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Evaluation of Flood Resilience Strategies as Climate Adaptation for Residential Properties in Lekki, Lagos.

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Abstract
The impact of flooding in recent times on housing are increasing with rapid urban expansion in both developed and developing countries. Various studies have shown the relationship between high flood levels in coastal regions and climate change which causes an increase in sea levels and ocean degradation. The rising flood frequency affects the residents of Lekki peninsula, destroys an array of urban infrastructure, disrupts economic activities and becomes a threat to sustainable development. This study aims at evaluating flood resilience strategies as response to the increasing flood vulnerabilities in residential properties in Lekki, Lagos state. Due to the empirical evidences the variables employed to evaluate Flood resilience and climate adaptation include: the elevation of land, building strategies for resilience and the water levels in Lekki, Lagos state. A Quantitative research approach was used where questionnaire survey was administered to the residents of Lekki, Lagos state. The data collected were analysed using both descriptive and inferential statistical tools. It was discovered that residential properties were affected by the increased flood risk with major damages to the structural stability, building façade, life and properties of the occupants of these residential properties. The findings showed that the residents applied flood resilient strategies that were inadequate to control flood. The research advanced the use of water inclusion and water entry technologies as the strategies adopted in designing residential properties that are adaptable to the flood and climate conditions. The study recommends the construction of proper drainage channels to enable efficient draining of flood water, water proofing of the building structure to keep the structural stability in check and the adaptation of amphibious technology water front design, elevated buildings and floating structures to adapt to the costal environment. In conclusion, the type of flood, the environment and Informed historical data affect the choice of strategy employed

in resisting flood risk and adapting to climate change and this is the new climate reality.

***Keywords**: Flood, Resilience, Adaptation, Vulnerability.*

Introduction

Structures should adjust to the reality of climate change, the rise in ocean level and ocean degradation causes flooding in prone regions. The world is affected by Natural disasters on a yearly basis with flooding having the greatest damage potential of them all (John-Nwagwu, *et. al*., 2014). Getahun & Gebre, (2015) defines Flooding as the excess flow of water which exceeds a river channel's carrying capacity, drainage system, dams and any other water bodies. The most expensive and one of the deadliest natural disasters in the world. Flood risk cuts across various continents as areas in coastal regions are mostly affected. In recent years, it has become increasingly common and severe as a result of increasing population growth, human interventions and socio-economic activities in the floodplain on an ever-increasing scale (Md Abdullah, *et al*, 2020). This in turn has led to the loss of life and properties as a result of the ingress of water into developed physical infrastructures. Now there is a need for resilient strategies to mitigate the impact of these damages. Though climate change can be said to be the primary cause of flooding, other factors such as heavy rainfall, oceans storm and tidal waves usually along the coast, human causes like; dam failures, population pressure, deforestation (mostly in parts of the north), damaged water pipes all contibute (Magami, *et. al.* 2014). In recent years, it has become increasingly common and severe as a result of increasing population growth, human interventions and socio-economic activities in the floodplain on an everincreasing scale (Md Abdullah, *et al*, 2020). This in turn has led to the loss of life and properties as a result of the ingress of water into developed physical infrastructures. The rising flood frequency affects the residents of Lekki peninsula, destroys an array of urban infrastructure, disrupts economic activities and becomes a threat to sustainable development.

