ Fulani ( ) Ibo ( ) Ijaw ( ) Others ( )
5. **Age bracket:** 18-30years ( ) 31-43years ( ) 44-55years ( ) 56-65years ( ) 66years+ ( )
6. **Marital status:** Single ( ) Married ( ) Divorced ( ) Widow/Widower ( )
7. **Religious inclination:** Christian ( ) Islam ( ) Other ( )
8. **Highest Level of Education:** No Formal Education ( ) Primary Seduction ( )  
Secondary education ( ) Tertiary education ( )
9. **Employment status:** Unemployed ( ) Self-employed within the area ( ) Self-employed  
outside the area ( ) Employee of private sector organization ( ) Government employee ( )  
Retiree ( )
10. **Number of people in the household:** 1 – 2 persons ( ) 3 – 4persons ( ) 5 – Above ( )
11. **Physically challenged person:** None ( ) 1 – 2 ( ) 3 – 4 ( ) 5 – Above ( )
12. **Number of cars in the household:** None ( ) 1 – 2 ( ) 3 – 4 ( ) 5 – Above ( )
13. **Occupancy Status of the Respondents:** Official residence ( ) Tenant ( ) Owner occupied ( )
14. **Reasons for living in the area:** Job transfer ( ) Personal residence ( ) Official  
residence ( ) To live with spouse ( ) Cheap accommodation ( )
15. **Source of family income:** Single ( ) Multiple ( ) None ( )
16. **Range of Family Income:** N18,000-49,000 ( ) N50,000-99,000 ( ) N100,000-299,000 ( ) N300,000-  
499,000 ( ) N500-Above ( ) No response ( )
17. **Financial services/ security:** Stable income ( ) Thrift ( ) Availability of loans ( ) Availability  
of government incentives ( ) Availability of insurance cover ( )

How would you evaluate the availability of the following social capital in your area? Please tick (✓) the column that best gives your answer to the question

	<b>Familial and social ties</b>	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
18.	Close friends and relatives live in my area					
19.	Close relationships with my neighbours					
20.	Mutual trust amongst the residents					
21.	Presence of ethnic segregation amongst neighbours					
22.	Presence of adequate religious activities					
23.	Presence of social activities					
24.	Presence of cultural activities					
25.	Presence of government and external support in crisis situation					

### Section B: Neighborhood Characteristics and Architectural Design Features of the Selected Housing Stock in Flood Prone Areas of Kosofe Local Government Area of Lagos State, Nigeria

How would you evaluate the availability of the following neighbourhood features in your area? Please tick (✓) the column that best gives your answer to the question

	<b>Neighbourhood characteristics</b>	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
26.	Natural recreational areas					
27.	Adequate health care facility					
28.	Adequate educational facilities					
29.	Adequate stormwater drainage facility					
30.	Adequate domestic waste disposal facilities					
31.	Adequate water					
32.	Adequate power supply					
33.	Good roads and streets networks					
34.	Space for social and religious activities					
35.	Shopping facilities					
36.	Pedestrian walkways					
37.	Floodwall/ barrier along the river channel					
38.	Flood retention ponds/ gardens					
39.	Flood warning systems					

40. **Proximity of building to a water body:** less than 30m ( ) 30-50m ( ) 50-70m ( )
41. **House type:** Single Bungalow ( ) Semi-detached Bungalow ( ) block of flats ( )  
Terrace row housing ( ) Massionate / Duplex ( )
42. **Number of bedrooms in the house:** 1room ( ) 2rooms ( ) 3rooms ( ) 4rooms ( )  
5rooms+ ( )
43. **Building Condition:** Very poor ( ) Poor ( ) Fair ( ) Very good ( ) Excellent ( )
44. **Ground floor height:** 150mm ( ) 300 ( ) 450 mm ( ) above 600mm ( )
45. **Walling materials:** Bricks ( ) Stone ( ) Sandcrete Blocks ( ) Stabilized Laterite ( )  
) Concrete ( )
46. **Roofing design:** Concrete with roof garden ( ) Concrete without roof garden ( )  
Mono pitch ( ) Double pitch ( ) Hip roof ( )
47. **External door material:** Solid hardwood ( ) Steel ( )
48. **Internal doors material:** Solid hardwood ( ) PVC ( )
49. **Window material:** Wood ( ) vinyl ( ) Aluminum ( ) Fiberglass ( ) composite ( )
50. **Interior floor finishes:** Tiles ( ) Cement and sand screed ( ) Terrazzo finish ( ) Marble ( )  
Carpet and rugs ( ) Wood ( )
51. **Exterior floor finish:** paved stone ( ) concrete flooring ( )  
Cement and sand screed ( ) sand ( )
52. **Wall finishes:** Ceramic Tiles ( ) Cement plaster ( ) Paint ( )
53. **Kitchen cabinet:** Wood ( ) Steel ( ) PVC ( )

54. **Position of electric sockets:** Low Level ( ) High Level ( )  
 55. **Position of Phone socket:** Low Level ( ) High Level ( )  
 56. **Position of meters:** Low Level ( ) High Level ( )

**Section C: Attributes of the Flooding Experienced in the Study Area**

1. **Causes of flooding experienced:** Intense Rainfall ( ) River overflow ( ) Poor Urban Design ( ) Urbanization ( ) Others ( )

How would you rate the following in agreement to factors influencing flood risk in the study area? Please tick (✓) the column that best gives your answer to the question.

