Barriers to passive retrofitting of residential buildings as interconnected systems: network analysis and qualitative perspectives from stakeholders

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Ayodele Samuel Adegoke, Rotimi Boluwatife Abidoye and Riza Yosia Sunindijo
School of Built Environment, UNSW, Sydney, Australia, and
Samson Efuwape Agbato
Department of Estate Management and Valuation, Moshood Abiola Polytechnic, Abeokuta, Nigeria

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Abstract

Purpose – Despite growing advocacy for sustainable building retrofitting, the construction sector remains faced with different barriers in developing countries. This study uncovers nuanced barriers to passive retrofitting of residential buildings from the perspectives of stakeholders in Lagos, Nigeria, and identifies the pattern of the associations amongst the barriers.

Design/methodology/approach – This study used a mixed-methods approach, which combined quantitative data gathered through a survey with 118 property managers and 163 homeowners and qualitative data from interviews with six building regulation officials. The quantitative data were analysed using exploratory factor analysis (EFA) and network analysis. In addition, qualitative data were thematically analysed to identify key themes.

Findings – EFA results identified four barrier dimensions, including information and communication (39.0% of total variance), financial and policy (8.5%), technical and professional capacity (6.1%) and compliance and implementation (4.9%). Further insights were derived using network analysis, which showed strong bidirectional connections across all four dimensions (with beta (β) ranging from 0.72 to 0.90; all $p < 0.01$). Qualitative data further revealed that people adopt passive measures informally, without recognising them as energy-efficiency interventions. Other key barrier themes identified include financial barriers and cost opacity, capacity and certification deficits, and physical and socio-cultural barriers.

Research limitations/implications – The study showed strong associations amongst all four dimensions of retrofit barriers in a context with low formal construction approval rates. It also highlights the existence of incidental retrofit practices amongst homeowners: basic passive measures implemented are not recognised for the purpose of energy efficiency. This emphasises the importance of strategies to tackle associated barriers together.

Practical implications – The research findings suggest the need for clarity of terminology, development of local certification schemes, increased cost visibility and formalisation of current practices. These actions can be followed by other interventions, such as awareness campaigns, financial incentives and targeted enforcement.

Social implications – The living standards of the residents can be improved by formalising the informal process of passive retrofitting. Given that most available loans have high interest rates, there is a need to explore more practical ways of financing, such as microfinance loans. This approach may allow for some improvement, while other long-term funding strategies help in undertaking retrofits.

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Originality/value – This study extends existing retrofit barrier research by applying network analysis in a weak regulatory context. It shows how dimensions of retrofit barriers are connected beyond traditional categorisation and identifies reported incidental retrofit practices amongst homeowners.

Keywords Carbon emissions, Network analysis, Passive retrofitting, Residential buildings, Retrofit barriers, Incidental retrofit practices

Paper type Research article

1. Introduction

Buildings consume a lot of energy and significantly contribute to climate change. The United Nations Environment Programme (UNEP) reported that 32% of the world's energy is consumed by existing buildings. Also, buildings account for 34% of total CO_2 emissions (UNEP, 2025). As revealed by Peiris *et al.* (2023), many of these buildings will be in use until around 2050. It is, therefore, crucial for countries that signed the Paris Agreement, including Nigeria, to be a pacesetter for sustainable actions through the implementation of sustainable measures, such as retrofitting. This is particularly important as it places considerable value on existing buildings, which cannot be demolished to give way to new green developments.

There are two aspects of retrofitting: active and passive. Active retrofitting involves the use of mechanically-powered systems, like the heating, ventilation and air conditioning (HVAC). These systems have been reported to enhance comfort in buildings, but they are considered costly for low-income societies in developing countries (Falchetta *et al.*, 2024). Passive retrofitting, on the other hand, involves the upgrading of the building envelope, orientation, ventilation and solar shading of buildings (Adegoke *et al.*, 2026a). This aspect does not depend on the installation of mechanical systems, and hence, several studies give it a better chance for low-income homes. This is especially pertinent for budgetary issues faced by stakeholders in developing countries (Adegoke *et al.*, 2025, 2026b). Escalating rates of electricity costs and the frequent interruption of power supply make the use of mechanical appliances financially impractical for most low-income households in Nigeria (Omo-Oghogho and Ofomaja, 2025).

The justification for passive retrofitting can be further illustrated by energy consumption patterns. Residential buildings in Nigeria use up 2,404 kWh of energy per year and generate a total emission of 2,500 kg CO_2-eq (Nwagwu *et al.*, 2024). Seventy per cent of the population of Nigeria is expected to be urban dwellers by 2050 (UN-Habitat, 2023). This prediction presents a challenge as an increasing urban population has a direct impact on energy demand. Energy-consuming buildings need to be retrofitted in alignment with the need to achieve sustainable development goals (SDGs) 11 on sustainable cities and communities and 13 on climate action.

Past studies have focused on the issues that arise when implementing retrofit techniques in different countries. The specific countries are Australia (Alam *et al.*, 2019; Bertone *et al.*, 2018), China (He *et al.*, 2019), South Africa (Amoah and Smith, 2024), Nigeria (Amasuomo, 2021; Beavor *et al.*, 2023) and the United Kingdom (Wise *et al.*, 2024). Barriers from the context of these studies may differ depending on the compliance regime adopted in the respective countries and the information transfer process. This can be illustrated by the fact that retrofit activities are limited in Nigeria (Ogunnaike *et al.*, 2025). These activities are merely known as repair works as opposed to efforts to improve energy efficiency (LASBCA Guide, 2023). Besides, around 25% of buildings in Lagos State obtain building permits (Ugbodaga, 2024), mirroring the reality faced in numerous Sub-Saharan African nations, where people live in informal settlements (Li *et al.*, 2025).

Despite this problem, there is little or no literary evidence that has examined how the barriers are associated in contexts where institutional frameworks are weak. This raises a structural issue with significant ramifications for the design of interventions. Therefore, the current research distinguishes itself by addressing this important gap within the retrofit literature. Two key research objectives were addressed: (1) identify the key barriers to passive retrofitting of residential buildings in Lagos and (2) examine the associations between the barriers.

The central argument of this research is that passive retrofitting barriers in Lagos form a system where knowledge, behaviour, financial and institutional barriers are mutually reinforcing. This study suggests, through the application of the theoretical domain framework (TDF) and institutional theory, that effective passive retrofitting is potentially better served by addressing barriers as systemic clusters rather than individually.

2. Literature review

Research on passive retrofitting has identified different barriers that have been explored (Adegoke *et al.*, 2026a). This study interprets the barriers theoretically through the lenses of TDF at the micro-/meso-level (Cane *et al.*, 2012) as well as institutional theory at the macro-level (Meyer and Rowan, 1977). TDF provides the basis for the individual and behavioural determinants of retrofits, whereas institutional theory concentrates on the structural and regulatory environment within which decisions are made. Both theories provide complementary lenses for understanding why passive retrofitting remains limited in Lagos despite its technical and economic feasibility.

2.1 Behavioural dimensions: TDF

2.1.1 Knowledge and skills domain. The issue of knowledge in building retrofitting can be conceptualised from two main perspectives. The first perspective revealed that not having enough knowledge can be a major barrier to the adoption of environmentally sustainable design methods, including passive retrofitting (see Amasuomo, 2021). This problem is not limited to a single stakeholder group. For instance, although construction and HVAC experts are aware of the significance of net-zero retrofits, there are a considerable number of property owners who have little information regarding different types of retrofitting techniques, their effectiveness, the expenses involved and the experts needed to implement them (Adegoke *et al.*, 2025; Alam *et al.*, 2019; Amoah and Smith, 2024; Djebbar and Mokhtari, 2023; Pajek *et al.*, 2023). Djebbar and Mokhtari (2023) pointed out that most property owners are often unaware of the resources available and that retrofitting is not just beneficial to the environment.

Residents, on the other hand, lack knowledge of what they should be doing because there is no standard set by the relevant authorities (Tohinaka *et al.*, 2011). Cluett and Amann (2014) and Tohinaka *et al.* (2011) indicated that most individuals are not aware of the ways to increase their buildings' energy efficiency. In another study conducted by Pajek *et al.* (2023), most stakeholders were unaware of the existence of retrofitting as an approach for sustainable development in multi-apartment buildings in Montenegro.

The second perspective is concerned about the way that knowledge flows amongst stakeholders within retrofit projects. For example, China shows a high level of specialisation in energy, building envelope and construction; however, the integration of this knowledge amongst different stakeholders remains poor (Liao *et al.*, 2025). In the UK, the problem is overloaded sources of information. This makes it difficult for stakeholders to choose the best strategy (Wise *et al.*, 2024). It is worth noting that such examples show that the idea of retrofitting is constrained by the uneven distribution of professional knowledge and the abundance of information. The problem becomes even more complicated in irregular urban settings. According to Nwagwu *et al.* (2024), improving the energy efficiency of buildings will be minimal if there are only minor changes in the architectural design. Furthermore, researchers emphasise that the introduction of passive retrofits into informal housing will positively impact residents and serve as an inexpensive solution to health problems caused by overheating and underheating (Kimemia *et al.*, 2020). It is, therefore, possible to argue that knowledge is not enough; there is a need for its proper communication.

The lack of knowledge is not limited to occupants but is also found amongst professionals. For instance, Ojelabi *et al.* (2024) found that construction professionals' knowledge was relatively low. According to Adegoke *et al.* (2023a), awareness of the possible benefits of using VGSs as nature-based approaches to cool buildings is not sufficient. In addition, the lack of knowledge on the part of property managers is one of the major hindrances to the adoption of VGSs during the operation phase (Adegoke *et al.*, 2023b). The results suggest that knowledge-based obstacles exist not only between property owners and their tenants but also amongst those who manage the buildings.

With this view in mind, it becomes incumbent upon policymakers to establish an agreement amongst stakeholders (Adegoke *et al.*, 2026a). This is necessary considering the existing shortcomings in the area of coordination and clarification of systems, policies and energy-saving measures. Moreover, Oladotun (2025) emphasises that there is an existing shortage of experts in tropical passive design.