This Study is aimed at evaluating flood resilience strategies as response to the increasing flood vulnerabilities in residential properties in Lekki, Lagos state. This evaluates the level of risk communities in the Lekki peninsula experiences and viable strategies to tackle this flood risk. The study leads to establish the concept of flood resilience. The concept of resilience covers the philosophy that, as a society, we should learn to live with floods and manage flood risk rather the thought of its elimination (Lukasz & Magdalena, 2020). A case study research was caried out evaluating other strategies employed around the world. Questionaires were also distributed in order to gather data regarding flood strategies employed in lekki and its environs. Flooding can be prevented uing serveral methods which when put in place can reduce the havoc caused by it, such a Flood barriers- A flood barrier, surge barrier or storm surge barrier which is the most common technique (Ruddiman, 2018). Lukasz & Magdalena, (2020) also concluded that Technological aspects, such as new inventive building components, materials, or solutions that consider interactions between materials, or socioeconomic aspects, such as climate change scenarios with long-term land use modelling and flood risk analysis to generate maps and time series of expected annual damages, which are examples of resilience. Aquatecture, "a watercentric approach to design in which flood-risk management, development pressure and adaptation to climate change are simultaneously reconciled to allow buildings and cities to live and work with water" (Barker & Coutts, 2016). A combination of architecture and water, how architecture shaped how we interact with water and importantly how to cope with flooding through integrated design approaches should be explored. These approaches enabling water entry technology for flood prone areas Includes Amphibious buildings, Floating buildings, Elevated buildings, and Waterfront designs.

Integrated Design for Resilience

Urban resilience is the capacity of urban systems to prepare and respond to the risks and impacts of natural hazards, climate variability, and climate change (Gigio, 2015). A resilient built environment is designed, located, built, operated and maintained in a way that maximises the ability of built assets, associated support systems (physical and institutional) and the people that utilises built assets, to withstand, recover from, and mitigate for the impacts of extreme natural and human-induced hazards (Dainty & Bosher, 2008).

Godschalk, (2003) also proposes the following for resilience;

a) new developments are guided away from known high hazard areas, and where possible, vulnerable existing improvement is moved to safe regions;
b) structures are built or retro-fitted to satisfy code guidelines dependent on risk dangers; regular natural defensive frameworks are monitored to keep up with significant risk relief capacities;
c) at long last, their legislative, nongovernmental, and private area associations are ready with state-of-the-art data about risk weakness and catastrophe assets, are connected with viable correspondence organizations, and are knowledgeable about cooperating.

Resilient Construction for Residential Building

The ability of an actor to cope with or adapt to danger stress is known as hazard resilience. Anunobi, (2013) describes it as the result of the level of planned preparedness conducted in light of prospective hazards, as well as spontaneous or deliberate adjustments made in response to perceived hazards, such as relief and rescue. Flood protection, prevention, and preparedness are all priorities for resilient strategies, both now and in the future (Zevenbergen, *et al.,* 2019). Structurally, buildings must be able to withstand the stress associated with high impact floods this also includes materials and their ability to cope. A strategy that highlights the development of hybrid approaches to property level resilience combining water exclusion measures with water entry measures. which includes;

Amphibious Buildings

An amphibious house is a building that rests on the ground but rised up whenever it floods, (Baca Architects, 2014). The Amphibious homes rest on concrete foundation and also starts floating when the water level rises and also during flooding. They are similar to normal homes with parking space, a garden and access from road. The inhabitant only feels that the house is floating only during flood conditions. (Tejas, *et al*., 2019). The buoyancy system beneath the building oust water to allow flotation as needed, 'and a vertical guidance system allows the rising and falling house to return exactly the same place upon descent. It works based on Archimedes principle: The mass and the volume of the house is less than that of water, and what determined its buoyancy' (Adithya & Manoj, 2021). It is an innovative approach that is rapidly gaining acceptance and finding application around the globe (Tejas, *et al*., 2019).

Figure I; Showing picture of an amphibious building in New Orleans and picture illustrating Architectural view of Amphibious House
Source; (Tejas, *et al*., 2019)

Floating Building

These are permanently anchored floating building built on a flotation system which is not for, navigation . A floating building must have a floatation system which maintains an acceptable level of stability appropriate to the use (Okeke, *et al.,* 2019). Unlike amphibious buildings, floating biuldings is always in the water, i.e., in a floating condition, while amphibious buildings is in the water only in a case of flooding. The floating houses are entirely prefrabicated before transported to the site, sometimes directly by water (Rosso, *et al*., 2020)

Figure II; Showing an overview of a floating house
Source; (Moon, 2013)

Elevated buildings.

