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Adoption and Utilisation of Hidden Roof Construction in Ghanaian Urban Housing: A PLS-SEM Study

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Abstract

This study investigates the adoption and utilisation of hidden roof construction as an innovative alternative to traditional roofing systems in Ghana's urban housing. Although hidden roofs offer advantages in climate adaptability, aesthetics, and cost efficiency, their adoption remains limited. Using a survey-based partial least squares structural equation modelling approach, this study identifies the factors influencing their acceptance and use. Quantitative data were collected through field surveys from residents and construction professionals within the Kumasi Metropolitan Area. A structured questionnaire was administered using purposive and convenience sampling, yielding 175 valid responses from a total of 220 distributed questionnaires (79.5% response rate). Findings indicate that hidden roof systems are valued for their climatic suitability, particularly their resistance to water leakage and reduced heat absorption, alongside their efficient drainage design. Aesthetic appeal, cultural relevance, and ease of maintenance also emerged as key determinants of positive perception and adoption. Structural analysis confirmed significant positive relationships between design concept, aesthetic and social values, sustainability, functionality, and overall acceptance. The study provides practical guidance for architects, engineers, developers, and policymakers seeking to promote sustainable, user-centred roof design in tropical urban contexts. Findings are, however, limited to Kumasi and may not fully generalise to other Ghanaian cities.

Keywords: buildings; hidden roof; housing; roof construction; roofing; roof design

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1. Introduction

Over the past few decades, the global construction industry has undergone a significant transformation due to advances in technology, changing urban landscapes, evolving

aesthetic preferences, and a growing emphasis on sustainability [1]. Roofing systems, as integral components of building envelopes, have evolved accordingly. Modern flat, green, and hidden roofs are increasingly replacing traditional pitched and thatched types in many regions [2]. Beyond functional considerations, factors such as climate, cultural preferences, and the global spread of minimalist architectural styles have shaped this shift.

Hidden roofs, typically characterised by parapet walls that conceal the roof structure, have become particularly popular in North America, Europe, and parts of Asia [3,4]. Their sleek, modern appearance, compatibility with contemporary architectural design, and potential for rooftop utilities such as solar panels or gardens make them appealing choices in dense urban settings where aesthetics, climate performance, and space efficiency are priorities [5,6].

In Sub-Saharan Africa, hidden roof adoption is a relatively recent trend. Traditional pitched roofs, constructed with timber trusses and covered with tiles or corrugated sheets, have long dominated both residential and commercial architecture [7,8]. However, rapid urbanisation, exposure to global architectural styles, and real estate marketing have accelerated interest in hidden roof designs in major African cities. In Ghana, this trend is particularly visible in the Ashanti Region, where lifestyle aspirations and technological advancement have reshaped construction practices [9]. The hidden or parapet roof concealing sloped structural members behind parapet walls creates a flat-roof aesthetic while preserving the drainage and structural efficiency of a pitched system [3,10].

Historically, Ghanaian roofs such as gable and hip types have been favoured for their affordability, ventilation benefits, and simplicity [11]. In the Ashanti Region, traditional roofing styles reflected both climatic adaptation and socio-economic conditions [8]. Yet, modern urbanisation has driven developers and homeowners to adopt hidden roof systems for their modern appearance, enhanced security, and improved weather resistance [7,8]. The growing preference in Kumasi, the country's second-largest city and a major construction hub, illustrates how hidden roofs have become synonymous with sophistication, social mobility, and aesthetic uniformity in urban housing [3,8].

Hidden roofs offer several practical advantages, including protection of roof trusses from theft or fouling, reduced sun and rain exposure, and improved material longevity [7,12]. However, they also pose technical challenges, such as complex parapet detailing, waterproofing and drainage issues, and maintenance difficulties requiring skilled labour. These challenges raise concerns about cost, performance, and long-term sustainability, especially for middle-income homeowners. Globally, hidden roofs are often associated with prestige and modernity, enhancing both architectural appeal and property value [13]. In Ghana, their rising popularity reflects changing architectural preferences and social aspirations tied to modern urban living.