	<b>Factors</b>	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
2.	Site Topography					
3.	Absence of Vegetation					
4.	Nature of soil					
5.	Poor channelization					
6.	Clogged drainages					
7.	Violation of planning regulation					
8.	Failure to heed flood risk warning					
9.	Building on flood plains					
10.	Time flooding occurs after intense rainfall starts					
11.	Flood pattern experienced					
12.	Building flood damage pattern experienced					
13.	Depth of flood					

14. **Time flooding occurs after high-intensity rainfall starts:** 0-3 hrs. ( ) 4- 9 hrs. ( ) 10 hrs. & above ( )  
 15. **Flood pattern experienced:** Street flooding ( ) compound flooding ( ) Neighbourhood flooding ( )  
 16. **Building flood damage pattern experienced:** Water penetration damage ( ) Pollution and contamination ( ) Structural damage ( )  
 17. **Depth of flood:** less than 300mm ( ) 300-600 mm ( ) 600+ ( )

Based on your previous flood experiences, rate the following flood impacts associated with the area

	<b>Flood impacts</b>	Never	Rarely	Sometimes	Very Often	Always
18.	Loss of lives					
19.	Displacement of people					
20.	Disruption of power supply					
21.	Disruption of communication					
22.	Interruption of businesses within the area					
23.	Traffic disruption					
24.	Destruction of infrastructure					
25.	Building collapse					
26.	Damages to building and contents					
27.	Damage to livestock					
28.	Erosion/ destruction of harvest					
29.	Blocked kitchen sink					
30.	Difficulty flushing					
31.	Blocked bathroom floor drain					
32.	Septic tank overflow					

**Section D: Adaptive Capacity and Physical Flood Vulnerability in the Study Area**

1. **What is your source of information on flood risk awareness:** Previous flood experience ( ) official information ( ) Environmental signals ( )  
 2. **Levels of flood preparedness:** Not prepared at all ( ) Not very prepared ( ) Slightly prepared ( ) Very well-prepared ( )

3. **Practice of preparatory measures:** Never ( ) Sometimes ( ) Always ( )
4. **I am aware of risks attributed to flooding:** Strongly disagree ( ) Disagree ( ) Not sure ( ) Agree ( )  
Strongly agree ( )
5. **What form of intervention have you received after severe flooding in your area:**  
Government support ( ) Insurance cover ( ) Support from family/friends ( )  
Prayers ( ) Borrowing ( )

*How would you rate the following in agreement to coping strategies used in managing flood risks during severe flooding events in the study area? Please tick (✓) the column that best gives your answer to the question.*

	<b>Your Coping strategies</b>	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
6.	Use of drainage systems					
7.	Periodic maintenance of drainages					
8.	Exterior paving with permeable materials					
9.	Rain garden to reduce run-off					
10.	Trees planting to reduce run-off					
11.	Rainwater harvesting system to reduce run-off					
12.	Roof garden to reduce run off					
13.	Raised building ground floor					
14.	Location of living accommodation on first floor					
15.	Raised electrical services above flood line					
16.	Use of flood barriers across external doorway					
17.	Anti-flooding devices are fixed to sewage systems					
18.	Use of non-return valve in bathrooms					
19.	Standby pump					
20.	Use of flood alarm system					

*How would you rate the influence of following indicators on the physical flood vulnerability in the study area? Please tick (✓) the column that best gives your answer to the question.*

**Influence of selected indicators on the physical flood vulnerability in the study area.**

	<b>Indicators</b>	Insignificant Influence	Little Influence	Not sure	Significant Influence	Very Significant Influence
21.	Flood water depth					
22.	Flood duration					
23.	Flood water Velocity					
24.	Construction type and material					
25.	Quality of the building					
26.	Stilts/Elevated buildings					
27.	Site topography					
28.	Building distance from river					
29.	Presence of sur. vegetation					
30.	Drainage system					
31.	Low income					
32.	land use					
33.	Dam and storage capacity					
34.	Existence of household coping capacity					

## Appendix IV

### Survey form for Experts on Scale of importance and relevance of indicators to the physical flood vulnerability.

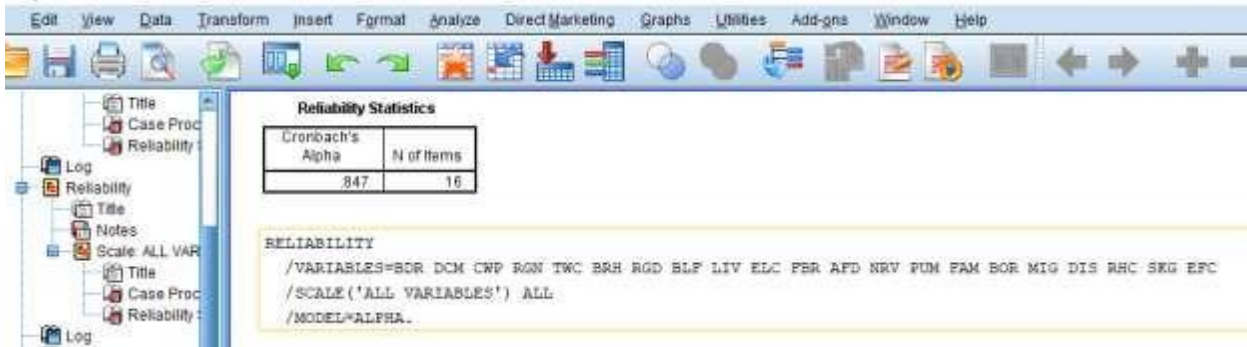
Scale	1	2	3	4	5	6	7	8	9	10
<b>Importance and relevance</b>	Insigni.	V. low	V. low to low	low	Low to mod.	Mod.	Mod. to high	High	High to V. high	Very high
Flood water depth										
Flood duration										
Flood water Velocity										
Water sedimentation										
Flood return period										
Frequency of flood experience										
Construction type and material										
Ground floor foundation material										
Number of floors										
Presence of basement										
Height of the building										
Exterior paving material										
Interior finishes										
Age of building										
Type/Use of building										
Building size										
Level of Maintenance/condition										
Height of opening from the ground										
Stilts/Elevated buildings										
Position of electrical sockets/fittings										
Roof design/materials										
Site topography										
Heavy rainfall pattern in the area										
Building distance from the coasts/ river										
Presence of surrounding vegetation										
Drainage system										
Proximity to major road										
Dam and storage capacity										
Flood risk awareness/ preparedness										
Warning system										
Existence of household coping capacity										
Emergency service										
Flood insurance										