These are buildings rised above the flood elevation on some support which is sufficiently strong to hold and carry the load of the building the force of the water acting on the building (Khan & Ahmad , 2017). Elevated building means a non-basement building built to have the top of the elevated floor elevated above the ground level by means of pilings, columns (posts and piers), or shear walls parallel to the flow of the water and adequately anchored so as not to impair the structural integrity of the building during a flood (Law Insider, 2021).

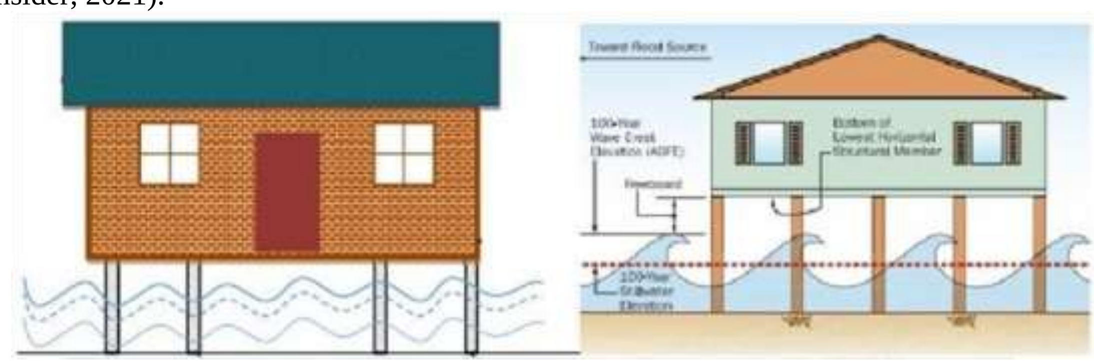

Figure III; Showing picture of elevated building structure along a flood plane and graphical illustrustion of the construction
Source; Researchers' case study

Waterfront Design.

The waterfront area is the confluence area of water and land. Since people make use of these areas, proper planning needs to be done so as not to allow the water flood the land, connect traffic, establish different functions, and how to communicate with inner cities (Hou, 2009). The proximity to the river, lake, or sea, has always been of great consideration in the choice of a community because of territories on the border between the settlements and water were inhabited because of their geomorphological characteristics: their rich resources for life, freshwater and food; for logistical reasons, as they offer access points to marine trade and transport; for recreational or cultural activities; or simply because of their special sense of place (Dal Cin, *et al.*, 2021). Today, there is the need to adapt the coast lines urban settlements to the increased risk of flooding in floodplains areas- to build resilient cities. In future climate scenarios, threshold urban areas, between the city and the water body, will become more vulnerable to flooding, due to rising average sea levels, and the reduction of permeable soil due to urbanization processes (Dal Cin, *et al.*, 2021) so a need for more well planned waterfront areas in flood prone location.

Figure IV and V; Showing picture of Singapor River before and after development of waterfront design approach
Source; (Al-Shams, *et al*., 2013)

Furthermore, the strategies explore in this survey shows flood resilient strategies adopted in other parts of the world. To achieve the aim of this study, a structured questionnaire comprising range of strategies established in the literature was designed to determine the strategies employed in mitigating floor risk and how effective they were. The Questionnaire piloted several times in order to validate and improve the survey.

THE RESEARCH METHOD

The research method adopted in this research process is quantitative research method. Primary data was collected with the aid of a structured questionnaire as the research Instrument to determine flood resilient strategies employed. It uses two types of closed-ended questions, namely the checklist and Likert item/scale. The target population of the study are general occupants of residential buildings which is projected at 401,272 residents in Lekki, Lagos state. The sample for the survey was distributed across lekki pennisula. The survey questionnaire was distributed using a convenience sampling method to reach residents in the area. Several avenues were employed to send out questionnaires such as emails, personal messages and others posted on social media channels. This helped to increase the number of respondents as well as enhanced the external validity of the study. This is a result of survey strategies employed by (Baltar & Brunet, 2012).