Despite these developments, scholarly research in Ghana has primarily focused on conventional roofing systems. Existing studies have examined topics such as roofing economics [3], architectural design and construction [14], parapet dampness mitigation [10], design education [15], and green roof performance [16]. However, there remains a notable research gap concerning the adoption and utilisation of hidden roof systems, particularly their construction performance, functional efficiency, economic viability, and socio-cultural significance in rapidly urbanising cities like Kumasi.

This study, therefore, aims to assess the factors influencing the adoption and utilisation of hidden roof construction in Ghanaian urban housing, using a Partial Least Squares Structural Equation Modelling (PLS-SEM) approach. Specifically, the study seeks to:

1. Identify the determinants influencing the adoption and utilisation of hidden roof systems in the Ashanti Region.

2. Examine the relationships between design concept, functionality, sustainability, aesthetic, and social value factors on the adoption and utilisation of hidden roof construction in the Ashanti Region.

By addressing these objectives, the study contributes to a better understanding of the drivers and constraints of hidden roof adoption, offering valuable insights for architects, engineers, developers, and policymakers working toward sustainable and contextually relevant urban housing solutions.

Following the introduction, the paper is structured into key sections. It starts with an overview of roofing systems and the evolution of hidden roof construction, then considers the environmental, economic, and design factors influencing its adoption. The study also reviews sustainable practices, functional and aesthetic benefits, and gaps in existing literature. Theoretical and conceptual frameworks based on systems and resilience theory are then outlined. The methodology describes the research design and analytical approach, followed by the findings, discussion, and final recommendations for future research and practice.

2. Literature Review

2.1. Overview of Roofing Systems

Roofing is a crucial aspect of building construction, especially in tropical climates like Ghana, serving both protective and aesthetic purposes. Traditional Ghanaian roofing systems, including gable, hip, and mono-pitch roofs, are preferred for their effective rainwater drainage, cost efficiency, and ease of construction [10]. In the Ashanti Region, corrugated aluminium sheets have historically been the material of choice, valued for their affordability and availability [17].

However, rapid urbanisation, increased access to global architectural trends, and socio-economic shifts have led to the adoption of more complex roofing types, including hidden roofs. This relatively modern construction approach has become increasingly prevalent in urban centres in the Ashanti Region [3].

2.2. Concept and Evolution of Hidden Roof Construction

Hidden roof construction, also known as parapet roofing, concealed roof systems, or flat-top architecture, is a modern roofing solution. It is a sloped system concealed behind vertical parapet walls, creating a minimally sloped roofline and giving the illusion of a flat roof. Despite this appearance, the roof structure typically has a sufficient slope for water drainage, usually through internal gutters and hidden downpipes [3]. This system is popular for its minimalist aesthetic, enhanced security, and compatibility with multi-storey buildings [13]. It is particularly favoured in high-end residential developments and commercial structures. However, while existing literature highlights its architectural appeal and practicality, limited studies have critically examined its long-term performance in tropical climates, where heavy rainfall poses distinct design challenges [3,13].

The hidden roof concept, originating in Europe and the Middle East, has been used in arid climates for centuries. However, its emergence in Ghana is relatively recent, driven by a combination of climatic necessity and urban modernism [8]. The evolution of hidden roofing is closely tied to developments in architectural modernism, where simplicity, geometric clarity, and functional efficiency became central design ideals [18]. Hidden roof systems gained popularity in Europe, North America, and the Middle East for their ability to integrate HVAC units, reduce external ornamentation, and accommodate additional floors or rooftop terraces [5,6]. In tropical regions, however, the hidden roof had to be adapted to cope with high rainfall and humidity, leading to innovations in drainage systems and waterproofing technologies [13]. Yet, while prior studies have documented these

adaptations, they often overlook how local construction expertise, material availability, and maintenance culture influence the success or failure of such systems in developing contexts like Ghana.