V. stands for very; Mod stands for moderate; H stands for high.

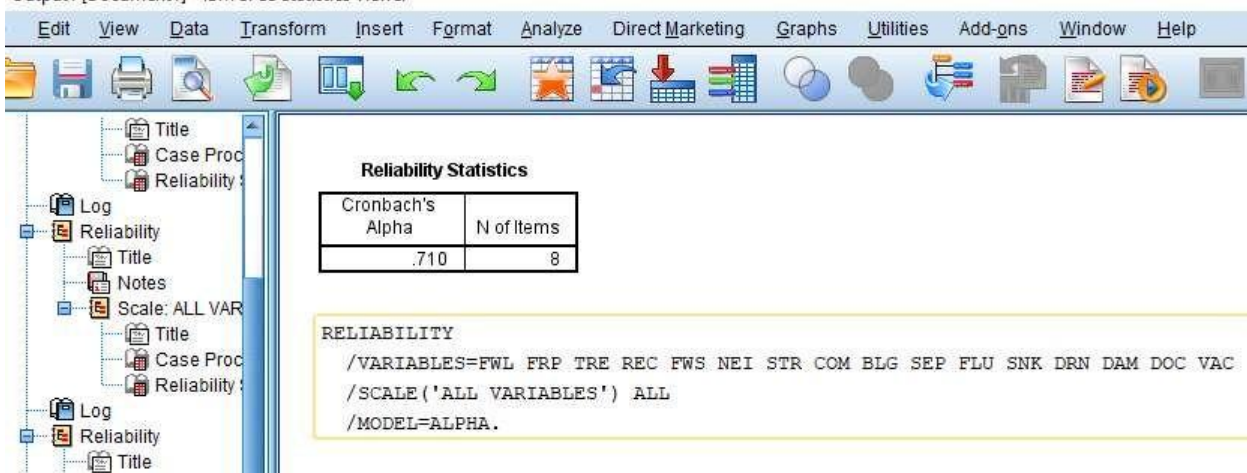
## Appendix V

### Cronbach Alpha's result

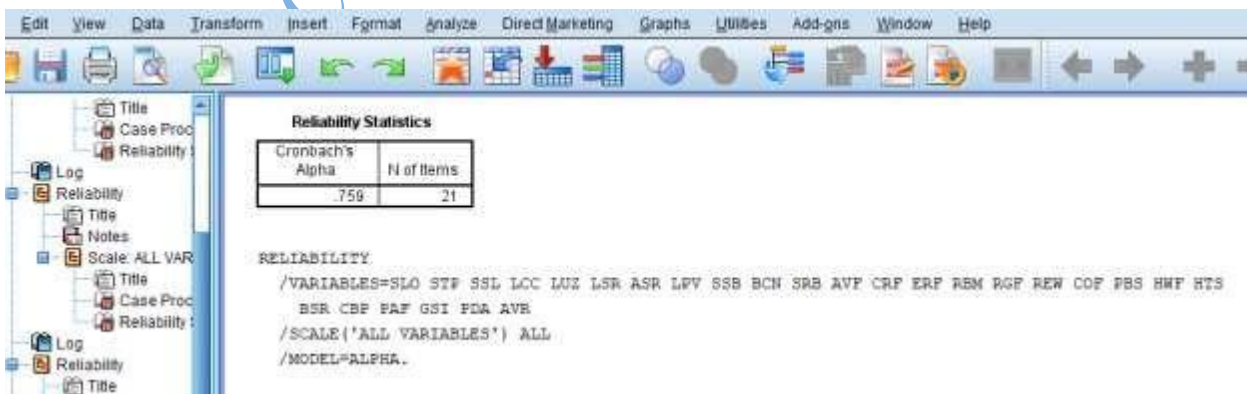
#### Objective 2



#### Objective 3



#### Objective 4



## Appendix VI

Result of KMO Measure of Sampling Adequacy and Bartlett's Test of Sphericity on factors influencing flood occurrences in the Study area

### KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.856
Bartlett's Test of Sphericity	Approx. Chi-Square	3901.274
	df	28
	Sig.	.000

**Table 4.16: Total Variance Explained**

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.140	76.745	76.745	6.140	76.745	76.745	4.607	57.582	57.582
2	1.085	13.562	90.307	1.085	13.562	90.307	2.618	32.725	90.307
3	.318	3.970	94.276						
4	.167	2.083	96.359						
5	.130	1.623	97.983						
6	.084	1.052	99.035						
7	.053	.658	99.694						
8	.025	.306	100.000						

Extraction Method: Principal Component Analysis.