The skills domain covers the practical competencies needed for implementation. This includes accessible and effective building retrofitting tools and technologies, safety management during long-lasting retrofit activities and sufficient professional/technical capability to perform a successful retrofit (Liu *et al.*, 2020; Stiess and Dunkelberg, 2013). Other barriers to retrofitting are related to logistical issues (Weiss *et al.*, 2012), as well as issues in complying with building regulations (Adegoke *et al.*, 2026a; Wilson *et al.*, 2015). In Arkansas, United States, Wehbi *et al.* (2024) studied the challenges of urban officials, engineers and architects towards the design of the low-carbon multi-generational passive house. In particular, they pointed out the difficulty in thermal design, moisture management and performance modelling as significant barriers.

Overall, the conclusion reached from the reviewed studies is that retrofitting cannot be done alone but requires cooperation from everyone involved. However, most studies assume that stakeholders understand what a retrofit is before they act on it. Whether this pattern holds in contexts dominated by a weak regulatory framework and informal construction remains empirically unknown, as well as how constructs related to knowledge and skill form a cluster of networks with other dimensions of barriers; thus, this study addresses this gap.

2.1.2 Beliefs about consequences and motivation domain. For both developing and developed countries, financial constraints tend to be the most pressing problem (Madushika and Lu, 2023). Initial investment costs tend to come up as the most significant single problem worldwide (Alajmi, 2012; Sodangi and Salman, 2024). Other factors include aspects related to the market for property (Egbelakin *et al.*, 2014), lack of ability to assign value apart from cost savings (Bertone *et al.*, 2018), lack of investment incentives, payback periods, lack of clarity about split incentives (Ernst and Young, 2015; Hrovatin and Zoric, 2018) and uncertainties about prices of green materials (Bertoldi *et al.*, 2021; Ernst and Young, 2015).

A significant retrofit investment is necessary to achieve energy sustainability, and only wealthier companies can conveniently afford the cost involved (Jagarajan *et al.*, 2017). Funding retrofit projects is often difficult for individual owners who do not have proper financial approaches (Baek and Park, 2012). In Nigeria, due to inflation and fluctuating exchange rates, the problem is compounded, considering that there is a lack of proper financing options like long-term loan facilities for retrofitting in the country (PwC Nigeria, 2025). Some of the issues faced when investing include high retrofitting costs, lack of capital and lack of awareness on how to finance such investments through grants and loans (Beavor *et al.*, 2023; Bertoldi *et al.*, 2021). The presence of these barriers is generally dire in sub-Saharan Africa, where the retrofit literature is peripheral (Ejidike *et al.*, 2025).

The process of retrofitting is technically possible; however, for South Africa, homeowners and professionals still regard it as costly and cumbersome due to the difficulty of estimating its payback period (Amoah and Smith, 2024). Similarly, Adegoke *et al.* (2025) observed that motivation drops considerably when there is no proof that the investment made results in positive outcomes. This becomes more difficult considering that the effects are often thermal and health-related and hence cannot be quantified economically (Welch *et al.*, 2023; Zheng *et al.*, 2019).

While financial barriers dominate the literature, less attention has been paid to contexts where there regulations are weak, upfront costs are unpredictable and permit fees are not clearly defined. This study identifies the financial barrier items that tend to cluster together.

2.1.3 Social influences and behavioural regulation domain. Social and behavioural barriers have also been identified in the literature as important. For example, public awareness of retrofit benefits remains poor, comfort gains are misunderstood and cultural preferences may clash with passive measures (Trencher *et al.*, 2016). For instance, the conflict between traditional construction methods and modern ones might be a reason for the challenges faced in their application in Nigeria (Emusa and Idakwoji, 2023). Security, privacy, noise and pollution may make the use of passive cooling less effective (Study Team, 2021). Besides, bioclimatic architecture and passive cooling encounter other obstacles when applied in the tropics since stakeholders often have limited experience with these techniques (Chen *et al.*, 2023).

While landlords pay for retrofitting, tenants receive energy savings (Schleich *et al.*, 2021), become more comfortable (Ma *et al.*, 2012) and are more productive (Fuerst and McAllister, 2011). Dependance on existing rental streams creates hurdles for capital recovery and mutual benefit sharing (Kong *et al.*, 2012; Menassa and Baer, 2014; Rhoads, 2010). Short-term tenants are not beneficiaries of retrofitting, making the property owners less willing, although the long-term benefits can be huge (Alam *et al.*, 2019). In Nigeria, existing tenancy laws have contributed to inequalities in which homeowners have the most bargaining power, tenants lack tenure security and are therefore unwilling to adopt energy-saving measures (Tohinaka *et al.*, 2011). The process of making a retrofit decision can be hindered by different levels of awareness amongst homeowners, property managers and building regulatory authorities (Adegoke *et al.*, 2025). The retrofitting process may also be influenced by different factors such as changing resistance, different interests and a lack of trust (Kim *et al.*, 2020).

As pointed out by Liu *et al.* (2021), property owners remain passive receivers of energy bills due to the fact that they are not actively involved in assessing the performance of their buildings. Moreover, according to Tozer *et al.* (2023), the connection between trust and communication affects the readiness of energy-poor households to participate in retrofitting. This problem is very much relevant in Nigeria because communication, particularly between tenants and building owners, poses a challenge when there is a need for a formal agreement (Ernst and Young, 2015; Liang *et al.*, 2019). While retrofitting requires a coordinated effort amongst various stakeholders, a lack of collaboration remains a critical barrier that is often reported (Amoruso *et al.*, 2018). Other barriers include a lack of societal understanding, inadequate engagement of homeowners, inadequate engagement of tenants, inadequate presentation of information, cultural insensitivity, a lack of support for the adoption of community-based energy generation and a lack of support from clients concerning data observation (Zuhaib *et al.*, 2017).

The expected return of energy-efficient technologies can be weakened by occupant behavior within the building (Sun and Hong, 2017). As pointed out by Tozer *et al.* (2023) in their systematic review on retrofit behaviour in energy-poor households, thermal discomfort and poor quality of the indoor environment cannot trigger any retrofit behaviour without trust-building and health communication. This further supports the notion that the disconnect between occupants experiences and behaviours is socially constructed rather than based on a lack of information.

The link between building quality and occupant behaviour has also been explored through a post-occupancy evaluation approach. The behaviour of the building occupants in relation to hot climatic conditions is based on the aspect of thermal comfort and indoor quality, which are elements that enhance occupant satisfaction (Karimi *et al.*, 2025). This research has not emphasised the perception of the occupants concerning the performance of the building enclosure, but it acknowledges the role played by indoor environmental quality. This discussion can be further expanded with specific reference to the Nigerian context.

For instance, Adegoke *et al.* (2021) established that university students in halls of residence were dissatisfied to some extent by the physical attributes of the built environment compared to the acceptable standards on campus.

2.2 Structural dimensions: institutional theory

2.2.1 Regulative pressures. An important problem facing policymakers in their activities is the creation of a structural and adaptive regulatory environment (Adegoke *et al.*, 2024). Although policies are proposed to promote energy efficiency retrofits, regulatory actions are not necessarily consistent, and the absence of an effective enforcement mechanism may affect the implementation of passive retrofitting measures. While such measures might be viable in some cases, their effectiveness might be hampered by the failure to have consistent enforcement processes (Beavor *et al.*, 2023; Ochedi and Taki, 2019). Retrofitting, according to Xiaoxiang *et al.* (2024), is technically possible, but inconsistent regulations and irrational energy standards could make the process difficult.

It is important to acknowledge the difficult compliance environment prevailing in developing countries (Ernst and Young, 2015). The absence of accredited agencies to conduct evaluations of building performance in terms of energy consumption contributes to significant barriers (He *et al.*, 2015). Also, the absence of standardisation contributes to a loss of trust in the evaluation process. Although retrofitting is mentioned in the national climate change policy of Nigeria, the route to net-zero energy buildings through tackling existing barriers in Nigeria is not clearly defined (Beavor *et al.*, 2023). The reason could be the prevailing uncertainties in the country regarding the potential administrative and financial obstacles that may arise during policy implementation.

Wehbi and Messadi (2024) pointed out that the building codes currently available are insufficient with regard to passive retrofitting, creating confusion amongst architects and engineers. In particular, the residential building sector in Lagos State accounts for 75% of buildings constructed without permission or authorisation. This large proportion suggests that, in addition to the problems associated with regulations, the lack of institutional infrastructure within which the retrofitting process is carried out has been brought about (Ejidike *et al.*, 2025). An important context was further provided by Mukhtar *et al.* (2023), who noted that electricity provision in the region has not yet been realised fully in many sub-Saharan African countries.

Only a few studies are available that examine issues of regulations in contexts where there is an abundance of informal construction. In Nigeria, a structural gap exists for this study to map empirically because the current building codes do not address retrofitting in terms of the barriers stakeholders face. This leaves stakeholders unclear about what to do and who to consult to find solution to their concerns.

2.2.2 Normative and cultural-cognitive pressures. Normative institutional forces shape retrofit strategies based on the professional standards they promote and legitimise. Amoah and Smith (2024) found that the professionals working in the built environment industry have been known to adhere to the current standards and norms provided by the communities within which they operate. The construction sector continues to favour conventional and active technologies on a different scale. In the present situation, the use of passive technologies are often considered to be a regular renovation activity, thus not widely recognised for their significant energy efficiency potential (Adegoke *et al.*, 2025; Solanki *et al.*, 2022). This, therefore, calls for the training of professionals in countries where there is a shortage of retrofit specialists. The professional standards work together with the cultural cognition framework in shaping what is legitimate in making retrofit decisions (Liao *et al.*, 2025). This framework can be supported by a network of barriers from professionals at different levels of operation (Wade and Han, 2024).

