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Leveraging on Building Characteristics for Household Flood Adaptation

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Abstract

Buildings are designed to provide passive climate adaptation and protection for occupants against harmful environmental conditions. Today, many households in sub-Saharan Africa are subjected to physical, social and economic losses from flood impact. As flood risk and associated impacts continue to grow in the built environment, there is need to evolve strategies to advance the resilience of these vulnerable communities. Unfortunately, there are limited empirical studies on buildings' role in flood risk reduction in these regions. This study sought to bridge this gap in knowledge by examining currents levels of awareness of household flood adaptation *strategies, and the influence of specific building characteristics on household flood adaptation. The study takes a cross-sectional research design approach involving data collection through a questionnaire survey from 47Architectural Educators in ARCON accredited Schools of Architecture in Lagos, Nigeria. The data were analyzed using descriptive and inferential statistics. Results indicate a high level of awareness of household flood adaptation strategies. Also, findings suggested that building's floor height and drainage systems have the most influence on reducing flood impact to vulnerable households. The highlighted building characteristics can thus be leveraged on to optimize buildings' function in the flood adaptation process. Recommendations are also made on the way forward based on the results obtained from the study.*

Keywords: Buildings, Architectural educators, Flooding, Flood adaptation; Urban areas.

Word Count: 211

Introduction

The built environment is human constructed physical environment that provides the setting for all kinds of human activities (Maxwell, Grambsch, Kosmal, Larson, & Sonti, 2018). Although the constructed built environment notion is a recent one, Rapoport, a social scientist, is credited with its invention in 1976 (Rapoport, 1976). The term "urban built environment" may be used to refer to virtually any human-made infrastructure, encompassing all types of buildings, including residential, commercial, and industrial ones, as well as the networks that connect them (Hassler & Kohler, 2014). Buildings are among the key important components of the built environment that sustain social institutions and needs, including housing, enterprises, the government, the economy, and other essential services (Chen, Liu, & Chen, 2020; Kamara, Heidrich, Tafaro, Maltese, Dejaco & Cecconi, 2020). Today, buildings continue to be exposed to increasing stresses and more frequent co-occurrence of climate induced flood risks (Abid, Sulaiman, Wei, & Nazir, 2021). These realities coupled with the quest for more sustainable practices, have all elevated emphasis on the need for improved flood resilience to mitigate growing vulnerability. Invariably, resilience thinking as a means of adaptation and transformation with the soul aim of surviving against man-made or natural risks is critical (Chen, Liu, Lu, Zhe, Tong & Akram, 2022). This is because resilience as a systems' attribute extends beyond simply reducing risks, it is primarily geared towards improving a system's (for instance, a building) performance in the face of multiple hazards (Hassler & Kohler, 2014). More so, resiliency is perceived as the capacity to endure severe natural disaster without suffering severe losses (Liao, 2012). As such, resilience is a crucial factor in determining how well buildings and other built environment components can adjust to change and meet societal norms and sustainability goals (Chen *et al.,* 2020).

Existing body of literature on flood resilience shows that the notion of 'living with floods' has grown in importance as a crucial component of flood management (Fu, Meng, Casado, Kalawsky, 2020).In other words, the capacity of a building to tolerate flooding and to allow occupants adjust should physical damage and socioeconomic disruption occur, so as to prevent deaths and injuries and maintain current functions in the event of flood defines resilience to floods (Chen et al., 2020; Liao, 2018).From the aforementioned, it can be concluded that resilience to floods is the ability to avoid flood disaster based on the buildings' flood ability. Where flood ability, implies flood tolerance based on existing function, structure, resources and capacities (Loggia, Puleo &Freni, 2020). Hence, resilience to floods is basically a process of adaptation, which involves improving the buildings' capacity to withstand flooding without causing physical damages and socioeconomic upheaval to vital components.