**Rotated Component Matrix<sup>a</sup>**

	Component	
	1	2
Site Topography	.909	.190
Absence of Vegetation	.914	.313
Nature of soil	.855	.460
Poor channelization	.356	.844
Clogged drainages	.136	.913
Violation of planning regulation	.779	.575
Failure to heed flood risk warning	.960	.157
Building on flood plains	.735	.609

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

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## Appendix VII

Result of KMO Measure of Sampling Adequacy and Bartlett's Test of Sphericity on availability of neighbourhood characteristics of the study areas

**KMO and Bartlett's Test**

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.925
Bartlett's Test of Sphericity	Approx. Chi-Square	10194.281
	df	91
	Sig.	.000

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Table of factor loadings on dimensions that best represent variables used in assessing availability of neighbourhood characteristics in the study areas.

**Table 4.21: Total Variance Explained**

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.286	80.616	80.616	11.286	80.616	80.616	7.222	51.589	51.589
2	1.394	9.954	90.571	1.394	9.954	90.571	5.457	38.982	90.571
3	.508	3.626	94.197						
4	.276	1.970	96.167						
5	.152	1.085	97.251						
6	.084	.597	97.848						
7	.068	.486	98.334						
8	.053	.379	98.713						
9	.045	.321	99.034						
10	.043	.310	99.344						
11	.033	.236	99.580						
12	.023	.161	99.741						
13	.020	.140	99.881						
14	.017	.119	100.000						

Extraction Method: Principal Component Analysis.

**Rotated Component Matrix<sup>a</sup>**

	Component	
	1	2
Availability of natural recreational areas	.936	.269
Availability of an hospital/ health center	.644	.654
Availability of adequate educational facilities	.146	.949
Availability of adequate stormwater drainage facility	.921	.313
Availability of adequate domestic waste disposal facilities	.914	.299
Availability of adequate water supply	.904	.355
Availability of adequate power supply	.525	.780
Availability of good roads and streets networks	.741	.619
Availability of Space for social and religious activities	.448	.875
Availability of shopping facilities	.384	.879
Availability of Pedestrian walkways	.621	.720
Availability of floodwall/ barrier along the river channel	.836	.448
Availability of flood retention ponds/ gardens	.771	.503
Availability of flood warning systems in the area	.745	.491

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

## Appendix VIII

### KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.792
Bartlett's Test of Sphericity	Approx. Chi-Square	4709.494
	df	21
	Sig.	.000

### Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.191	88.438	88.438	6.191	88.438	88.438	3.928	56.118	56.118
2	.379	5.419	93.858	.379	5.419	93.858	2.642	37.740	93.858
3	.219	3.135	96.992						
4	.154	2.197	99.190						
5	.029	.418	99.608						
6	.018	.251	99.859						
7	.010	.141	100.000						

Extraction Method: Principal Component Analysis.

## Appendix IX

ANOVA<sup>a</sup>

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	39.551	14	2.825	428.257	.000 <sup>b</sup>
	Residual	2.038	309	.007		
	Total	41.590	323			

a. Dependent Variable: Physical flood vulnerability

b. Predictors: (Constant), Existence of household coping capacity, Drainage system, Site topography, Low income, Flood water Velocity, Construction type and material, Stilts/Elevated buildings, Presence of surrounding vegetation, Flood duration, land use, Dam and storage capacity, Quality of the building, Flood water depth, Building distance from the coasts/ river

**Coefficients<sup>a</sup>**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.909	.147		12.954	.000
	Flood water depth	-.220	.059	-.360	-3.746	.000
	Flood duration	.157	.051	.266	3.060	.002
	Flood water Velocity	.016	.025	.029	.638	.524
	Construction type and material	-.032	.024	-.060	-1.331	.184
	Quality of the building	.122	.042	.258	2.915	.004
	Stilts/Elevated buildings	.453	.033	.689	13.869	.000
	Site topography	.023	.033	.043	.699	.485
	Building distance from the coasts/ river	.022	.053	.047	.417	.677
	Presence of surrounding vegetation	-.142	.026	-.272	-5.415	.000
	Drainage system	.101	.023	.205	4.429	.000
	Low income	.218	.038	.204	5.801	.000
	land use	-.027	.033	-.063	-.812	.417
	Dam and storage capacity	.083	.053	.135	1.553	.122
	Existence of household coping capacity	-.154	.039	-.136	-3.976	.000

a. Dependent Variable: Physical flood vulnerability

## Appendix X

**Model Summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.975 <sup>a</sup>	.951	.949	.081

a. Predictors: (Constant), Existence of household coping capacity, Drainage system, Site topography, Low income, Flood water Velocity, Construction type and material, Stilts/Elevated buildings, Presence of surrounding vegetation, Flood duration, land use, Dam and storage capacity, Quality of the building, Flood water depth, Building distance from the coasts/ river

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## Appendix XI

### KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.913
Bartlett's Test of Sphericity	Approx. Chi-Square	5568.587
	df	190
	Sig.	.000