Another factor that should be considered when making retrofit decision is cultural cognition. As explained by Adegoke *et al.* (2024), energy retrofitting requires consideration of both the technological elements and materials involved, as well as the social perceptions of the process. Different countries have their own energy retrofit culture. For instance, cost sharing has been a major concern amongst property owners and tenants, as observed in China (Kong *et al.*, 2012). In contrast, homeowners in the UK are more interested in retrofitting properties they privately occupy (Rhoads, 2010). The situation with regard to cultural-cognitive considerations is further complicated in developing countries by the normative rationale of the informal construction sector, which places greater emphasis on using materials that construction professionals are accustomed to, irrespective of their technical viability, than following formal retrofitting procedures (Nwagwu *et al.*, 2024). In the specific case of Nigeria, challenges to passive retrofitting persist despite the fact that there are sociotechnical norms defining "modern" in terms of technology; there are habits of cognition and influential ideas that make such changes difficult (Stephenson *et al.*, 2010). This together highlights issues of enforcement challenges and legitimacy. While this seems to resonate with many other developing countries, there is relative silence on where individual-level and institutional barrier constructs are associated in a weak regulatory environment.

In summary, the review of literature has shown that retrofit barriers have been widely studied. Nonetheless, an important gap persists in weak regulatory settings. Previous studies from this setting often treat retrofit barriers individually, with less attention to the associations between them. However, in some cases, the barriers are associated, thus making it inappropriate to address them independently (Ejidike *et al.*, 2025; Tozer *et al.*, 2023; Xiaoxiang *et al.*, 2024). The limited information about the associations between these barriers justifies the need for this study.

Table 1 presents the 27 items of the barriers, which include knowledge and skills, beliefs about consequences and motivation, social influences and behavioural regulation, regulatory and normative pressures, and cultural-cognitive pressures. Each construct contains three to six items, which reflect the results obtained through the review and instrument validation processes.

3. Methodology

3.1 Instruments and research design

Given that many barriers to passive retrofitting are perceptual and relate to stakeholders' behaviour, self-reported data were considered appropriate for capturing diverse variables. Accordingly, data were collected from stakeholders using questionnaires designed on the Qualtrics platform and interviews. Hence, in this research study, a mixed-methods design was adopted, where both quantitative and qualitative data were analysed and integrated to give reliable findings (Cooper and Schindler, 2014).

To ensure the relevance and clarity of questions contained in the questionnaire, five estate surveyors and valuers (with a minimum of 10 years of experience in property management in Lagos) and two built environment researchers reviewed the study instruments. The final questionnaire included 27 barrier items with a five-point Likert scale ranging from strongly agree (1) to strongly disagree (5), as recommended by Chyung *et al.* (2018). However, it should be noted that these responses represent perceived barriers rather than objectively measured barriers. In addition to questionnaire administration, semi-structured interview questions were asked to gather qualitative data. The interview guide was prepared, focusing on the key issue: to identify key barriers related to the passive retrofitting of residential buildings. Further questions were asked for the sake of following up on individual responses.

3.2 Data collection

The data for this study were collected from three key stakeholders during the operational life of buildings: homeowners, property managers and the officials of building regulation and control

Table 1. Summary of retrofit barriers

Category	Barrier	References
Knowledge and Skills (Knowledge/information-related and technical-related)	Stakeholders' limited/lack of awareness/knowledge or information regarding building retrofit	Alam *et al.* (2019), Amoah and Smith (2024), Kong *et al.* (2012), Ochedi and Taki (2019)
	Confusion and lack of trust due to unclear information	Tohinaka *et al.* (2011), Wise *et al.* (2024)
	Lack of communication with building owners	Liang *et al.* (2019), Zhang and Wang (2022)
	Difficulty in finding reliable professionals to successfully retrofit residential buildings	Alam *et al.* (2019), Chen *et al.* (2023), Hrovatin and Zoric (2018)
	Some residential buildings are difficult to retrofit	Karlsson *et al.* (2013), Zhang and Wang (2022)
	Lack of access to efficient passive tools and technologies for building retrofitting	Liu *et al.* (2020), Stiess and Dunkelberg (2013)
	Safety risk associated with extensive renovation process	Liu *et al.* (2020), Stiess and Dunkelberg (2013), Zhang and Wang (2022)
	Logistics issues relating to passive retrofit material sourcing and transporting	Weiss *et al.* (2012), Wise *et al.* (2012, 2024)
Beliefs about consequences and motivation (Financial-related)	Lack of capital to implement residential building retrofitting	Baek and Park (2012), Beavor *et al.* (2023), Bobrova *et al.* (2021), Jagarajan *et al.* (2017), Madushika and Lu (2023)
	Lack of motivation to invest in retrofitting	Ernst and Young (2015), Hrovatin and Zoric (2018), Jia *et al.* (2018), Zheng *et al.* (2019)
	Long payback period	Ernst and Young (2015), Hrovatin and Zoric (2018), Jia *et al.* (2018), Kong *et al.* (2012), Rhoads (2010), Zheng *et al.* (2019)
	Differing interests of stakeholders	Alam *et al.* (2019), Fuerst and McAllister (2011), Li and Froese (2017), Ma *et al.* (2012), Menassa and Baer (2014), Schleich *et al.* (2021)
	Price fluctuations for green materials	Bertoldi *et al.* (2021), Ernst and Young (2015)
	Limited supply of dedicated financing instruments	Beavor *et al.* (2023), Bertoldi *et al.* (2021), Ernst and Young (2015)
	Difficulties in access to loans and higher upfront payments	Bertoldi *et al.* (2021), Ernst and Young (2015), Hrovatin and Zoric (2018), Jia *et al.* (2018), Madushika and Lu (2023)
	Lack of government subsidies	Amoah and Smith (2024), Zhang and Wang (2022)
	Uncertainty of return on investment	Welch *et al.* (2023), Zheng *et al.* (2019)
	Cost implications and time-consuming paperwork for retrofit project approval	Ernst and Young (2015), Sodangi and Salman (2024)
Social influences and behavioural regulation (Social/behaviour-related)	Poor retrofit/renovation culture amongst homeowners	Amoah and Smith (2024), Liu *et al.* (2021), Tohinaka *et al.* (2011)
	Absence of desire from owners to monitor and record building energy data	Liu *et al.* (2021), Zuhaib *et al.* (2017)
	Lack of interdisciplinary expertise and collaboration	Amoah and Smith (2024), Amoruso *et al.* (2018), Beavor *et al.* (2023)

(*continued*)

Table 1. Continued

Category	Barrier	References
Regulatory pressures (Regulation-related)	Inadequate or lack of overarching government policies, laws, standards, codes or guidelines	Alam *et al.* (2019), Willand *et al.* (2020)
	Lack of long-term strategic guidance	Liu *et al.* (2020), Zhang and Wang (2022), Zou *et al.* (2018)
	Enforcement issues	Xiaoxiang *et al.* (2024)
	Difficulty in meeting building regulation requirements	Wilson *et al.* (2015), Xiaoxiang *et al.* (2024)
Normative pressures (Professional/industry practice-related)	Lack or shortage of qualified institutes capable of assessing and certifying residential building energy performance	Amoah and Smith (2024), He *et al.* (2015), Wise *et al.* (2024), Zhang and Wang (2022)
Cultural-cognitive pressures (Culture-related)	Lack of social acceptability of retrofit measures and confidence in the retrofit process	Kim *et al.* (2020), Liu *et al.* (2021), Wilson *et al.* (2015)

agencies. As described in Figure 1 [1], these stakeholders are usually meant to collaborate even though their roles are different in the retrofit process. The details of the quantitative and qualitative data collected from them are provided in the following subsections.

3.2.1 Survey sample and procedure. A structured questionnaire was used as an instrument for collecting quantitative data from property managers and homeowners. Email addresses for property managers were collected from the directory of the Nigerian Institution of Estate Surveyors and Valuers (NIESV, 2023). The directory had 857 email addresses, out of which 813 were recorded. The questionnaire was sent to 796 potential respondents, out of which 190 responses were recorded, but after data cleaning, only 118 were useful for data analysis. Nine estate surveying and valuation firms (ESVFs) purposively selected across Lagos divisions, including high-density urban and suburban areas, provided the data (Hendriks, 2020). Homeowners were identified through the firms' management records, resulting in 235

Figure 1. Relationship between stakeholders

responses, 163 of which were complete and included in the analysis. Altogether, a sample size of 281 responses was gathered. The sample size exceeded the established guidelines for both traditional and simulation-based EFA (a minimum of 100) (Mundfrom *et al.*, 2005).

3.2.2 Interview procedure. The officials of LASBCA and LASPPPA were consulted to obtain the qualitative data required. Both agencies are instrumental in the building process in Lagos, with LASPPPA handling building plan approvals and LASBCA handling the implementation of LASPPPA's building standards upon the commencement of site work (Venturanna, 2025). Respondents from these agencies were interviewed, and their profiles are presented in Table 2.

The officials had at least five years of experience working with each agency and were actively involved in planning, permitting, inspecting or monitoring the construction and re-construction of residential buildings. Although an institutional analysis of retrofit barriers could include different stakeholders, the objective was to understand institutional mechanisms, rather than conducting an exhaustive qualitative analysis of other stakeholders' experiences, already captured in the survey data from property managers and homeowners.

The official website was the primary point of contact for participant recruitment. Thereafter, the department heads helped in identifying participants who met the set criteria. Each interview, conducted online via Microsoft Teams, lasted for approximately 45 minutes. The sessions were audio- or video-recorded but not after obtaining participants' consent. Based on data saturation, it was ascertained that no new themes emerged after the fifth interview. Consequently, the interview process concluded at the sixth to avoid redundancy in the thematic contents.

3.2.3 Ethical considerations. This study was approved by the University of New South Wales's Human Research Ethics Approval Panel B (HREAP B), with project ID iRECS 7205 dated 8 October 2024. After approval, data collection for this study began. The participants were informed firsthand about the research purpose and the rights they have to withdraw from the process at any time without being penalised. Before proceeding with data collection, informed consent to participate in the survey was obtained through the Qualtrics platform for quantitative data and verbally for qualitative data. The anonymised data was collected via Microsoft Teams, securely stored and only accessible to the research team in accordance with the university's guidelines.