The hidden roof has gained popularity in Ghana, especially in urbanising cities like Kumasi, due to global architectural influence and changing urban dynamics, such as limited plot sizes, rising land costs, and the need for efficient space utilisation in dense neighbourhoods [7]. The growing popularity of hidden roofing is also linked to increasing demands for aesthetic uniformity, modern building façades, and security-enhancing features, especially in high-income residential and commercial developments [7,8]. While these factors are well-documented, less attention has been given to how socio-cultural perceptions and economic considerations affect adoption among different income groups. This gap highlights the need to critically explore not only physical or aesthetic drivers but also behavioural and contextual determinants of hidden roof adoption.

Unlike traditional pitched roofs, such as gable or hip types, which are characterised by exposed slopes and prominent ridgelines, hidden roofs are designed to minimise visual bulk [11]. The parapet wall often masks the roofline from street level and gives buildings a more streamlined silhouette. In the Ashanti Region, this design is often seen as a symbol of modern taste, wealth, and architectural sophistication, particularly in upper-class suburbs and newly planned residential enclaves [8]. Nonetheless, while previous works describe this trend as a reflection of modern aspirations, few have critically interrogated whether such preferences align with sustainable housing goals in the Ghanaian context, where affordability and climatic suitability remain pressing issues.

The hidden roof system in urban Ghana addresses functional needs by protecting roofing materials from direct environmental exposure, potentially extending the structure's life, and discouraging unauthorised access. It also eliminates large overhangs, reducing vulnerability to theft, a common concern in the region prone to intense sunlight and heavy rainfall [13]. However, in Ghana, hidden roofs face some setbacks due to their reliance on internal drainage and parapet wall integrity, requiring precision and maintenance. Improper execution can cause water stagnation, leakage, and structural decay. While studies have identified these risks [10], there is limited empirical evaluation of how construction practices and technical supervision mitigate such challenges in local building projects. Balancing aesthetic ambition with environmental practicality, therefore, remains a challenge being addressed by architects, engineers, and builders [10]. The hidden roof, a symbol of modernity and functionality, requires localised design frameworks and construction guidelines for sustainable use in cities in the Ashanti Region. It is crucial to adequately evaluate its technical attributes and social, economic, and cultural implications [3,13].

2.3. Factors Influencing the Adoption and Utilisation of Hidden Roofs

The perception of hidden roof construction, especially in urban areas, is influenced by aesthetic preferences, socio-economic status, functionality, and cultural transitions in architectural design. Public perception significantly determines the adoption, value, and sustainability of these roofs. While several studies have discussed the aesthetic and functional appeal of hidden roofs, few have critically explored how these perceptions interact with broader urban housing dynamics and socio-economic disparities in Ghana [3,13,18]. This suggests a gap in understanding how individual preferences and contextual constraints jointly shape adoption behaviour in developing urban settings.

Aesthetic perception and the modern identity of hidden roof systems are often linked to modernity and urban sophistication, with homeowners and developers in Ghana seeing them as symbols of elite status and refined taste. This visual appeal has made hidden roofing a popular choice for estate developments, apartment complexes, and urban villas [3,18].

The clean lines and flat appearance enhance the minimalist aesthetic sought in contemporary urban planning. Perception is not just about function but also closely connected to architectural identity and cultural aspiration [13]. However, while prior studies highlight the aesthetic and social appeal of hidden roofs, they often overlook the tension between modern architectural aspirations and environmental suitability, particularly in a tropical context where drainage performance and maintenance remain critical challenges [13,18]. Thus, existing literature tends to privilege visual form over practical functionality, leaving questions about climatic responsiveness insufficiently addressed.