Data Collection

The instrument was administered with the help of two trained research assistants. They were exposed to training on contents of the questionnaire, how to interpret the items in the questionnaire and how to get participants' informed consent by the researcher. To achieve the set objectives, comparative analysis with the use of ordinal scale for ranking based on weighted mean and weighted scores and a bivariate correlation were used to analyze the responses gotten from the survey.

Data Analysis

Descriptive analysis was used to summarize respondents' demographic data while inferential statistics were used to achieve the problems itemized in the objectives.

Descriptive Statistics

Descriptive statistics was used to establish occupants' demographics in form of tables as well as the availability of low impact materials in the study area. According to Scherbaum and Shockley, (2015) descriptive statistics is the process that analyzes quantitatively summarized data. Specifically, The weighted scores and the weighted mean of each statement were computed and ranked using the ordinal scale. Ordinal Ranking makes use of ordinal numbers such as 1,2,3,4, to rank a set of items based on a casual relation in an ascending or descending order.

Inferential Statistics

Inferential statistics was employed to make inferences about a population based on data that was gathered from the sample of the study. Correlation was used to derive inferences based on the relationship between the variables from the sample population.

RESULTS

In view of the projected population of 401,272 residents in Lekki, Lagos state, a total of 172 respondents were recorded from 200 questionaires administered. This shows a response rate of 86%. Based on gender, females have a greater outcome with a frequency of 65 respondents as against females with 102 respondents as shown in Table 2. This is because mostly women we met at home at the time the data was taken. Gender, age of respondents, as well as level of income went a long way to determine the profile of the sample population selected. The results obtained are displayed in the table belows:

Table 1. Summary of the relaibility for the questionaire survey.

Cronbach's Alpha	Number of questions	Conclusion
0.59	26	Moderately reliable

Table 2. Summary of the relaibility for the questionaire survey.

Gender	**Frequency**	**Percentage**
Male	65	37.4
Female	102	58.6
Others	5	2.9
Total	172	100

Table 3. Summary of the relaibility for the questionaire survey.

Characteristics	**Frequency**	**Percentage**
0-5 years	107	62.3
6-10 years	43	25
11-20 years	19	11
20 years above	3	1.7

Table 4. Data of presence of flood resilience in sample

Characteristics		**Frequency**	**Percentage**
Valid	Not applicable	7	4.0
	Yes	61	35.1
	No	85	48.9
	Not Sure	21	12.0
	Total	172	100.0

Table 5. Construction materials Employed in construction of residential buildings

Materials Specified	**Frequency**	**Percentage**	**Rank**
Sandcrete Block	112	65.1	1st
Mud	1	0.6	6th
Thatch	3	1.7	5th
Burnt Clay	2	1.2	4th
Wood	7	4.1	3rd
Steel	47	27.3	2nd

Table 6. Structural system employed in the building

Materials Specified	**Frequency**	**Percentage**	**Rank**
Reinforced cement concrete (RCC)	42	24.4	3rd
Mixed (Reinforced Cement Concrete + Masonry)	78	45.3	1st
Load Bearing Structure	-	-	-

Timber structure	7	4.1	4th
Steel Structure	45	26.2	2nd
Mixed (steel + Masonry) Structure	-	-	-