3.3 Data preparation and analysis

3.3.1 Quantitative data. The reliability of the data collected from property managers and homeowners was tested using Cronbach's alpha. For all 27 barrier statements tested, there was a high level of internal consistency in the data, with Cronbach alpha values of 0.944 and 0.928 for property managers and homeowners, respectively. Given the collection and use of self-reported data from stakeholders, common method bias (CMB) was tested using Harman's single-factor test. The results revealed that the first components accounted for 39.017%, which

Table 2. Profiles of interview respondents

Participant	Attributes (agency; years with agency; expertise)
LAS001	LASBCA; 5 years; Civil Engineering
LAS002	LASBCA; 24 years; Town Planning
LAS003	LASPPPA; 11 years; Town Planning
LAS004	LASPPPA; 16 years; Architecture
LAS005	LASBCA; 8 years; Civil Engineering and Geographic Information Systems
LAS006	LASPPPA; 15 years; Architecture

is below the 50% threshold of the total variance. Therefore, CMB is not likely to be a significant concern in this study.

Using IBM SPSS version 28, data analysis proceeded with descriptive statistics performed on the study data. By using the five-point Likert Scale described earlier in Section 3.1, the lower the mean score, the higher the degree of agreement. For instance, barrier statements that scored a mean value of 2 or less reflect higher agreement than 3, the mid point on the scale. This method has also been employed by past construction research (see Osuizugbo *et al.*, 2024).

The exploratory factor analysis (EFA) process was also carried out to minimise the number of factors (Fabrigar and Wegener, 2012). As the name suggests, Principal Axis Factoring (PAF), an extraction method that allows for factor correlation, was used with Promax rotation (kappa = 4). This method emphasises shared variance and it is useful for analysing non-normally distributed data used in this study (Hair *et al.*, 2010). It is also appropriate for analysing the interconnectivity between paired retrofit barriers (see Tabachnick and Fidell, 2019). Two criteria were used for assessing the significance of the findings: firstly, significant items with a loading of 0.5 or above were retained (Costello and Osborne, 2005). Secondly, barrier dimensions with eigenvalues of 1.0 or above were further retained (Kaiser, 1960).

The graphical lasso method was used for the network analysis to explore associations between the dimensions found as barriers (Friedman *et al.*, 2008). Since the normality assumption did not hold true for the given dataset, the authors transformed the Likert scale responses using a non-paranormal semiparametric approach before estimating the precision matrix (Liu *et al.*, 2009). Although this approach allows conducting an analysis without requiring normality, transforming ordinal data through ranks implies the possibility of introducing some approximation error, especially since there are relatively few response options. Accordingly, the resulting network should be interpreted with caution. Instead of causal relationships, the estimated partial correlations represent conditional associations amongst variables and are interpreted as such throughout. The analysis was done using RStudio version 2025.09.2 + 418.

As shown in Table 3, the barrier items were assigned alphanumeric codes for ease of reference and analysis.

3.3.2 Qualitative data. The interview transcripts were analysed to identify prominent themes. Following the methodology proposed by Braun and Clarke (2006), the twelfth version of NVivo software facilitated the systematic coding of qualitative data. The evolving themes were examined to ensure that the barriers to implementation were represented appropriately. Based on the process of mixed-methods triangulation, the qualitative and quantitative results were compared and integrated to create new insights into the barriers to passive retrofitting within the context of Nigeria.

These methodological details are summarised in the research framework, as shown in Figure 2.

4. Results and discussion

4.1 Quantitative results

This section presents the survey's quantitative findings from property managers and homeowners. The analysis commenced with descriptive statistics that rank the barriers to implementing passive retrofitting. However, it is noteworthy that the ranking of mean scores reflects perceptions of engaged stakeholders. The descriptive statistics are followed by EFA to reveal their dimensional structure and network analysis, which shows the association between paired factors at the item and dimension levels.

4.1.1 Descriptive statistics. The first preference was "difficulties in access to loans and higher upfront payments" (BAR16; mean = 1.74) and was closely followed by "lack of government subsidies" (BAR17; mean = 1.75). This result is reinforced by qualitative results (see Section 4.3.2), where one official, LAS006, noted, *"There's no way you can write money off"* The mean scores indicate that all stakeholders perceived loan accessibility and subsidy

Table 3. Alphanumeric coding scheme for retrofit barrier items

Barrier item	Code
Stakeholders' limited/lack of awareness/knowledge or information regarding building retrofit	BAR1
Confusion and lack of trust due to unclear information	BAR2
Lack of social acceptability of retrofit measures and confidence in the retrofit process	BAR3
Lack of communication with building owners	BAR4
Poor retrofit/renovation culture amongst homeowners	BAR5
Absence of desire from owners to monitor and record building energy data	BAR6
Lack of interdisciplinary expertise and collaboration	BAR7
Cost implications and time-consuming paperwork for retrofit project approval	BAR8
Lack of capital to implement residential building retrofitting	BAR9
Lack of motivation to invest in retrofitting	BAR10
Long payback period	BAR11
Differing interests of stakeholders	BAR12
Price fluctuations for green materials	BAR13
Limited supply of dedicated financing instruments	BAR14
Uncertainty of return on investment	BAR15
Difficulties in access to loans and higher upfront payments	BAR16
Lack of government subsidies	BAR17
Inadequate or lack of overarching government policies, laws, standards, codes or guidelines	BAR18
Lack of long-term strategic guidance	BAR19
Enforcement issues	BAR20
Lack or shortage of qualified institutes capable of assessing and certifying residential building energy performance	BAR21
Difficulty in finding reliable professionals to successfully retrofit residential buildings	BAR22
Some residential buildings are difficult to retrofit	BAR23
Lack of access to efficient passive tools and technologies for building retrofitting	BAR24
Safety risks associated with extensive renovation process	BAR25
Logistics issues relating to passive retrofit material sourcing and transporting	BAR26
Difficulty in meeting building regulation requirements	BAR27

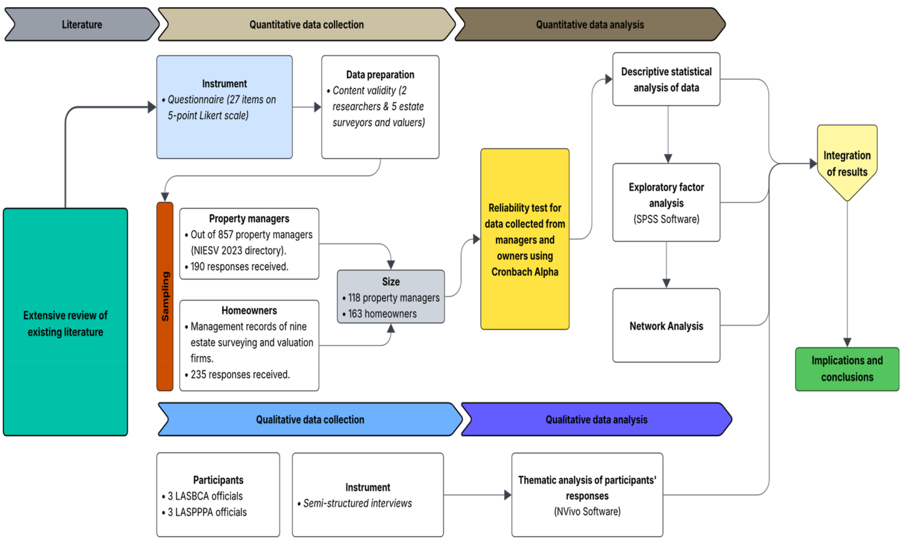

Figure 2. The research framework

availability to be of similar importance since both are issues of immediate financial concern. Importantly, these findings support past studies that found financial issues to be significant challenges in both developed and developing countries (Beavor *et al.*, 2023; Bobrova *et al.*, 2021); Madushika and Lu, 2023). In Nigeria, however, these barriers are intensified by other cost-relatd factors; for example, the removal of oil subsidies and the depreciation of the naira value have resulted in an inflationary spiral, posing an adverse impact on long-term credit markets (PwC Nigeria, 2025). This condition of uncertainty in retrofit financing results from the inability of stakeholders to forecast costs over six months or accurately determine the payback period.

The next most significant factor, beyond financial constraints, was "enforcement issues" (BAR20), which came third with an average of 1.80. As detailed in section 4.3.4, regulatory officials confirmed this gap between policy and practice: "*Clearing a drawing is one thing, but actually ensuring that the person does the right thing on site is another*" [LAS004]. This reflects the existence of enforcement implementation gap, as also revealed by Willand *et al.* (2020). Moreover, the high ranking of this barrier also needs to be considered in relation to the EFA variance distribution. In this regard, enforcement loads onto the compliance and implementation dimension, which only makes up a low variance of 4.869% (see section 4.1.2.4). This goes on to show that poor enforcement is an existing condition in the retrofitting process in Lagos, Nigeria.

The barrier statements concentrated in the middle of the mean range include "differing interests of stakeholders" (BAR12), which ranked 13th with a mean of 2.02; "poor retrofit/renovation culture amongst homeowners" (BAR5) at the 14th position with a mean of 2.03; and "lack of interdisciplinary expertise and collaboration" (BAR7), ranked 15th with a mean of 2.04. The clustering of these barriers between 2.02 and 2.04 indicates moderate significance of these barriers.

The final category of barriers consists of those with lower mean scores. The low rating for "lack of social acceptability of retrofit measures and confidence in the retrofit process" (BAR3), which ranked 27th with a mean of 2.38, contrasts with literature that emphasise the presence of cultural resistance in developing countries (Emusa and Idakwoji, 2023). However, interview responses (as shown in section 4.3.1) indicate that the issue appears not to be strictly social acceptance but rather due to incidental retrofit practices: "*Some that are doing the passive retrofitting don't even know that's what they're doing* . . ." [LAS004]. This pattern, therefore, suggests the need to investigate cultural barriers to passive retrofitting beyond social acceptability.