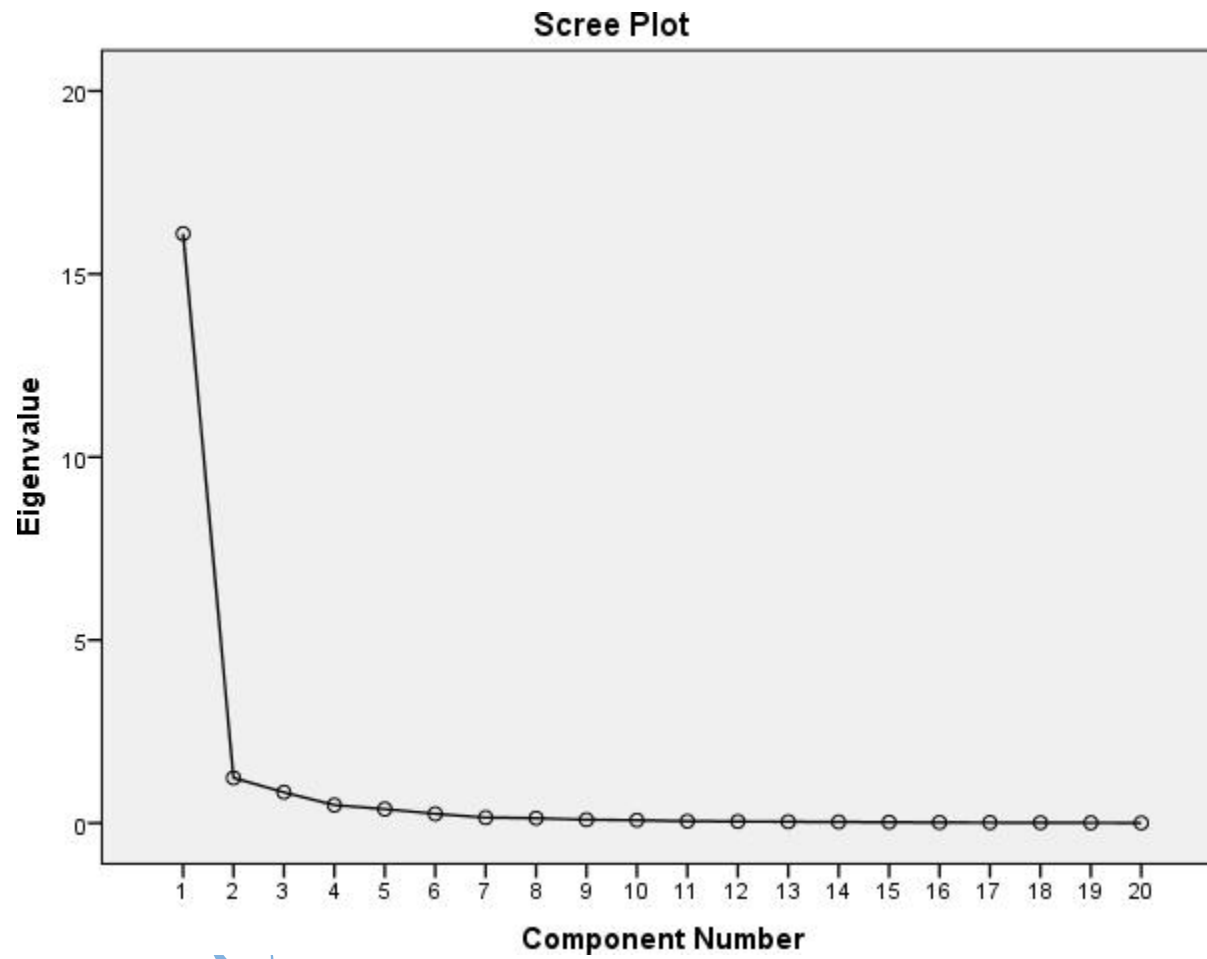
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## Appendix XII

### Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	16.103	80.516	80.516	16.103	80.516	80.516	9.992	49.962	49.962
2	1.233	6.167	86.683	1.233	6.167	86.683	7.344	36.721	86.683
3	.842	4.211	90.894						
4	.491	2.457	93.351						
5	.383	1.914	95.265						
6	.253	1.267	96.531						
7	.150	.749	97.281						
8	.134	.670	97.951						
9	.091	.453	98.404						
10	.080	.401	98.805						
11	.053	.263	99.068						
12	.046	.228	99.295						
13	.036	.182	99.478						
14	.030	.151	99.628						
15	.025	.123	99.752						
16	.016	.082	99.833						
17	.013	.064	99.897						
18	.012	.058	99.955						
19	.007	.037	99.993						
20	.001	.007	100.000						

Extraction Method: Principal Component Analysis.



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Figure 1.1: satellite imagery showing proposed study area within kosofe local government Area  
 Source: Google earth imagery



Figure 1.2: Damped imagery showing encroachment on the riverbanks in parts of the proposed study area.  
 Source: Google earth imagery