Within the context of this study, the concept of flood adaptation has to do with adjusting buildings and households to minimize flood impacts. It involves constructing buildings to withstand floodwater (Loggia et al., 2020). It is based on the idea that each flood that is prevented erodes the opportunity to learn and develop capacities to cope with flooding when the flood-control infrastructure fails (Kakulu & Brisibe, 2014). This notion aligns with an earlier study which observed that flood-control infrastructure decreases urban resilience to floods through its very function, which is to prevent periodic flooding; noting that periodic flooding is a critical mechanism to maintain the ecological functions and high biodiversity of floodplains (Liao, 2012). In other words, the ideas of 'disaster cycle' or 'flood risk cycle' which represents the consecutive phases of flood events (before, during, and after) have also encouraged a shift to flood risk mitigation through effective adaptation (Meng, Dabrowski & Stead, 2020). Consequently, successful building adaptation strategies as grounded in the idea that designing for flood ability produces a more successful outcome can contribute to flood disaster risk reduction in at risk households.

Today, coastal cities are experiencing a shift from hydrological engineering defenses toward integrated flood risk management (APFM, 2015; Nkwunonwo, Whitworth & Baily, 2016;Fu et al., 2020).This is because flood control infrastructure as a centralized measure gives people a false sense of security and ignores the need for localized flood response capacity, leading communities that rely on it to address just the river and not the built environment (Liao, 2018). That is why the United Nations' New Urban Agenda in line with the Sendai Framework for Disaster Risk Reduction for the period 2015–2030, have drawn attention to the need to increase resilience via the creation of high-quality buildings, effective spatial planning, and the renovation and improvement of existing housing stock in informal settlements (Begoña, Alexei, Amaya, Avi, Alonso & Al, 2020; UNEP, 2021). In response, studies have examined diverse architectural and planning based strategies as it relates to flood disaster risk reduction and climate change.

Findings suggests obvious building-based and households' strategies applicable in pre-flooding, during flooding and in post-flooding scenarios such as building elevation above estimated flood depths, use of flood-resistant building materials, construction of flood walls and barriers, improved drainage systems and periodic maintenance, wet and dry flood proofing, rainwater and sewage diversion, provision of green spaces and flood sinks(Munyai, Musyoki, Nthaduleni, 2019; Chen, *et al.,* 2020; Kometa, Petiangma, Kang, 2021).Similar to this, low impact developments (LID)or sustainable urban drainage system (SuDS) are becoming a more widespread method of adapting to floods. Typically, LID/SuDS relies on building materials, components and design to harvest, infiltrate, slow, store, convey and attenuate floodwaters (Palazzo & Wang, 2022). Common LID/SuDS strategies identified by previous research include rainwater harvesting, green rooftops, permeable pavements for parking lots and sidewalks, tree planting, rain gardens, swales, detention basins, and retention ponds (Ajijola, Obaleye, Ajijola & Arayela, 2021).

From these studies it is understood that flood adaptive measures for buildings consider aspects of building material, building components and design strategies. These studies also help to understand that specific building features and their neighborhood characteristics such as envelope, structure, proximity to water bodies and storm water channelization play an influential role in flood adaptation. In spite of these, UNEP (2021) has observed that flood adaptation in the building industry is still in its early phases, and actions must be quickly ramped up to deal with the repercussions of climate change, which are becoming more severe.

Statement of the Problem

Current trends in climate change issues and socio-economic development are indicative that the built environment will increasingly experience flood risk in the future. Already, there has been significant increase in the frequency, intensity, and magnitude of flood events in different parts of the world (Rubinato,Nichols, Peng, Zhang & Lashford, 2019; Surminski & Mehryar, 2020; Kaoje, Zulkarnain, Rahman,Idris, Razak, Nurul, Wan, Rani & Tam, 2021; Ahmed, Alrajhi, Alquwaizany, Maliki & Hewa, 2022). According to a Technical Report (2015), 70% of cities are already experiencing the effects of climate change because almost all of them are in danger. For instance, the majority of cities and homes worldwide are at risk of flooding due to rising sea levels and powerful storms because more than 90% of urban areas are coastal

(UCCRN, 2015). In addition, poverty and increased housing developments in informal settlements of coastal cities are further intensifying vulnerability to flood risk in developing countries (Atufu & Holt, 2018). These events have highlighted the fragility and vulnerability of the built environment to flood risk.