Perception of security and the practical functionality of hidden roofs are often regarded as greater than those of exposed pitched roofs because their parapet walls act as barriers, preventing easy access points for intruders. This is particularly significant in urban areas with high petty theft rates [3]. Furthermore, residents and developers believe that hidden roofs protect structural components from direct exposure to the elements, thereby enhancing the durability of the building and reducing long-term maintenance costs for visible roof surfaces [13]. Yet, despite these functional advantages, limited empirical evidence exists on whether these perceived benefits translate into measurable performance improvements over time, especially under Ghana's climatic conditions. This gap highlights the need for further investigation into the relationship between perception, functionality, and actual building performance rather than relying solely on anecdotal satisfaction.

Economic and maintenance perceptions of hidden roofs offer aesthetic and security benefits, but their cost and maintenance burden are significant. Many clients view hidden roof construction as expensive and technically demanding due to the additional materials and skilled labour required [3]. The concealed nature of the roof's drainage system also raises concerns about maintenance challenges, such as frequent leaks and ceiling damage during rainy seasons. This situation has caused concern among some individuals, particularly those who have experienced substandard implementations [13]. While prior literature acknowledges these challenges, it often fails to analyse how economic constraints, design complexity, and inconsistent workmanship influence adoption decisions across different income groups, particularly within the informal housing market. Therefore, the discourse on cost and maintenance remains largely descriptive, with insufficient critical analysis of affordability and long-term sustainability.

The social and cultural perception of hidden roofing in Ghana is shaped by sociocultural values, where traditional architecture and symbolism are important. Traditional roofs carry historical and symbolic significance, especially in rural and peri-urban areas [4,18]. However, younger generations and urban dwellers are increasingly adopting hidden roofs as part of a modern cultural shift, influenced by globalisation, media, and changing social norms, reflecting a wider trend in architectural preferences [5,6,19]. Nonetheless, while this transition represents progress toward global architectural integration, prior studies rarely critique the potential cultural homogenisation and loss of indigenous design identity resulting from this trend. Understanding these cultural shifts is therefore essential to ensure that architectural modernisation does not undermine local identity, environmental adaptation, and cultural continuity.

Professional and industry perception of construction professionals, architects, engineers, and contractors often view hidden roofs with caution due to their design flexibility and visual benefits. They emphasise the need for strict adherence to technical specifications, particularly in slope design, waterproofing, and drainage integration [3]. Some professionals advocate for clearer regulatory guidelines and training to improve construction outcomes and reduce client dissatisfaction, which can distort public perception of hidden roofs [13]. While existing research identifies these professional concerns, it tends to describe rather than critique them; few studies systematically assess how institutional capacity,

regulatory enforcement, and knowledge transfer shape the long-term success of hidden roof implementation in Ghana's construction industry. This omission points to the need for more robust analysis of the professional and institutional frameworks supporting hidden roof adoption.

The design concept and construction characteristics allow for a hidden roof, which combines the efficiency of a sloped roof with the visual appeal of a flat structure. These roofs are usually constructed from light-gauge steel or timber trusses, roofing sheets, and reinforced concrete parapet walls [3,4]. Internal gutters and downpipes direct rainwater away from the roof surface. The top of the parapet is typically waterproofed to prevent water seepage [14]. This roof design provides flexibility for rooftop utilities such as water tanks, solar panels, and satellite dishes without impacting the building's appearance. It also supports modular extensions, especially in urban housing schemes with vertical expansion [13]. However, while these design advantages have been well-documented, the literature remains largely silent on the cost–benefit analysis of such configurations and their sustainability in Ghana's construction ecosystem. Future research must therefore move beyond descriptive accounts to critically evaluate the long-term performance, maintenance costs, and technical adaptability of hidden roof systems in local contexts. A more analytical understanding of these issues would better inform policy and practice, particularly as Ghana moves toward modern yet sustainable urban housing design.