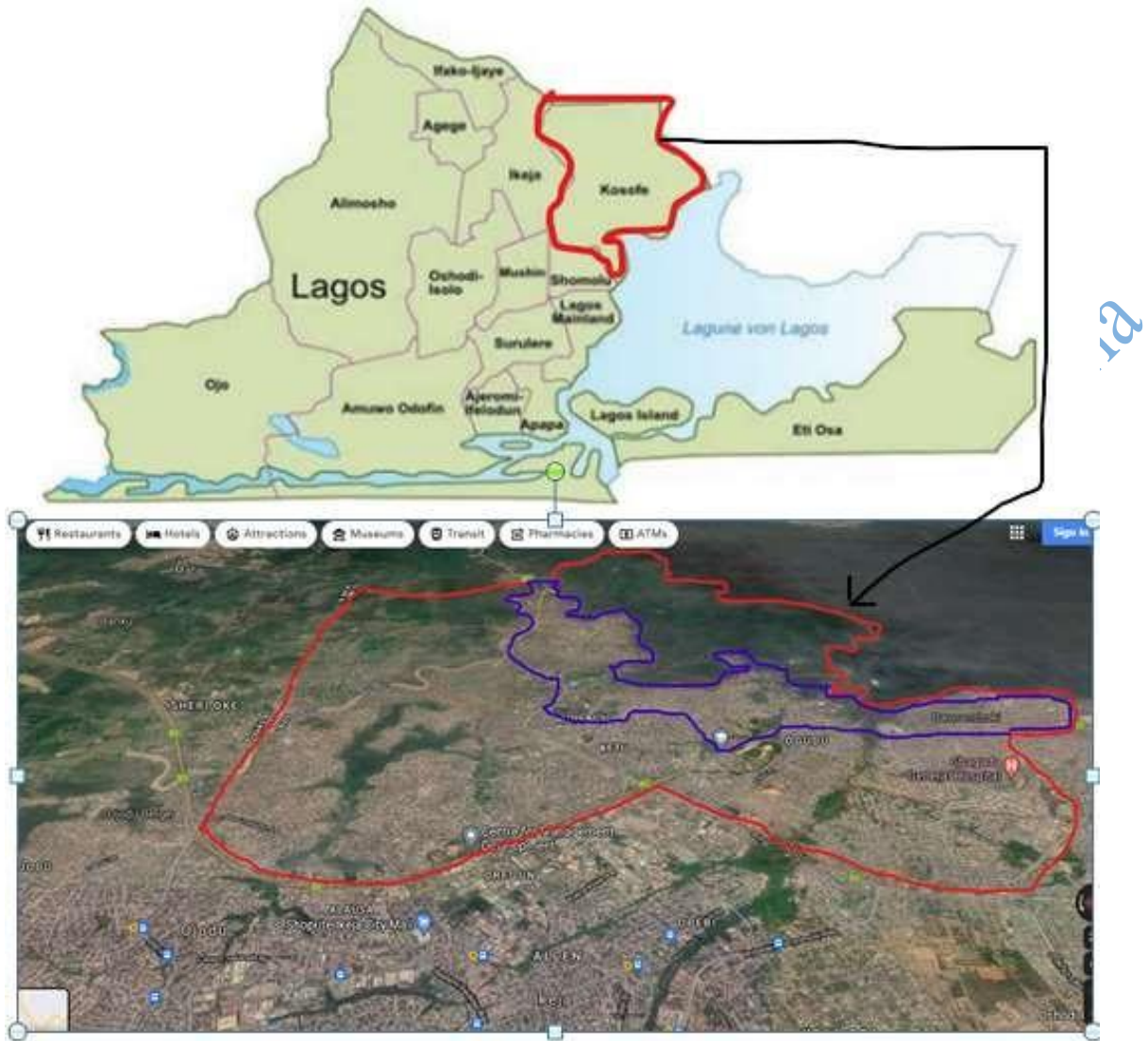


Figure 1.3: Map of Lagos-state showing Kosofe and other geographical locations within Lagos  
Source: Google earth imagery

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Figure 1.4: Housing situation in the Ajelogo/Mile 12 area of the proposed study area.  
Source: Google Earth imagery



Figure 1.5: Housing situation in Irawo part of the proposed study area.  
Source: Google Earth imagery



Figure 1.6: Housing situation in Oworonshoki part of the proposed study area.  
Source: Google Earth imagery

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## Bio-data

<b>Name</b>	Saudat Oluwakemi <b>Ajijola</b>
<b>Contact Address</b>	Department of Architecture, Lead City University, Nigeria +234-7080152199/ saudatajijola@yahoo.com
<b>Date And Place Of Birth</b>	20th July, 1988; Ado- Ekiti
<b>Nationality</b>	Nigerian
<b>Present Position</b>	Lecturer I
<b>Faculty</b>	Faculty of Environmental Management and Design
<b>Department</b>	Architecture

### EDUCATION

▪ St Joseph Cath. Nur/Pri Secondary School, Ado- Ekiti	1991 – 1998	<b>Primary School Leaving Certificate</b>
▪ Holy Child Cath. Secondary School Ado-Ekiti	1998-2004	<b>WASSCE</b>
▪ Federal University of Technology Akure, Ondo-State	2005 – 2011	<b>Bachelor of Technology in Architecture (3.86/5.0)</b>
▪ Federal University of Technology Akure, Ondo-State	2011 – 2014	<b>Master of Technology in Architecture (4.44/5.0)</b>

### AWARDS AND FELLOWSHIP

<b>Deakin University, Australia</b>	<b>2020</b>
Certificate of Achievement, 'Introduction to Sustainability and Development'	
<b>United State Green Building Council, USA.</b>	<b>2015</b>
LEED Green Associate	
<b>Daystar Leadership Academy</b>	<b>2014</b>
Advanced Certificate in Leadership	
Basic Certificate in leadership	
<b>National Youth Service Corp</b>	<b>2014</b>
Federal Government of Nigeria	

### MEMBERSHIP OF PROFESSIONAL AFFILIATION

▪ Architect's Registration Council of Nigeria (ARCON) (P/1777)	<b>2021</b>
▪ Nigerian Institute of Architects. (NIA)	<b>2021</b>
▪ United State Green Building Council (USGBC)	<b>2015</b>

### ADMINISTRATIVE EXPERIENCE IN EDUCATION MANAGEMENT (with date)

▪ Examination Officer, Department of Architecture, Caleb University	<b>Nov. 2020-Jan. 2022</b>
---	----------------------------