More so, the enormous impact of flooding on critical infrastructure (housing, transportation networks, water, electricity, and public health services) have further intensified the importance of flood adaptation and resilience in effective disaster management (Surminski & Mehryar, 2020). This is particularly evident in many coastal communities in sub-Saharan Africa, where very limited empirical studies exist on the role of buildings in flood adaptation (Ouikotan, Kwast, Mynett & Afouda,2017; Brisibe, 2020; Lucas, 2021). As such, identifying Building Characteristics which can be leveraged on for successful household flood adaptation becomes paramount. The outcome of this study can inform targeted policies on architecture and planning as it relates to flood disaster risk reduction and climate change; and also empower built environment professionals, home-owners, and particularly people in vulnerable situations to work together to drive development, as opposed to being subjected to externally designed and instigated development initiatives.

Aim and Objectives of the Study

The current study is conducted for the purpose of examining the influence of specific building characteristics on household flood adaptation, so as to improve understanding on aspects architects can leverage on to create more flood resilient buildings. The specific objectives are to:

1. assess the level of awareness of household flood adaptation strategies.
2. determine what building characteristics have the most influence on household flood adaptation.

Research Questions

The key research questions this study attempted to address are:

1. What is the level of awareness of household flood adaptation strategies?
2. What building characteristics have the most influence on household flood adaptation?

Methodology

The study takes a cross-sectional research design approach, which relied on primary and secondary sources. Using the deductive approach, secondary data were used to gain general understanding of urban resilience and flood adaptation, as well as building-based flood adaptation; thereafter, tested through survey to identify aspects of building which can be leveraged on to promote household flood adaptation (Blackwell, 2018; Holden & Lynch, 2004). The primary data were sourced from close-ended questionnaire survey administered to Architectural Educators working in accredited Schools of Architecture in Lagos, Nigeria. Architectural Educators are involved in the training of prospective architects and architectural technicians. Based on the status of universities offering architecture in Nigeria published by Architects' Registration Council of Nigeria (ARCON) in 2020; Architectural Educators in the University of Lagos and Caleb University were selected for the study. A total of 63 educators were identified using a census count of both full-time lectures and adjunct academic staff in both universities.

The study employed the questionnaire data collection instrument hosted on Microsoft forms to capture their opinions on the role of specific building characteristics in flood adaptation. In order to ensure content validity, a pilot study of the questionnaire was performed with 11 architectural educators in Caleb University, Imota; representing about 17% of the estimated sample size. The questionnaire was subsequently refined based on feedback from the pilot study. For example, it was suggested that the basic information of the educators be included. Similarly, the Cronbach's Alpha reliability coefficient test was carried out using Statistical Package for Social Science (SPSS)-v24 in order to ensure reliability and internal consistency of the questions.

The test results showed high Cronbach's Alpha of 0.874. Result of the test is showed in Table 1.

Table 1. Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.874	.885	9

Afterwards, a mailed questionnaire survey was used to collect data (n = 47) in February 2022 from architectural educators in Lagos State. The study's objectives were added to better explain the study to participants. The return of the completed survey implies consent. The design of the questionnaire is made up of two (2) sections. Section 1 included basic demographic variables such as gender, years of experience, and professional registration; and assessment of level of awareness of household flood adaptation strategies. Section 2 listed nine (9) indicators representing specific building characteristics identified from literature, namely: *proximity to water bodies, building footprint, building landscape, external paving material, wall material, floor height, number of stories, roof type, and building drainage system*. Respondents were required to evaluate on a 4-point Likert scale including: Not Influential (NI), Rarely Influential (RI), Influential (I), and Very Influential (VI); how significant these indicators are in flood adaptation. Overall, 47 of the 63 questionnaires administered were valid representing around 74.6% response rate.