2.4. Sustainable Practices in Hidden Roofs

Hidden roof systems can promote environmentally responsible practices in construction when designed and implemented correctly. These systems offer practical opportunities to integrate energy-efficient techniques and green building technologies, despite their historical focus on aesthetic innovation. However, while earlier research has predominantly emphasised the visual and modernist appeal of hidden roofs, there is limited empirical discussion on how these systems contribute to environmental sustainability in tropical urban contexts like Ghana [13,14].

Solar energy potential allows solar panels to be mounted on hidden roofs' flat or gently sloping surfaces without detracting from the building's overall aesthetic appeal. By integrating photovoltaic systems on hidden roofs, carbon emissions related to electricity use are decreased, and energy independence is promoted [13]. This potential aligns with global sustainability goals, yet studies seldom evaluate the economic feasibility or long-term maintenance implications of solar integration on hidden roofs in developing countries. While prior studies show the architectural compatibility of hidden roofs with renewable energy installations, they fail to address context-specific barriers such as initial cost, technical expertise, and policy support necessary for large-scale implementation in Ghana.

Rainwater harvesting systems include internal drainage systems and parapet walls, which are common features of hidden roofs and are ideal for regulated rainwater collection. These systems can assist with water conservation in both residential and commercial buildings by directing rainfall into storage tanks via hidden downpipes [14]. However, while such systems offer sustainable advantages, the literature often overlooks the technical and maintenance challenges associated with water storage quality, leakage risks, and system durability in high-rainfall regions. This gap indicates the need for studies that assess not only design efficiency but also the operational reliability of these systems in tropical climates.

Green roof integration allows low-slope or flat hidden roofs, also known as green roof systems, to be modified. In addition to promoting biodiversity, these systems reduce the impact of the urban heat island and help regulate indoor temperatures. Although

more common in temperate climates, this practice is increasingly popular in tropical areas, including parts of Ghana, where it can offer benefits for stormwater management and passive cooling [20–22]. Nonetheless, while prior research highlights the environmental benefits of green roofs, there is limited critique of their practical adaptability in local contexts where construction costs, structural design limitations, and maintenance capacity differ significantly from temperate settings. Therefore, future studies should examine how the adoption of such systems can be technically and economically optimised for Ghana's building conditions.

Material selection enhances the sustainable benefits of hidden roof construction by using durable, low-embodied-energy, locally sourced materials. Adding additional cementitious materials like fly ash or slag can improve concrete, commonly used in hidden roof systems, and decrease its carbon footprint [3,4]. Extended lifespan and reduced maintenance of hidden roofs are possible because of their concealed structure and less exposure to harsh weather conditions (in comparison to traditional pitched roofs). Over the building's lifespan, this diminishes material waste and resource use [23]. However, while these material innovations are recognised, most existing studies tend to focus on their environmental potential rather than their accessibility or cost implications in local markets. There remains a gap in critically analysing how economic and logistical factors influence the widespread adoption of sustainable materials in hidden roof construction across Ghana.

Thermal performance and insulation allow more insulation to be added to hidden roof systems than to traditional pitched roofs, especially when reinforced concrete slabs are used in their construction. Better insulation reduces the need for mechanical cooling systems, enhances thermal comfort, and improves building energy efficiency [13,23]. Nevertheless, while these thermal benefits are well-documented, few studies compare the actual energy performance of hidden roofs with that of conventional systems under Ghanaian climatic conditions. This lack of empirical validation limits understanding of their true efficiency and cost-effectiveness in real-world applications. Thus, while hidden roofs present significant sustainable potential, a more critical and evidence-based analysis of their performance, adaptability, and lifecycle costs is needed to fully understand their role in promoting green urban housing in Ghana.

2.5. Functional and Aesthetic Merits of Hidden Roofs

Hidden roof systems are gaining popularity in urban and peri-urban environments due to their architectural sophistication, security, and spatial efficiency. These systems offer functional and aesthetic advantages beyond just visual style, contributing to their growing adoption [13]. While several studies highlight their architectural appeal and practical benefits, few have examined the contextual and technical factors influencing their long-term suitability in tropical urban environments like Ghana. This indicates a gap between descriptive appreciation and empirical performance evaluation.