- 100 level Staff Advisor/ Coordinator April 2018-Jan. 2022
- Member, Fund raising committee, Caleb International Conference 2021
- Students' Club Coordinator 2020
- Member, Caleb University ICT Committee 2020
- Member, Caleb University Student Support services 2020

**TEACHING EXPERIENCE (Including Courses taught)**

• **DEPARTMENT OF ARCHITECTURE, LEAD CITY UNIVERSITY**

**Lecturer I**

**Feb 2022- Date**

**Courses taught at Undergraduate Level:**

- ARC 406 Architectural Brief Synthesis and Analysis
- ARC 416 Introductions to Professional Practice
- ARC 312 Environmental Psychology

**Courses taught at Postgraduate Level:**

- ARC 732 Thesis Written Report/Dissertation
- ARC 731 Advanced Design Studio IV
- ARC 715 Advanced Research Methods & Seminar
- ARC 700 Advanced Architectural Research
- ARC 704 Advanced Landscape Architecture
- ARC 711 Advanced Design Studio II

**Research Supervision within current Academic Session:**

- Achieving ease of Movement through circulation definition in Bus-Train Interchange
- Landscape Parameter for Faculty Building design
- The Role of Anthropometrics in Faculty Building
- The Role of Compartmentalization in Faculty Building

• **DEPARTMENT OF ARCHITECTURE, CALEB UNIVERSITY**

**Lecturer 1**

**July 2021- Jan 2022**

**Lecturer 2**

**May 2019- June 2021**

**Assistant Lecturer**

**May 2016- April 2019**

Courses Taught:

- |         |   |                             |
|---------|---|-----------------------------|
| ARC 463 | Environmental Impact Assessment (EIA)       | Four (5) Academic Sessions  |
| ARC 469 | Physical Development Issues                 | Three (3) Academic Sessions |
| ARC 412 | Architectural Design Studio IV              | Two (2) Academic Sessions   |
| ARC 345 | Building Construction II                    | Three (3) Academic Sessions |
| ARC 213 | Basic Computer Appreciation                 | Four (5) Academic Sessions  |
| ARC 214 | Computer Aided Design (CAD/BIM)             | Four (5) Academic Sessions  |
| ARC 111 | Architectural Design Studio I (Lead Critic) | Two (4) Academic Sessions   |

**Research Supervision:**

Reducing Vulnerability through Adaptive Architecture

Environmental Psychology in Architecture studio Design

Achieving Water Security through Building Water Efficiency in Lagos State, Nigeria

**• PROFESSIONAL EXPERIENCE****Project Architect**

Oct. 2014- Apr. 2016

AEK Design Services, Lagos, Nigeria (www.aekdesignservices.com)

Building design and Project Management.

Projects:

Union Bank Muri-okunola, Union Bank Oregun, Residential developments and mixed use designs.

**Architect**

Mar. 2014 – Sep. 2014

ARCLEC Design Konsult, Ibadan, Nigeria

**Graduate Architect**

Mar. 2013 – Feb. 2014

Ministry of Housing, Asaba, Nigeria

**PUBLICATIONS****Thesis/Dissertation****Submitted and Published Dissertations/Theses****i. Ajijola S. O (2023). Ph.D. Architecture, Thesis, Lead City University, Ibadan, Nigeria.**

Title of Thesis: Assessment of Physical Vulnerability Indicators for Developing Adaptive Architectural Design Strategies in Flood-prone Residential Areas of Lagos, Nigeria.

Duration of Programme: 2020 - 2023 (3 yrs.)

Sole Supervisor: Prof. F. M. Adedire

**ii. Ajijola S. O. (2014). MTech. Architecture Thesis, Federal University of Technology, Akure, Nigeria**

Title of Thesis: Ekiti State Centre of Arts (Improving Public Patronage of Arts through the provision of creative spaces).

Duration of Programme: 2011-2014 (3 yrs.)

Sole Supervisors: Dr. M.O. Adegbe

**iii. Ajijola S. O. (2011). BTech. Architecture Thesis, Federal University of Technology, Akure, Nigeria**

Title of Thesis: Assessment of Design Deficiency in Building Construction Failure in Nigeria.

Duration of Programme: 2006-2011 (5 yrs.)