The data were analyzed using simple descriptive statistics and the Relative Importance Index (RII). The RII is measured for each of the indicators and ranked accordingly. The RII was calculated by using the equation RII= $\sum \frac{W}{A * N}$ Where, w = weight (1, 2...4), A = highest weight, and N = number of responses. Generally, RII values close to 1 are considered to be of high importance and vice versa (Akadiri, 2011). The results are presented in tables.

Results

The results were analyzed according to the research questions and presented as follows:

Research Question One: What is the level of awareness of household flood adaptation strategies?

The basic characteristics of the respondents as shown in Table 2 reveal that 59.6% of the respondents are male, while the remaining 40.4% are of the female gender. In addition, the result also suggests that all the respondents are registered with the Architects Registration Council of Nigeria (ARCON), and that majority (40.4%) have five to eight years of teaching and research experience. Similarly, results as shown in Table 2 indicate that majority (76.6%) of the respondents have a substantial level of awareness of household flood adaptation strategies.

Table 2. Summary of Basic Characteristics of the Surveyed Architectural Educators

Basic Characteristics of Respondents	Frequency	Percentage
Gender		
Male	28	59.6
Female	19	40.4
Registration status with a professional Organization		
Yes	47	100
No	0	0
Years of experience		
1-4 years	2	4.3
5-8 years	19	40.4
9-12 years	12	25.5
13 years and above	14	29.8
Level of awareness of household flood adaptation strategies		
Very low	0	0
Low	8	17
Not sure	3	6.4
High	15	31.9
Very high	21	44.7

Research Question Two: What building characteristics have the most influence on household flood adaptation?

Table 3 provides summary of the descriptive statistics of respondents' perception of the influence of specific building characteristics on household flood adaptation. Analysis of the RII as shown in Table 3 indicates that '*floor height*' and '*building drainage system*' (0.95) are the most influential building characteristics among the 9 indicators in flood adaptation; it is the highest ranked and is followed by '*Building landscape*' (0.93) and '*proximity to water bodies*' (0.90): these are the most influential indicators. However, the lowest ranked building characteristics are the roof type (0.63), number of storeys (0.67) and building footprint (0.71).

Table 3: Descriptive Statistics of Influence of Building Characteristics on Flood Adaptation

Indicators	Not Influential	Rarely Influential	Influential	Very Influential	Mean	SD	RII
Proximity to water bodies	2	1	10	34	3.62	.739	0.90
Building footprint	1	18	15	13	2.85	.859	0.71
Building landscape	0	1	11	35	3.72	.498	0.93
External paving material	4	1	28	14	3.11	.814	0.78
Wall material	2	9	23	13	3.00	.808	0.75
Floor height	1	1	5	40	3.79	.587	0.95
Number of storeys	8	9	20	10	2.68	1.002	0.67
Roof type	11	11	14	11	2.53	1.100	0.63
Building drainage system	0	0	9	38	3.81	.398	0.95

Discussion of findings and Implication

The first finding of the study is that there is a high level of awareness of household flood adaptation among architectural educators in Lagos, Nigeria. This finding seems to be a departure from earlier studies which indicated that there is a low level of awareness of flood resilient and adaptable buildings among practicing Architects in Yenagoa, Nigeria (Brisibe, 2018).Similarly, Ezeokoli, Okolie & Onwuka (2019) found out that flood resilience measures are not largely incorporated into the design and construction of buildings in Ogbaru, Anambra State, Nigeria. Furthermore, in a related study in Ibadan, Nigeria, households in the survey never practiced any adaptation measures to mitigate flood risk (Salami et al., 2017). This finding implies that architectural educators seem to have a higher level of awareness of household flood adaptation than architectural practitioners. The observed difference may be linked to better research exposure, and technological advancement in the academics. The implication of this finding is that there appears to be a gap in translating research findings to practice, which may be attributed to the lack of collaboration and knowledge sharing among researchers, practitioners, policy makers and other stakeholders.