Hidden roofs provide functional benefits, particularly in densely built urban areas, by shielding roofing components from direct exposure to the elements. Unlike traditional roofs, hidden roofs shield trusses, purlins, and roofing sheets behind parapet walls [23]. This protective feature enhances roof longevity by reducing material degradation due to ultraviolet (UV) radiation and heavy rainfall, thereby reducing the overall structure's exposure to these elements [13]. Hidden roofs in urban communities, particularly in multi-tenant housing and mixed-use developments, enhance building security by concealing structural elements and eliminating easily accessible roof overhangs. This physical deterrence is particularly valuable in high-density areas and rapidly developing suburbs, as theft and unauthorised roof access are common concerns [13]. However, while prior studies highlight these advantages, they often overlook how variations in construction

quality, material selection, and maintenance practices affect the durability and security performance of hidden roofs under local conditions. Thus, there remains limited evidence on how these systems perform beyond their theoretical or design intent in Ghana's humid and high-rainfall context.

Hidden roofs, when combined with insulation and reflective materials, can enhance interior thermal comfort in buildings. International research suggests that these systems, when paired with appropriate insulation, can limit heat gain through the roof surface, reducing reliance on mechanical cooling systems [23]. This is particularly important in countries where rising temperatures and poor indoor ventilation are pressing concerns [13]. However, while prior studies document these thermal advantages, they tend to generalise findings from temperate or arid climates without critically considering their applicability to tropical conditions. The absence of region-specific empirical studies in Ghana limits understanding of how hidden roofs perform in terms of thermal efficiency, especially when locally sourced materials and construction techniques are employed.

Hidden roofs are a popular architectural style in modern architecture due to their clean, minimalist exterior. They create uniformity and symmetry in buildings, aligning with global urban design trends [23]. This aesthetic is increasingly seen as a sign of sophistication and affluence in developing economies, as they are often associated with a clean, minimalist exterior [13]. While previous research acknowledges this modernist appeal, it rarely critiques its social implications. Specifically, the association between hidden roofs and social prestige may reinforce housing inequalities, as their adoption is often limited to middle- and upper-income groups who can afford the associated costs. Thus, while prior studies show that hidden roofs symbolise modernity and status, they fail to address how such symbolism may exclude lower-income homeowners and deepen socio-spatial disparities in urban housing.

Hidden roofs in multi-storey buildings maintain consistent building heights, reduce visual clutter, and create cohesive streetscapes, making them ideal for gated residential communities and commercial developments [23]. They eliminate traditional eaves and overhangs, allowing for efficient use of boundary lines, making them ideal for compact urban plots [13]. The social implications of aesthetic preference in communities are significant. Housing style is closely tied to social status and identity [23]. The adoption of hidden roofs by middle- and upper-income homeowners signifies a symbolic transition towards modernity and urban sophistication, communicating values of success, progress, and upward mobility [13]. Yet, while this social transformation is well-documented, there is limited critical engagement with how these preferences interact with local climate adaptation, affordability, and sustainability priorities in Ghana's urban housing market.

Within Ghana's context, hidden roofs are becoming a defining feature of contemporary urban housing, as developers prioritise visual appeal, security, and long-term performance. However, their functional and aesthetic benefits must be balanced against cost and maintenance demands [23]. Proper detailing, particularly in drainage design, can prevent hidden roofs from becoming liabilities [13]. Nevertheless, while prior studies stress the importance of technical detailing, they fail to address how inadequate regulation, limited technical capacity, and inconsistent workmanship undermine these design intentions. Future research must therefore move beyond descriptive assessment of design appeal to critically evaluate the institutional, technical, and economic factors that influence the sustainable adoption and utilisation of hidden roof construction in Ghanaian cities.