4.1.2 EFA. 4.1.2.1 Data suitability for EFA. The appropriateness of the data for EFA was confirmed by a Kaiser–Meyer–Olkin value of 0.926, which indicates that it is excellent for further analysis, as shown in Table 4. The KMO value was further supported by a highly significant Bartlett's test of sphericity with χ^2 (351) = 4069.212, $p < 0.001$.

4.1.2.2 Communalities. The range of values obtained in the extraction process was from 0.199 to 0.660. To further improve the results, specific barrier items (BAR11 and BAR15) with low communalities (i.e. less than 0.4) were removed. Most of the initial values retained were greater than 0.5. Details of this analysis are presented in Table 5.

4.1.2.3 Factor extraction and structure. The scree plot (Figure 3) illustrates the first factor's significant explanatory power (eigenvalue = 10.535) before a sharp decline to the second factor (eigenvalue = 2.288), forming the typical elbow indicating meaningful dimensionality.

Table 4. KMO and Bartlett's test of sphericity

Measure		Statistic
KMO measure of sampling adequacy		0.926
Bartlett's test of sphericity	*Approx. Chi-Square*	4069.212
	Df	351
	Sig	0.000

Table 5. Communalities

Barrier item	Initial	Extraction
BAR1	0.415	0.470
BAR2	0.518	0.518
BAR3	0.431	0.421
BAR4	0.491	0.487
BAR5	0.500	0.443
BAR6	0.519	0.491
BAR7	0.543	0.484
BAR8	0.576	0.593
BAR9	0.629	0.614
BAR10	0.550	0.507
BAR11	0.329	0.199
BAR12	0.500	0.449
BAR13	0.625	0.611
BAR14	0.633	0.610
BAR15	0.462	0.395
BAR16	0.588	0.584
BAR17	0.649	0.660
BAR18	0.654	0.582
BAR19	0.617	0.587
BAR20	0.576	0.561
BAR21	0.586	0.593
BAR22	0.586	0.597
BAR23	0.508	0.429
BAR24	0.575	0.511
BAR25	0.496	0.493
BAR26	0.555	0.588
BAR27	0.477	0.412

Note(s): Extraction Method: PAF

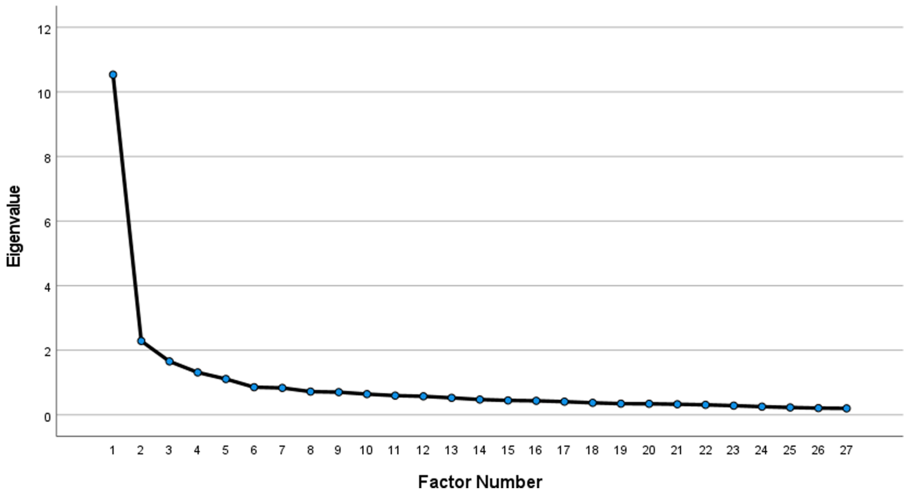

Figure 3. Scree plot

The result of analysis using PAF method revealed a clear factor structure associated with retrofit barriers. The total variance explained metric indicates the variability accounted for by the retained factors (Hair *et al.*, 2010). As shown earlier, the scree test helped find the inflection point in the eigenvalue curve, while the Kaiser criterion identified and retained four dimensions of barriers with eigenvalues greater than 1.0 and factor loadings greater than or equal to 0.5. In detail, Table 6 presents the factor loadings, eigenvalues and variances of each of the four dimensions of barriers.

4.1.2.4 Results interpretation. From Table 6, it is shown that the cumulative variance explained was 58.495%. This indicates a strong coverage of the barrier landscape. The 20 statistically significant barrier items that were retained had factor loadings ranging from 0.506 to 0.897. In other words, items with factor loadings less than 0.5 were removed from the list.

4.1.2.4.1 . Component 1: information and communication (IAC). With a variance of 39.017%, IAC is the leading component and is considered under the knowledge and skills domain of TDF. The dominance recognises the gap in knowledge in today's world of retrofits (Zhang and Wang, 2022). This finding provides a useful explanation for retrofit decisions in a setting characterised by heterogeneous institutional guidance and limited information on energy savings. The knowledge gap amongst stakeholders might affect their decisions to adopt passive retrofitting. However, viewing the issue purely as a knowledge deficit may oversimplify the problem. Qualitative evidence from this study (detailed in Section 4.3.1) shows that homeowners sometimes implement basic passive measures, but they do not recognise them as "energy efficiency" measures; they simply think of them as renovations.

Table 6. Results of PAF with Promax rotation

S/N	Category	Factor loading	Eigenvalue	Variance (%)	Cumulative variance
1	*Information and communication (IAC)*		10.535	39.017	39.017
	BAR1	0.697			
	BAR2	0.654			
	BAR3	0.604			
	BAR4	0.606			
2	*Financial and policy (FAP)*		2.288	8.476	47.493
	BAR13	0.684			
	BAR14	0.677			
	BAR16	0.804			
	BAR17	0.897			
	BAR18	0.657			
	BAR19	0.755			
	BAR20	0.694			
3	*Technical and professional capacity (TPC)*		1.656	6.132	53.626
	BAR21	0.667			
	BAR22	0.725			
	BAR23	0.524			
	BAR24	0.581			
	BAR26	0.760			
4	*Compliance and implementation (CAI)*		1.315	4.869	58.495
	BAR6	0.506			
	BAR8	0.547			
	BAR9	0.529			
	BAR27	0.529			

Note(s): Extraction method: *PAF*; Rotation method: *Promax with Kaiser Normalisation*; Rotation converged after 8 iterations
Items such as BAR5, BAR7, BARs10-12, BAR15 and BAR25 were removed because their factor loadings were less than 0.5

This instance points to the need for terminology standardisation, although whether this alone could shift retrofit behaviour remains an unanswered question that future studies can consider.

4.1.2.4.2 . Component 2: financial and policy (FAP). The FAP component can be linked to the beliefs about consequences domain and regulatory pressures. In simple terms, this component highlights the intricacies of financial constraints and the pressure exerted by institutional regulations. It accounts for 8.476% of the total variance. This goes on to demonstrate how critical the issues related to finance and policy are in the retrofit process (Madushika and Lu, 2023; Oladotun, 2025). In particular, the relevance of this construct might be attributed to economic consequences resulting from the removal of subsidies on fossil fuels in Nigeria (Elusoji, 2024). According to Beavor *et al.* (2023), these factors, as well as financial instrument fragmentation, can make access to loans a herculean task. In the same vein, it may be challenging to deal with high upfront costs of retrofitting if no clear provision is made for financial incentives within the existing regulatory framework.

While financial issues were perceived as the main barriers in the descriptive statistics, the underlying data structure points to information and communication-related barriers as being more widely distributed or interconnected amongst respondents. The discrepancy between what the stakeholders perceived and what was found through the data highlights a topic that needs further investigation.

4.1.2.4.3 . Component 3: technical and professional capacity (TPC). The TPC component, which can be linked to the knowledge/skills domain and normative pressure, highlights that technical and professional capabilities are a notable barrier. Put simply, when enough professional capacity is not available, this can lead acts as a hindrance to development. This lines up with the findings of earlier studies (Alam *et al.*, 2019; Allouhi *et al.*, 2015). However, it is necessary to understand from the existing literature that the problem cannot be sufficiently described as an absence of professional skill sets alone. As an illustration, in most developing nations, local experts tend to understand how to design buildings that can withstand climate conditions, with emphasis on proper ventilation, shading and material selection. However, the major hindrance is that certification authorities overlook the expertise of these individuals, branding them as “unskilled” practitioners. In addition, as shown in Section 4.3.3 of this paper, global certifications like Leadership in Energy and Environmental Design are costly and thus not in wide use, which further limits the formal acknowledgment of local expertise.

4.1.2.4.4 . Component 4: compliance and implementation (CAI). This component explains regulative pressures from the institutional theory. It demonstrates that stakeholders encounter difficulties associated with compliance in the implementation of passive retrofit measures, although this challenge accounts for a small percentage of the total variance (4.869%). The complexity of the procedural aspects of compliance, as identified by Sodangi and Salman (2024), can also be a discouraging factor in private sector engagement. This problem could be compounded by the lack of clear issuance of permits, difficulty in meeting building requirements and a lack of alignment of the requirements with current performance standards. CAI also highlights the discrepancy that exists between policy formulation and implementation. From an institutional theory point of view, there is potential for regulations and processes to result in problems, despite the benefits of retrofitting.

The four components together highlight key barriers to passive retrofitting of residential buildings in Lagos. All together, these factors account for 58.5% variance and appear structurally linked, such that poor information, weak policy, limited professional expertise and slow compliance may not operate in isolation. Instead of being treated as separate barriers, these components might show some associations between them when paired.

4.1.2.5 Reliability assessment of factors. A Cronbach’s alpha value of 0.779 indicated that the composite scale, consisting of the four-factor construct identified, was reliable (Nunnally and Bernstein, 1994). As shown in Table 7, the analysis of the item statistics indicated that the items’ total correlations provided acceptable values of the adjusted item-total correlations, ranging from the lowest item-total contribution to the scale, with a value of 0.572 for IAC, to CAI, with a value of 0.683, which was the highest contribution to the scale. However, if any of

Table 7. Item-total statistics

Components	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's alpha if item deleted
IAC	31.8434	98.740	0.572	0.740
FAP	27.4947	64.358	0.623	0.739
TPC	29.1922	83.770	0.591	0.721
CAI	32.5480	96.984	0.683	0.705

the items are deleted, Cronbach's alpha will reduce to a range between 0.705 (CAI) and 0.740 (IAC), indicating that all four components were necessary conditions for the final scale computation.