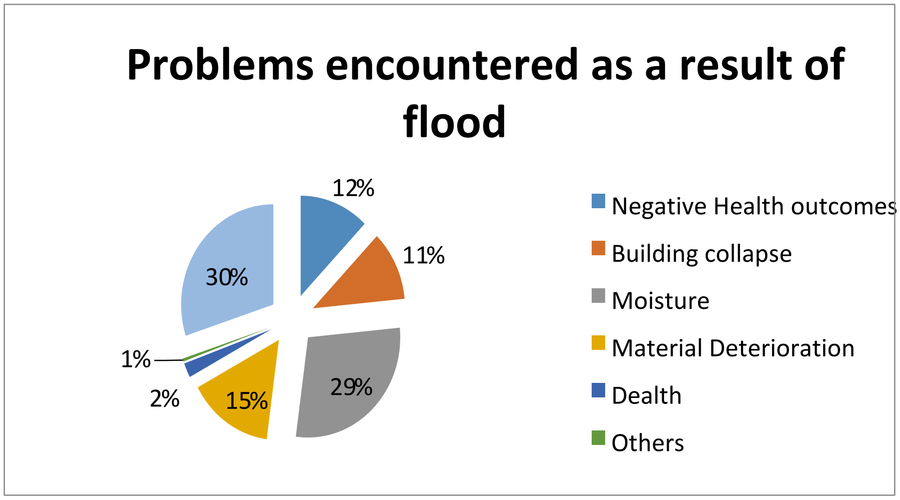

Figure I : Data of problems encountered due to flood

Source: Author's field work

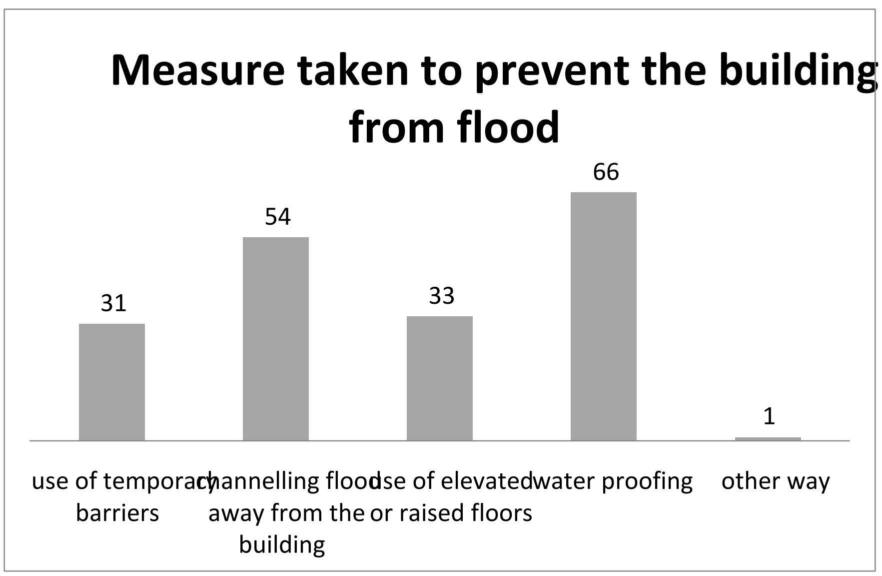

Figure II: Measures taken to prevent the building from flood

Source: Author's field work

Table 8. Validity of Measures taken to prevent to prevent building from flood.