2.6. Gaps in Existing Literature on the Adoption and Utilisation of Hidden Roofs

The adoption of hidden roof construction, particularly in urban centres, is growing, but academic and technical literature on the subject remains limited. There is a lack of

comparative analysis between hidden roofs and conventional roofing systems in terms of cost-effectiveness, durability, and maintenance. Existing works often focus on conventional pitched roofs, overlooking how hidden roof systems perform in Ghana's unique climatic, economic, and cultural context. This limited scholarly focus restricts a holistic understanding of the practical, environmental, and social implications of hidden roof utilisation in tropical regions. While prior studies acknowledge the functional merits of conventional roofing systems, they fail to address the emerging architectural, climatic, and socio-economic realities that make hidden roof construction increasingly relevant in urban Ghana.

Li and Liu [24] concentrate on estimating the potential for solar energy on pitched roofs. Comparing a pitched roof and a flat roof for a two-story house is the main focus of Pitroaca et al.'s [25] study. Based on the Life Cycle Assessment (LCA), Carretero Ayuso & García Sanz-Calcedo [26] compare various building roof construction systems. While these studies offer valuable insights into roof performance and sustainability across different contexts, they largely examine temperate or arid climates, leaving a gap in understanding how hidden roof systems perform under the heavy rainfall, humidity, and temperature fluctuations characteristic of Ghana and similar tropical regions. Therefore, while prior research shows the environmental and energy advantages of certain roof configurations, it fails to address how such findings translate into tropical architectural applications or the practicalities of local implementation.

Empirical data on the long-term structural performance and drainage efficiency of hidden roofs in tropical regions is scarce, as the risk of water retention and leakage is high. This gap suggests that most existing studies are conceptual or design-based, with insufficient empirical testing to validate claims of durability or maintenance efficiency. While previous works recognise drainage as a key design challenge, they often fail to examine how variations in workmanship, materials, or maintenance culture influence performance outcomes in developing urban environments. Addressing these issues is crucial to moving beyond general assumptions and toward context-specific technical guidelines for hidden roof adoption in Ghana.

Additionally, there is a gap in the social and perceptual dimensions of hidden roof construction, with few studies formally analysing user satisfaction, cultural acceptance, or perceived value across different income levels. While prior research has documented the growing preference for modern, minimalist designs, it fails to account for the socio-cultural dynamics shaping these preferences, particularly how notions of modernity, prestige, and identity intersect with housing design choices in Ghana. This oversight limits understanding of how aesthetic perception and social aspiration influence the adoption and utilisation of hidden roofs in both residential and commercial developments.

Furthermore, there is an absence of design and construction guidelines specific to hidden roofs within Ghana's building code framework, leading to inconsistent implementation and increased risk of construction failures, especially when executed by untrained contractors. While existing building standards cover general roofing principles, they fail to address the unique design requirements, waterproofing measures, and drainage specifications that hidden roofs demand. This regulatory gap highlights a critical area where policy and professional training must evolve to support safe, sustainable, and standardised hidden roof construction in Ghana. Without such frameworks, the potential benefits of hidden roofing, both functional and aesthetic, may be undermined by poor execution and maintenance inefficiencies.

2.7. Theories Underpinning the Study

This study is underpinned by three (3) interconnected theories to explain the rise, function, and implications of hidden roof construction in buildings, focusing on their aesthetic and functional responses to urban development, technological advancement, and local environmental conditions. These theoretical perspectives collectively shape the conceptual framework and guide the formulation of hypotheses tested in this study.

Firstly, the Modernist Architectural Theory promotes simplicity, clean forms, and the elimination of superfluous ornamentation. It rose to prominence in the early 20th century [27,28]. Modernist principles state that logical planning, standardised forms, and material honesty should be used in architectural design to reflect the industrial age [29,30]. These concepts are supported by hidden roof construction, which conceals traditional pitched buildings behind parapet walls while providing a minimalist flat-roof aesthetic in Ghanaian urban housing. Hidden roofs are increasingly popular due to modern urban identity aspirations, associated with sophistication and social mobility among middle- and upper-class homeowners. However, while prior studies have recognised the aesthetic alignment between hidden roofs and modernist ideals, they have not sufficiently linked these aesthetic values to design decision-making processes or user perception in developing urban contexts. This theoretical gap informs Hypothesis H1, which examines how aesthetic value influences the design concept of hidden roofs, and H3, which explores the relationship between social value and design concept.