4.2 Analysis of association networks

Network analysis was conducted at two levels, item and dimension, each answering a different question. The item level identifies which specific individual barrier shares direct conditional associations to another individual barrier. On the other hand, the dimension level helps to understand whether broader barrier clusters share a common variance. Both perspectives are reported and interpreted as follows:

4.2.1 Item-level analysis. Partial correlation coefficients at the item level represent the unique conditional association between two barrier items while controlling for all others. Due to the shrinkage imposed by regularisation, coefficients at the item level are relatively small and are not directly comparable to conventional bivariate correlation benchmarks (Epskamp and Fried, 2018). Having said that, the coefficients (r) found in this study range from 0.15 to 0.33 (details of analysis are provided in Table 8).

Items within the same dimensions were most notably associated. This association between BAR21 and BAR22 ($r \approx 0.33$) within the TPC dimension suggests that the problems of finding reliable professionals and a lack of certification organisations occur together as one problem (Alam *et al.*, 2019). The situation is the same for BAR8 and BAR9 ($r \approx 0.27$) from the CAI

Table 8. Partial correlations between barrier items estimated via non-paranormal graphical lasso

Item 1	Item 2	Partial correlation
BAR21	BAR22	0.3299349
BAR22	BAR21	0.3299321
BAR24	BAR23	0.3092872
BAR23	BAR24	0.3092808
BAR9	BAR8	0.2682907
BAR8	BAR9	0.2682858
BAR18	BAR19	0.2531617
BAR19	BAR18	0.2531482
BAR2	BAR1	0.2392985
BAR1	BAR2	0.2392939
BAR16	BAR17	0.2145293
BAR17	BAR16	0.2145205
BAR17	BAR13	0.2039531
BAR13	BAR17	0.2039430
BAR2	BAR4	0.1849068
BAR4	BAR2	0.1848973
BAR21	BAR26	0.1825478
BAR26	BAR21	0.1825473
BAR14	BAR16	0.1501811
BAR16	BAR14	0.1501758

dimension, which focuses on procedural difficulties and financial barriers. Furthermore, the connection between BAR18 and BAR19 (with $r \approx 0.25$) under FAP points to the inadequacy of policy and strategy. These results are consistent with Beavor *et al.*'s (2023) claims that surmounting such barriers is crucial for successful organisational performance. The association between BAR1 and BAR2 under the IAC dimension ($r \approx 0.24$) reinforces the claim that low awareness about retrofitting can cause misconceptions (Wise *et al.*, 2024).

Most of the items across dimensions did not show any significant conditional association. This suggests that, in cases of weak regulation, some of the barriers exist independently because there is no institution that connects them. On the other hand, findings of research conducted in developed environments revealed that policies and guidelines lead to stronger connections between items in different dimensions (Alam *et al.*, 2019; Wise *et al.*, 2024). An exception to that is BAR17, carrying cross-dimensional edges to BAR16 at $r \approx 0.21$ and BAR13 at $r \approx 0.20$. The association between provision of subsidies, availability of loans and uncertainties about material prices is consistent with the findings of Bertoldi *et al.* (2021) and Liang *et al.* (2019). It suggests that the barriers strongly exist in places where green financial ecosystems are not yet fully developed. Like Tozer *et al.* (2023) suggested, addressing BAR17 especially can be help to connects the divide.

It is important to mention that item-level partial correlations alone do not provide sufficient evidence for a systemic interconnection. Dimension-level inference is required here, where total variance provides more significant correlations as discussed in Section 4.2.2.

4.2.2 Dimension-level analysis. The dimension-level analysis is based on aggregates formed through EFA, which results in more apparent associations compared to the item-level analysis. The large difference in strength between correlations in item-level (r) and dimension-level beta (β) is expected since dimension-level measures explain more variance in comparison with the variance explained by the pairing of two items. Amongst all four dimensions of the aggregates, there were significant bidirectional associations with β from 0.72 to 0.90 and $p < 0.01$ (see Table 9 and Figure 4). This result supports previous studies that emphasise the complicated associations between barriers to retrofit (Trencher *et al.*, 2016).

The strongest associations were observed between two barrier dimensions (CAI → FAP: $\beta \approx 0.90$; FAP → CAI: $\beta \approx 0.85$), as also revealed by Beavor *et al.* (2023) and Sodangi and Salman (2024). When approval pathways are unclear and permit costs are unpredictable, homeowners cannot plan retrofit costs with confidence. The strength of this association suggests that financial barriers manifest together with unpredictable institutional arrangements, as opposed to what obtains in developed countries (see Alam *et al.*, 2019).

The associations between CAI and TPC ($\beta \approx 0.75$) and TPC and CAI ($\beta \approx 0.80$), respectively, align with the finding that regulatory vagueness and professional uncertainties go

Table 9. Significant regression pathways between dimensions

Predictor	Outcome	β	*p*-value	Significant
CAI	FAP	0.8958261	9.883300e-89	True
FAP	CAI	0.8496236	9.883300e-89	True
IAC	CAI	0.8110366	1.824180e-62	True
CAI	IAC	0.7788923	1.824180e-62	True
CAI	TPC	0.7507411	5.904130e-58	True
TPC	CAI	0.8036215	5.904130e-58	True
IAC	FAP	0.8098873	4.618887e-57	True
FAP	IAC	0.7376739	4.618887e-57	True
FAP	TPC	0.7161682	2.517399e-54	True
TPC	FAP	0.8083018	2.517399e-54	True
IAC	TPC	0.7439284	6.593809e-53	True
TPC	IAC	0.7647676	6.593809e-53	True

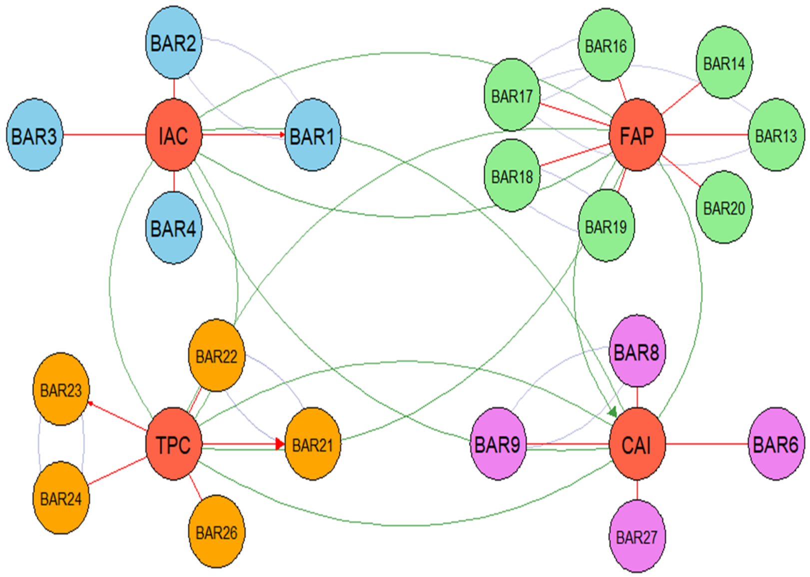

Figure 4. Clustered network

together in situations where there are no clear definitions of retrofitting practices (Alam *et al.*, 2019; He *et al.*, 2015). The key rationale behind compliance issues is that any ambiguity or inconsistency in implementing building codes may lead to additional professional uncertainties in terms of defining standards and create disincentives for formal certification. In the absence of regulations that outline definitions of passive retrofitting and its service providers, professional capacity will not be able to organise itself around a defined practice. According to qualitative data, competent craftsmen with an understanding of passive designs exist, but there are no official certifications or qualifications through which they can be formally recognised. A comparable trend is observed in China even though the country's more developed institutional environment means the association is less pronounced (see Liao *et al.*, 2025).

The strong associations, IAC → FAP ($\beta \approx 0.81$) and FAP → IAC ($\beta \approx 0.74$), correspond to evidence that cost opacity worsens when there is not a clear understanding from stakeholders of what they regard as valuable (Zheng *et al.*, 2019). Bertoldi *et al.* (2021) revealed that the implementation of financial instruments is largely contingent on information clarity, and hence, the ambiguity in information can affect financial decisions. The correlation between IAC and TPC (IAC → TPC: $\beta \approx 0.74$; TPC → IAC: $\beta \approx 0.76$) suggests that, in cases where there is no clarity concerning what retrofit terminology means, practitioners encounter difficulties in executing a certain standard practice. This corresponds to past studies on the association between information/communication and professional expertise for building retrofitting (Liao *et al.*, 2025; Wise *et al.*, 2024).

Overall, the strong conditional association between all four factors suggests that any institutional context creating barriers in one cluster will most likely create barriers in other categories at the same time. Therefore, the solution of a single cluster of barriers, without taking into account its association with other clusters, may not have a significant effect on the entire picture of barriers.

4.3 Qualitative results

Qualitative data from six officials from LASBCA and LASPPPA offered additional insights into the barriers associated with the passive retrofitting of residential buildings. The thematic analysis results, which revealed contextual factors unique to the densely populated urban environment of Lagos, Nigeria, are discussed under four key themes: incidental retrofit practice, financial constraints and cost opacity, capacity and certification deficits, and physical and socio-cultural barriers. Each of these themes is discussed below.

4.3.1 Incidental retrofit practices. One of the key themes recognised by the interview participants is incidental retrofit practices. This is a situation where people undertake non-energy-motivated renovations without recognising the energy-efficiency implications of their actions. This scenario was revealed by one of the participants.