	Frequency	Percent	
Valid	Not applicable	13	7.5
	Yes	44	25.6

No	63	36.6
Maybe	52	30.2
Total	172	100

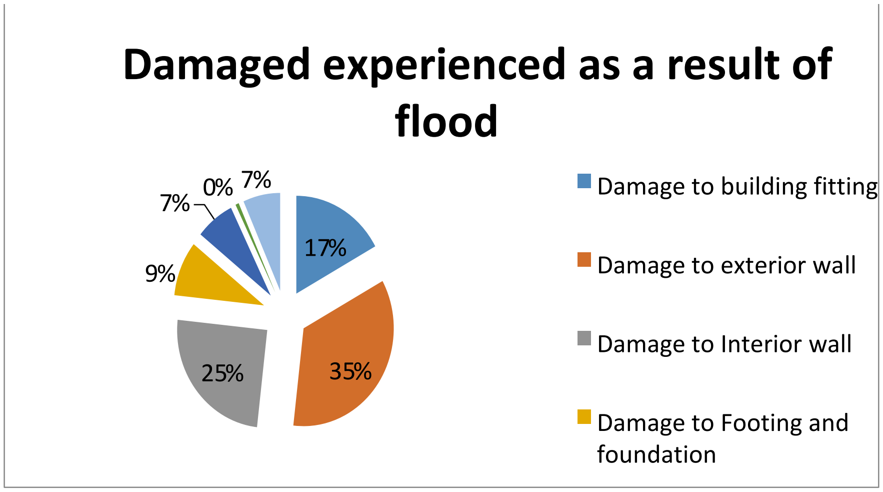

Figure III: Data of level of damage by flood
Source: Author's field work

FINDINGS

The presence of exixting flood reslience in the study area represents 4% of samples with flooding not applicable to those residential building. 35.1% of the residents admits to using local flood resilient techniques. 48.9% of residents reports that no flood resilient strategy has been adopted in the construction of the building while 12% are not sure if their stucture is flood resilient or not as shown in Table 4 above. Table 5. Also shows building materials employed in the residential buildings in lekki lagos reports Sandcrete blocks as a dominating building material in the study are with 65.1% Ranking 1st with steel, wood, burnt clay, Thatch and mud ranking 2nd, 3rd,4th,5th and 6th respectfully. Table 6. Highlights structural system and employed in the residential buildings. Mixed Method (Reinforced cement concrete + Masonry) ranking 1st with 45.3% and Steel structures, Reinforced cement concrete (RCC) and Timber structure comes in 2nd, 3rd and 4th respectfully. Mixed (Steel + Masonry) Structure and Load bearing structure were void with 0%. The results shows that 12% of the respondent experience negative health outcomes, 11% of the building collapse due to flooding, while 29% of the respondents experience moisture and 15% of the respondents' material deteriorating due to flood and only 2% of the respondent were confirmed dead due to flooding.

From figure II above, which illustrates how 31 of the respondent applied temporary barriers to control flood, 54 of the respondents control flooding by channelling the water away from the building, 33 of the respondents uses elevated or raised floors and lastly, 66 of the respondent uses water proofing as a measure to prevent the building from flood.

From table 8 above, the measure taken by the respondents to prevent the building from floor only yielded a low result as only 25.6% of the respondents admit that the measure they have taken actually caused a reduction in flood risk. This percentage is very low; this implies that other measure need to be adopted in order to reduce flood risk as the initial measure did not result to a reduction in flood risk. Figure III shows 17% of the respondent experience damage due to building fitting, 35% experience damage to exterior wall and 25% experience damage to interior wall, 9% experience damage to footing and foundation while only 7% of the respondent experience damage to opening such as doors and windows.

CONCLUSION

The aim of this study is focused on evaluating the flood resilience strategies as response to the increasing flood vulnerabilities in residential properties. In achieving this aim, a threefold objective was set each tied to a research question. The first objective identified residential buildings prone to flood in Lekki, Lagos state. It was discovered that flood vunerability in the study area is usually in the wet and rainy season. Most residential houses suffer from poor planning, poor drainage systems and are obstructing waterways due to terrain. The second objective focused on determining flood resilient strategies that could be employed to mitigate flood risk in residential building. Three variable were considered as influencers in the choice of a prefered strategy to use in mitigating flood risk. They include water entry/inclusion, water exclusion and water avoidance technology. The third objective focused on the proposal of suitable flood resilience strategies for the safety of both the building and its occupants in lekki lagos state. This includes the construction of proper drainage channels to enable efficient draining of flood water, water proofing of the building structure to keep the structural stability in check and the adaptation of amphibious technology, water front design, elevated buildings and floating structures to adapt to the costal environment. In conclusion, the type of flood, the environment and informed historical data affect the choice of strategy employed in resisting flood risk and adapting to climate change and this is the new climate reality.

Recommendations

From the study, the following recommendations will be of great help. This strategies that can result in flood resilience as climate adaptation for residential properties include;

a. Structures should be built retro-fitted to satisfy code guidelines dependent on risk and dangers associated with flood vulnerabilities.
b. Building code should be reviewed with risk awareness as a factor with decisions made through knowledgeable findings.
c. Adoption of water inclusive strategies by the integration amphibious building approach, water front design, elevated buildings and floating structures.

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