Supervisors: Dr. Y.M D Adedeji

## Published Articles/ Journals

- i. **Ajjola Saudat**, Adedire Funmilayo. M., Eziyi O. Ibem, & Tanimowo Taiwo. (2023). Leveraging on Building Characteristics for Household Flood Adaptation. Accepted for publication in *\*Journal of Capital Development in Behavioral Sciences\**.  
**Publisher, Country, ISSN & Contribution:** Faculty of Arts & Education, Lead City University, Ibadan, Nigeria, ISSN: ONLINE 2449-0679; PRINT: 2354-3981; 70%  
**Indexing:** Copernicus, Google Scholar, Open Access
- ii. **Ajjola, Saudat**, Adedire, F., Ibem, E. O., & Adetoye, M. (2023). Potentials of Building Information Modeling (BIM) Tools for Water Usage Simulation and Efficiency Optimization in Residential Buildings in Lagos. *Archiculture*, 5(1), 126–137.  
**Publisher, Country, ISSN & Contribution:** Department of Architecture, University of Jos, Jos, Nigeria, ISSN: 2636-6747; 70%  
**Indexing:** Google Scholar, Open Access
- iii. **Ajjola, S. O.**, Musiliu, A. R., Obileke, R. (2021). Understanding Sustainability and Challenges with Sustainable Building Design and Construction Practice in Lagos-State, Nigeria. *International Journal of Advances in Engineering and Management*, 3(3), 167-174.  
**Publisher, Country, ISSN & Contribution:** Sarath Research Centre, India, ISSN: 2395-5252; 70%  
**Indexing:** Copernicus, Google Scholar, Jour Info, Open Access
- iv. **Ajjola, S. O.**, Oludare, J. O., Ajijola, O., & Arayela, O. (2021). Exploring Public Perceptions of Nature Based Solutions To Flood Management In Lagos, Nigeria. *International Journal of Advances in Engineering and Management*. 3(1), 736-747, <https://doi.org/10.35629/5252-0301736747>  
**Publisher, Country, ISSN & Contribution:** Sarath Research Centre, India, ISSN: 2395-5252; 70%  
**Indexing:** Google Scholar, Jour Info, Open Access
- v. **Ajjola, S. O.**, Arayela, O., Bello, J. (2020). Equifinality of Flood Determinants in the Wetlands of Lagos State, Nigeria. *International Journal of Innovative Research and Development*, 9 (8), 81–89. <https://doi.org/10.24940/ijird/2020/v9/i8/AUG20025>  
**Publisher, Country, ISSN & Contribution:** Inderscience Publishers, India, ISSN: 2278 – 0211; 70%  
**Indexing:** Google Scholar, i-scholar, Open J-Gate, Crossref, Open Access
- vi. Oludare, J.O., Ejiga, O., Oluwatoyin, O. A., **Ajjola, S.**, Babamboni, A. S. (2021). Understanding the relationship between users’ and experts’ perception of university senate building façade elements in southwest Nigeria. *Caleb International Journal of Development Studies*, 4(1). 181-197. <https://doi.org/10.26772/cijds-2021-04-01-011>  
**Publisher, Country, ISSN & Contribution:** Caleb University, Lagos, Nigeria, ISSN: 978-978-53693-8-9; 20%. **Indexing:** Google Scholar, Open Access
- vii. Obaleye J.O., Opaluwa .E., Ajayi, O.O., & **Ajjola, S.** (2021). Understanding the Relationship Between Users’ and Experts’ Perception of University Senate Building Façade Elements In Southwest Nigeria. *Caleb International Journal of Development Studies*. 4 (1), 181-197. <https://doi.org/10.26772/cijds-2021-04-01-011>.  
**Publisher, Country, ISSN & Contribution:** Caleb University, Lagos, Nigeria, ISSN: 978-978-53693-8-9; 20%. **Indexing:** Google Scholar, Open Access
- viii. Ejoor A., Obaleye J.O., Oniare A., **Ajjola. S.**, & Ajayi. O.O. (2021). Experts Identification of Post-Occupancy Evaluation Concepts Relevant To Building Performance. *Caleb International Journal of Development Studies*. 4(2), 158-172. <https://doi.org/10.26772/cijds-2021-04-02-08>  
**Publisher, Country, ISSN & Contribution:** Caleb University, Lagos, Nigeria, ISSN: 978-978-53693-8-9; 20%. **Indexing:** Google Scholar, Open Access

- ix. Obaleye O. J., Opaluwa .E., **Ajjola S.**, Obaribirin. A., & Chukwuka O. P. (2021). Craftsmanship and Aesthetic Appreciation of the Built Environment. *Journal of Ceramics and Environmental Design*. 8(2), 63-74.
- x. Obaleye. O., Onosemuode. M., Opaluwa. E., Aderounmu. P., Tongo. S., & **Ajjola. S. O.** (2022). Covid-19 and the e-learning challenges experienced by architecture students of a typical Nigerian private university. In 16th annual International Technology, Education and Development Conference. 7th-8th March 2022, Valencia, Spain. [https://iased.org/concrete3/paper\\_detail.php?paper\\_id=95310](https://iased.org/concrete3/paper_detail.php?paper_id=95310)

### **Manuscript Submitted for Publication**

Ajjola, Saudat. (2023). Contextualizing Household Adaptation to Flooding in Urbanized Floodplain Areas: Pre-disaster Adaptation, Coping Capacity and Post-disaster Intervention, *Urban Forum*.

Tanimowo, Taiwo, Ajjola, Saudat. (2023). Promoting Community development through Social Inclusive Design Strategies in Civic Centers in Nigeria, *Community Development*.

### **Conferences and Workshops Attended**

- Oct. 2021 Caleb University International Conference. Paper presented: Potential of Building Information Modeling in achieving domestic water security in Lagos, Nigeria.
- Sep. 2021 Research Supervision workshop, Caleb University.
- Sep. 2018 Staff training and development on organizational performance

### **Extra-curricular Activities**

- Community Services
- Arts

### **Technology Proficiencies**

AutoCAD Revit Atlantis Microsoft Office (Teams, Forms, Word, PowerPoint, Excel) SPSS, Mendeley

### **Relevant Skills**

- IT savvy
- Teaching
- Creative thinking
- Analytical and self-motivated
- Creative writing
- People management and diplomacy
- Versatile and resourceful
- Data Collection, Documentation and analysis

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### The University Compliance Certification

This is to certify that, Saudat Oluwakemi AJIJOLA with matriculation number LCU/PG/03624 carried out this research work titled ‘Assessment of Physical Vulnerability Indicators for Developing Adaptive Architectural Design Strategies in Flood-prone Residential Areas of Lagos, Nigeria’ in the department of Architecture, Faculty of Environmental Design and Mangement, Lead City University, Ibadan, Oyo State, is in full compliance with the approved Universitty format and style. .

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**Signature**

.....  
**Date**

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