> Some that are doing the passive retrofitting don't even know that's what they're doing. They just believe they're just doing it . . . number one, there's no awareness about passive retrofitting. [LAS004]

In this scenario, passive measures are mostly planned to achieve aesthetic value, for example, rather than to achieve energy efficiency. From another perspective, what people regard merely as "renovations", "repairs" or "alterations" often include passive measures that formal frameworks should normally classify as "energy efficiency retrofits". This adds further nuance to the knowledge and skills domain. In cases where the need for retrofit measures is not perceived as resulting from policy, the practice is initially adopted and its "energy efficiency" co-benefit is later recognised. This paradox in a weak regulatory context reveals the problem of classification, which makes it easier for homeowners to evade the required assessment for retrofit activities.

The results have clearly shown that IAC contributed the largest proportion of variance, which was 39.017%, as shown in the quantitative data. The problem is not about understanding; it is about characterising retrofit actions. Within this context, terminological vagueness could be a driver of adaptive resistance to institutional friction rather than simply ignorance. This is consistent with cultural-cognitive pressures, where the mutual comprehension of terms like "renovation" and "repair" is perceived to influence behaviour more than the policy requirements for retrofitting. In Lagos, people tend to adopt basic passive measures, such as those that require enhanced ventilation, shading, etc., based on their experience of inconsistent power supply, extreme temperature conditions and densely populated living conditions. In addition, regulatory agencies use terminology that somehow varies from specific global terminology, such as "energy efficiency retrofits," while popular culture favours "renovations" in the form of preventive or reactive maintenance, rather than explicit energy efficiency. While certain passive measures sometimes feature in this current practice, there is a need to establish a unified system that largely specifies what constitutes energy-efficient retrofitting.

4.3.2 Financial constraints and cost opacity. The literature clearly indicates that the major barrier to undertaking retrofits is financial in nature. This argument was likewise supported by participants, although with a specific emphasis on initial costs, which is in line with Alajmi's (2012) findings. It also underlines the perspectives of TDF from the perspective of *beliefs about consequences domain*, which can be used to mean that retrofitting has economic consequences that investors have diferent perceptions about, especially where there is no clear guidelines. A similar view was shared by one of the participants, who noted that

> There's no way you can write money off. [LAS006]

Citing the example of a man who depends solely on the rent from his property, the participant further provided the following explanation.

> I don't think the man can raise any money from anywhere. . . . unless somebody or banks or financial institutions give a loan to him to do such a project. [LAS006]

This challenge is further intensified by local economic volatility and import dependence, according to LAS001, who noted: "*If we can't even get those materials here in Nigeria, and we* *have to be importing . . . people will not want to buy into that idea . . . people would rather want to spend their money on something else."*

This is important because it is one level beyond the *regulative pressures* discussed by institutional theory. It provides a greater understanding of the role that the unpredictability and lack of certainty about the costs imposed by the regulatory environment contribute to the psychological challenges. These interviews shed more light on the reasoning behind the FAP component, which only represents 8.476% of the variance. It is because the financial challenges become even more pronounced when stakeholders are unable to discern the economic benefits of "energy efficiency" versus "renovation".

Furthermore, the total cost of obtaining permits is not always known from the onset. This was revealed by one of the participants, who noted,

> It's not until they get there that they will now say this is your assessment; this is what you'd pay. And you'd be like, ah, something million. I didn't plan for this.[LAS001]

These narratives highlight the need to have access to clear information to address the burden posed by high and opaque costs. Without addressing these issues, financial barriers will continue to rank high amongst the barriers to retrofit implementation in developing countries.

4.3.3 Capacity and certification deficits. Capacity is yet an important barrier identified by the participants. For example, LAS005 stated,

> . . . another barrier is a lack of capacity, especially for the professionals.

The issue of capacity is arguably critical at multiple levels: micro, meso and macro. At the micro- and meso-levels, built environment professionals play significant roles in terms of acquiring the requisite expertise to properly guide investors, which is why the participants recommended training as an essential mechanism for capacity building. At the macro-level, however, efforts to build capacity through building regulation frameworks face limitations because of the complex and bureaucratic nature of approval processes, which discourage compliance (Ojelabi *et al.*, 2017). Over time, nonconformity may become normalised, and people may feel less obligated to follow rules. These factors may further explain why approximately 75% of buildings in Lagos are constructed without proper approvals (Ugbodaga, 2024).

Lack of local certification was mentioned as another area of concern in building retrofitting. This point was further reinforced by one of the participants.

> . . . government bodies linked up with private sectors will come together and set up a certification process that is applicable to us in this country? So, financial institutions can use these certificates to issue loans and also monitor how well these people are complying with these measures that they claim they are implementing. [LAS005]

These results contribute to the existing literature by showing the challenges posed by global certification programmes in developing nations, particularly where compliance-related issues (CAI, 4.869% variance) need to be treated carefully to avoid demotivating retrofit investments (Sodangi and Salman, 2024). The qualitative emphasis on unpredictability and institutional constraints explains why enforcement issues ranked third in the descriptive statistical analysis despite appearing in a lower-variance EFA component.

While research in developed contexts often assumes that institutional frameworks deserve trust and compliance (Alam *et al.*, 2019; Wise *et al.*, 2024), an important question that may require further investigation is the understanding of why stakeholders need to engage in the face of enforcement unpredictability and legitimacy deficits.

4.3.4 Physical and socio-cultural barriers. Lagos's urban morphology creates constraints rarely elaborated in existing literature. Dense development and neighbours building to land boundaries make passive measures difficult. This point was confirmed by one of the participants, who noted,

> When you want to talk of building orientation . . . the only way you can have his building is orientation of the land facing the road. [LAS004]

Violations of setback requirements obstruct natural ventilation, as the same participant illustrated with the example of a property owner who makes retrofitting difficult for owners of his or her adjoining plot because: *"Already, s/he has created a wall that is not allowing air to circulate well"* [LAS004]. This observation correlates with the results revealed by Karlsson *et al.* (2013) on the problems related to urban density.

The participants' responses suggested that such barriers present cultural-cognitive pressures, meaning that existing land use and patterns of settlement could shape what is considered normal for achieving energy efficiency in buildings. From another pperspective, the profit-oriented build-sell model developed by builders and popular sentiment against the government make such robust hindrances:

> What they are after is their profit . . . they are not the ones staying there. So, they are less concerned. [LAS002]

> They would just think it's another . . . government's way of trying to look for money. [LAS001]

Consistent with the *social influences and behavioural regulation domain* of TDF, these findings revealed that industry norms that prioritise profit, as well as social pressures that reduce the need for builders to be accountable for long-term building performance, guide builders' actions.

Distrust of government is perceived to influence builders' willingness to follow formal guidance and enforcement. There is a significant enforcement gap in ensuring the approved drawings and specifications are actioned on site: *"Clearing a drawing is one thing, but actually ensuring that the person does the right thing on site is another."* [LAS004].

This statement explains that information campaigns alone cannot effect change without strong policies and profit-driven motivations that align with owners' goals and the development of trust in the government (Zhang and Wang, 2022).

In summary, the interviews uncovered some interesting findings: some stakeholders in Lagos are already implementing some passive retrofit measures; they recognise them ordinary repairs or renovations, rather than as a means to energy efficiency. They are usually motivated by the practical need to achieve indoor comfort. Aside from the incidental retrofit practice, officials highlighted other barriers, such as unpredictable costs, a lack of local certification standards and distrust in government processes, though these barriers play out differently. The highly-dense characteristics of Lagos and the build-to-sell culture of developers create conditions that are amenable to standard policy instruments. This suggests the need for specific actions provided in this study.

4.4 Integration of results

Quantitative and qualitative findings from this study revealed multiple barriers under weak regulatory conditions. According to the results of the descriptive statistics, the issue of finances emerged as the main barrier in the views of both property managers and homeowners, with cost considerations taking precedence amongst other barriers. However, EFA revealed that IAC barriers are structurally the most prominent in the data, accounting for the highest proportion of explained variance amongst the barrier dimensions. This difference between stakeholders' perception of financial issues as the most experienced barrier and the data structure (indicating IAC barriers as the most prominent) suggests that the most visible challenges may not always be the most foundational. Therefore, empirical research is required to better understand this experience.

Qualitative interviews with regulatory officials further highlighted incidental retrofit practices. Many homeowners reportedly view passive measures simply as renovations, not as energy efficiency interventions. Accordingly, many times these informal practices go unnoticed in the formal context of sustainability or energy frameworks, which makes it difficult for policy interventions to take place (Beavor *et al.*, 2023).

At the item level, network analysis indicated that barrier items display a complex web of associations, with several items acting as bridges between different types of barriers. Moving to the dimension level, the network analysis found strong positive associations amongst all four barrier clusters. This pattern implies that the stakeholders encounter substantial challenges in more than one area at a time. This further highlights the associated nature of retrofit barriers in this context.

As shown in Table 10, this study recommends a framework for understanding retrofit barriers in the context of Lagos State and offers some policy suggestions.

From this framework, several insights emerge. Conceptual fragmentation is the first insight reflected by the 39.017% variance in the IAC dimension and misconceptions due to terminologies, as explained by the qualitative findings in this paper. The second insight, legitimacy deficits and practice-policy decoupling, relates to CAI barriers, and helps to reduce the high proportion of sustainable renovations undertaken without the necessary permits. Another perspective on the issue is revealed through the TPC dimension, which suggests that while skilled artisans and indigenous expertise exist, there is no local mechanism through which these can be certified. Furthermore, cost opacity is the third insight arising from the FAP dimension. The strong connection between IAC and FAP shows that cost barriers are amplified when classification is unclear. This is consistent with LAS001's statement that fees are unknown until application. The last insight, practice-policy decoupling, is reflected by the strong bidirectional links that exist between CAI and FAP. This suggests that compliance and

Table 10. Framework for understanding retrofit barriers in weak regulatory contexts

Barrier component	What is widely known?	Insight	Policy suggestion
IAC	Knowledge gaps about retrofit options and benefits	Conceptual fragmentation arises from terminological displacement and institutional signal conflicts, resulting in stakeholders' inability to classify implemented practices within established sustainability frameworks	Standardise terminology across government/ professional/local discourse before awareness campaigns
CAI	Bureaucratic burden; process complexity	Legitimacy deficits and practice-policy decoupling cause widespread non-compliance, enforcement gaps, and government distrust, prompting rational system avoidance	Build trust through demonstration projects using public residential estates before enforcement mandates
FAP	High upfront costs; problem with cost affordability	Cost opacity and policy gaps: Unpredictable permit fees, unclear incentive levels, and currency fluctuations result in psychological barriers that surpass absolute costs	Ensure cost transparency and fee calculators before implementing subsidies
TPC	Skill shortages; training gaps	Indigenous expertise unformalised: International credentials are expensive, while bioclimatic knowledge remains implicit, resulting in existing competencies being unrecognised by formal systems	Develop locally credible certification documenting artisan/ contractor expertise before scaling training

implementation, as well as financial and policy, complement each other. This argument was also highlighted by LAS004, who noted that *"clearing a drawing is one thing; ensuring on-site compliance is another"*.