The second finding of the research is that '*floor height'* and '*building drainage system* 'have the most significant influence on household flood adaptation. These findings align with previous studies showing that elevating habitable spaces above flood level can further reduce flood impacts and associated damages (Liao, 2019;Shrestha, Bhakta et al., 2021). In fact, policy documents such as the "Planning Policy Guidance Note 25: Property Development and Flood risk" in UK and under the FEMA guidelines recommend that floor levels of buildings should be raised above estimated flood levels (Brisibe, 2020;Kometa et al., 2021). On the one hand, existing floor levels should be raised 300mm above the estimated flood levels, while foundation of buildings on the other hand, should be raised by at least 600mm above the highest adjacent grade where the flood level is not known. However, in cases where flood depth may be more extreme, consideration may be given to elevating the ground floor a storey above the ground and using the ground level for other uses such as basement.

Similarly, drainage systems have been widely construed as influential in runoff mitigation (Atufu & Holt, 2018; Ramos et al., 2017; Ajijola, S., Arayela, O., Bello, 2020). Providing an insight, Kaoje et al., (2021; 20), maintained that "*a high flood vulnerability to a building may be caused by a lack of drainage facilities, closeness to some natural drainage system or environmental settings, and its intrinsic characteristics*". In other words, a building's drainage system is critical to its resilience or susceptibility to floods. As such, a well-designed building drainage system is effective in preserving the value of the building envelope while reducing flood impacts on occupants.

Furthermore, the idea that a building's landscape plays an influential role in attenuating flood impacts and thus, facilitates flood adaptation aligns with suggestions in UNEP (2021). Rainfall interception by vegetation and trees reduces surface runoff, slows down flooding effects and reduces the pressure on urban drainage systems. Similarly, Pauleit et al., (2017) noted that permeable pavements and the various bio-retention systems are efficient in promoting infiltration and controlling runoff respectively. Also, findings from a post-flood empirical study in Kelantan, Malaysia suggested that a majority of flood-impacted buildings are located in proximity to main rivers (Rani, et al., 2017).

However, further analysis of the RII (Table 2) revealed that the least ranked indicator is 'roof type' with RII of 0.63. This finding suggests that the choice of roof has little influence on the flood adaptation of buildings. However, empirical study (Freni & Liuzzo, 2019), suggest that green roofs can significantly reduce the amount of rainfall that would otherwise run off hardscapes (such as, concrete, asphalt, bricks, aluminum, metal, etc), thus providing an important contribution to avoiding potential drainage system failures during flood events. Notably, Ezema et al. (2016) had argued that green roofs were not popular in Lagos State, Nigeria, due to cost, technical challenges, poor knowledge as well as limitations imposed by the interpretation of planning laws. As such, there is little evidence on the benefits of green roofs as it relates to flood adaptation in the area. However, this finding may be attributed to the very limited empirical studies on the influence of roof type, particularly green roof in attenuating flood risk in Lagos-state, Nigeria.

The implication of this finding is that in order for ensure improved flood adaptation at the property level, ground floor height and building drainage systems must be given utmost consideration and designed based on the climate and estimated flood depth of the area; such that there is minimal impact on households in future flood scenarios.

Conclusion

Based on the findings on the level of awareness of household flood adaptation, this study concludes that there is a gap between translating research findings to practice in Nigeria. Also, an inference may be drawn that the most effective building characteristics which may be explored for improved household flood adaptation are buildings' floor height and drainage systems. Therefore, in anticipation of increasing flood risk, architects and other built environment professionals can leverage on the deductions from this study to optimize building characteristics for flood adaptation.

Recommendations

In light of the conclusion of this study, it was recommended that

1. efforts from both architectural educators and architectural practitioners are needed to improve communication and collaboration channels, thereby making research findings more accessible and applicable to practitioners.
2. further studies on adaptive architectural design strategies for flood disaster risk reduction in flood-prone settlements.
3. efforts be made by the relevant building regulatory agency to develop and enforce a context specific policy document to guide building development within coastal regions and flood prone communities.
4. future comparative studies be carried out on the impact of pitched roof and green roof on flood mitigation in the built environment.

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