This framework links to theory in new ways. While the TDF is often interpreted as positing a linear relationship between knowledge and behaviour, the findings illustrate that the association between these factors may be more complex in the context of a developing country. For instance, there may be attempts by stakeholders to improve ventilation without referring to them as energy-efficient interventions. On the other hand, while institutional theory highlights the importance of regulatory pressure and normative expectation, 75% rate of non-compliance with building regulations indicates a lack of legitimacy and the role of cultural-cognitive pressures (indigenous knowledge). The high β values (0.72–0.90 range) further suggests that rationalised perceptions may result in regulatory opacity, although this interpretation requires empirical validation.

5. Implications

5.1 Practical

The large variance of the IAC dimension shows that a transparency deficit is considered a key barrier. Network analysis revealed that barriers at the dimension level are strongly associated; this pattern, therefore, suggests that targeted actions will be most effective. Addressing IAC alongside FAP, TPC and CAI is theoretically more consistent with the barrier structure identified. In environments with weak institutions, results suggest the need for policymakers to start with the phased approaches suggested below.

(1) Phase 1 (institutional foundations): Actions such as distinguishing "passive energy efficiency retrofits" from general renovation, introducing a user-friendly online permit calculator, and training staff to standardise retrofit classification can directly address issues related to information and communication, which emerged as structurally prominent in the EFA results.

(2) Phase 2 (indigenous legitimacy): Projects such as developing a passive retrofit certification pilot in Lagos, certification of artisanal skills and involving professional bodies in recognising informal competencies could be crucial in addressing some of the capacity barriers that exist. These strategies may strengthen recognition and support more intentional retrofit practices aimed at achieving local, national and global energy efficiency objectives.

(3) Phase 3 (financial deployment): The introduction of subsidies and financial instruments can be designed to be consistent with the network analysis results, which show that financial and policy-related barriers are centrally connected to information and communication as well as compliance and implementation.

This evidence-informed, phased approach aligns with the interconnected and multidimensional barrier structure revealed in this study and is, therefore, more appropriate than conventional, isolated interventions.

5.2 Social

The research findings are of considerable significance in real-life situations in Nigeria and similar developing countries. Since informal housing is rampant, as indicated by the extent of variation explained by IAC-related barriers, which amounts to approximately 39.0%, it is apparent that formalisation of the informal housing sector may offer a better starting point than retrofit projects. Through the definition and promulgation of retrofitting guidelines, terminology standardisation and explicit retrofit classification appear promising for reinforcing and validating traditional practices in markets where these actions have been widely undertaken. Furthermore, the identification of barriers associated with finance using EFA and network analysis suggests that the traditional approach to long-term green finance is incompatible with reality for many homeowners. In response to this situation, more flexible funding methods such as short-term microfinance could lead to gradual improvements, but they will not be sufficient to undertake a complete retrofit intervention.

The results underscore the need to consider, at a structural level, what a viable local green lending ecosystem might look like in practice. Given the role of private developers in driving the build-to-sell mindset, it is observed that there is a considerable degree of interrelationship between the financial, formalisation and other barriers to retrofitting. The strong associations amongst the factors of FAP, CAI and TPC ($\beta \approx 0.72$–0.90) suggest that the issues related to certification, incentives and regulations have to be addressed at the same time instead of separately in a way that reflects actual stakeholder behaviour and market dynamics.

5.3 Theoretical and educational

These findings build on retrofit theory by revealing the association between paired barrier dimensions in weak regulatory environments ($\beta \approx 0.72$–0.90, $p < 0.01$) compared to developed countries. Incidental retrofit practices highlight the prevalence of behaviour that falls outside the scope of the typical behavioural-change frameworks, such as the TDF framework, which assumes that people act once they become aware of retrofitting. In this case, there is a need to clarify what renovation actions double as energy-efficient retrofitting. This will ensure that existing informal practices are formally recognised rather than overlooked.

A lack of local certification and the occurrence of incidental retrofit practices may be indicative of a shortfall in training in the construction industry. Professionals trained without a working vocabulary for passive retrofitting or frameworks for evaluating informal building modifications as energy interventions cannot support the certification agenda this study proposes. Retrofits need to be classified, and the informal sector needs to be integrated into the curriculum of built environment programmes. The documentation of artisanal knowledge can be used for two purposes: certification and the creation of contextually relevant teaching aids that may be absent in foreign textbooks.

6. Limitations

This study is not without some limitations. First, this study has not fully captured the complexity of Lagos in terms of the sample size of the stakeholders considered. Despite being sufficient for data analysis, caution needs to be exercised when applying the research findings to residential buildings in Lagos and cities with different characteristics in Nigeria and beyond. Second, the use of NIESV directories of property managers and firms suggests a level of skewness in the sample towards the organised end of property management and likely under-represents property managers and homeowners operating outside a formal arrangement. The results might not be widely generalisable because informal sector views on barriers and adoption could be very different from those reflected in the NIESV directory.

Third, respondents were not asked if they had ever tried to passively retrofit their buildings. The findings rather reflect perceived barriers amongst a general population of homeowners and managers rather than those with direct retrofit experience, which may overstate or mischaracterise certain barriers. As there are energy inefficiencies associated with most buildings in Nigeria, it is important to capture stakeholders' subjective opinions about such barriers, particularly amongst homeowners in Nigeria. This may provide additional insight into how such barriers can be overcome. Looking towards further work on the topic, a question about experience with retrofits would help researchers compare the perceptions of stakeholder groups. Lastly, the different cross-sectional nature of the study meant that the evolution of retrofitting barriers was not studied. Furthermore, the selection of officials from LASBCA and LASPPPA based on their regulatory oversight capacity meant that perspectives from developers, occupants, artisans and financial institutions were not captured in the interviews.

Future research can incorporate stakeholder groups because of their important role in the process of retrofits. Longitudinal research might reveal whether the barriers change over time with growth in capacity or whether the formalisation just changes the informal practices. Other cities from sub-Saharan Africa at different levels of legislative development (like Nairobi, Accra, Dar es Salaam, and others) need to be considered to understand if there is any regional pattern in the interrelations between the barriers.

7. Conclusions

This study investigated the barriers to passive retrofitting in weak regulatory environments such as Lagos, Nigeria. The study found that barriers are expressed in a manner different from what is normally seen in developed environments. Through a mixed-method research approach comprising EFA of 281 surveys and thematic analysis of six interviews with building regulations officers, four types of barriers were established: information and communication (IAC, 39.0%), financial and policy (FAP, 8.5%), technical and professional capability (TPC, 6.1%) and compliance and implementation (CAI, 4.9%). Network analysis showed that barriers are part of a network (pairwise $\beta = 0.72$–0.90; $p < 0.01$). This indicates that the barriers reinforce each other and are mutually inclusive. Additionally, the qualitative data analysis identified the possibility of passive retrofitting of buildings taking place incidentally without formality. These activities are outside of an explicit policy.

The research proposes an approach in line with the above findings. These include standardising the terminology used by the government, professionals and local community; launching a pilot project for developing indigenous certification; setting cost structures; and practising formalisation through documentation of the indigenous knowledge before undertaking any awareness campaign, subsidy or compulsory measures. It is important to confirm whether there is a correlation between improved formal capacities and barriers or invisibility. Formalisation can lead to increased recognition but may also undermine valuable informal knowledge if not designed inclusively.

Existing measures for climate change adaptation may be missing informal adaptations or underestimate them and may therefore result in the sub-optimal allocation of resources and inappropriate policy transfer from developed countries, as the policy context for sub-Saharan Africa suggests similar conditions. In Nairobi, for example, the process of standardisation could start with an analysis of existing practice. Demonstration projects can be a beneficial starting point in places like Dar es Salaam, where there is a lot of building activity, but the regulatory structures are poorly coordinated, underdeveloped and often poorly implemented. The policy recommendations made for Lagos and similar contexts explicitly include passive retrofitting but do not define it in general building codes or regulations. This can be done by establishing a policy document, which is currently lacking, and supporting it with pilot projects, particularly in relation to public estates. Cost schedules and an online calculator should also be introduced, as well as the certification of artisanal skills used to date. If these are lacking, the average awareness campaign or subsidy will likely generate little interest.

To conclude, the need for proper application of passive retrofitting technologies in urban areas like Lagos has been identified. The retrofit process needs to be comprehensible, affordable and beneficial to those who retrofit their buildings. The barrier framework identified in this study will support successful retrofit implementation once barriers associated with conceptual fragmentation, legitimacy deficits, cost opacity and informal indigenous expertise are tackled. This framework is significant for practice, academic and applied studies in the Global South.

Ethics statement

This study received approval from the University of New South Wales' Human Research Ethics Approval Panel B (HREAP B) under project ID (iRECS 7205) on 8 October 2024.

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Note

1. Owners and property managers (Pardo-Bosch *et al.*, 2019).

Acronyms

The following acronyms are used in this manuscript:

TDF	Theoretical domain framework
EFA	Explanatory factor analysis
IAC	Information and communication
FAP	Financial and policy
TPC	Technical and professional capacity
CAI	Compliance and implementation
LASBCA	Lagos state building control agency
LASPPPA	Lagos state physical planning permit authority

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Corresponding author
Ayodele Samuel Adegoke can be contacted at: a.adegoke@unsw.edu.au