Secondly, the Functionalist Theory in architecture emphasises that architectural elements should serve a clear and logical purpose. Hidden roof systems, as argued by Louis Sullivan, ensure sloped structures perform critical drainage functions despite appearing flat from the exterior [31,32]. This multifunctional approach to roofing includes roof trusses, internal drainage integration, and parapet walls [30,33]. Functionalism suggests that architectural forms should cater to performance needs such as rain protection, structural integrity, and utility accommodation, which is exemplified by the increasing use of hidden roofs in high-density urban areas for space optimisation and security [34]. While prior research has noted these functional advantages, it has often neglected to empirically test how design functionality affects perception and satisfaction among end-users. Consequently, H5 and H6 derive from Functionalist Theory, linking sustainable construction and functional performance to the overall perception of hidden roofs.

Thirdly, the Climatic Design Theory emphasises how environmental factors such as temperature, humidity, and precipitation impact building design [35,36]. The tropical climate of Ghana requires roofing systems with hidden designs that divert water into downpipes and gutters, shielding structural elements from the elements. Where seasonal rains and heat necessitate context-appropriate architectural solutions, hidden roofs with parapet walls provide shade and reduce thermal gain, thereby promoting passive climate control principles. However, while this theory underscores the relevance of climate-responsive design, prior studies rarely assess how climate adaptation specifically shapes hidden roof design outcomes or sustainable construction practices in tropical regions. This shortfall justifies H2, which examines the influence of climate adaptation on design concept, and H4, which tests how design concept impacts sustainable construction practices.

Together, these three theories provide a coherent framework linking aesthetic, functional, and climatic considerations to the adoption and utilisation of hidden roof construction. They also provide the theoretical justification for the model pathways tested using PLS-SEM in this study, as shown in Table 1.

Table 1. Mapping Theories to Variables and Hypotheses.

Theory	Core Principle	Linked Variable(s)	Related Hypotheses	Theoretical Logic
Modernist Architectural Theory	Emphasises simplicity, aesthetics, and modern identity	Aesthetic Value, Social Value, Design Concept	H1, H3	Aesthetic and social aspirations of modernity influence hidden roof design preferences.
Functionalist Theory	Architectural form follows function; performance and usability are central	Sustainable Construction, Functionality, Perception	H5, H6	Functional performance of hidden roofs enhances sustainability and shapes user perception.
Climatic Design Theory	Design should respond to environmental conditions	Climate Adaptation, Design Concept, Sustainable Construction	H2, H4	Climate-responsive design affects roof design concepts and sustainable practices.

Source: Authors construct 2025.

2.8. Conceptualisation of the Adoption and Utilisation of Hidden Roofs

The Design Concept of the Hidden Roof (DCHR) involves a complex architectural approach that reflects both cultural heritage and environmental responsiveness. As shown in Figure 1, key thematic areas include the Climate Adaptation of the Hidden Roof (CAHR), which emphasises its role in responding to environmental conditions; the Sustainable Construction Method of the Hidden Roof (SCMHR), highlighting resource efficiency and durability; and the Aesthetic Value of the Hidden Roof (AVHR), which adds to its visual and cultural significance. Additionally, the Functionality of the Hidden Roof (FHR) underscores its practical architectural uses. Meanwhile, the Perception of the Hidden Roof (PHR) indicates how it is understood and valued by the community. Finally, the Social Value of the Hidden Roof (SVHR) reflects its role in shaping identity and fostering communal values, all of which are summarised in Figure 1.

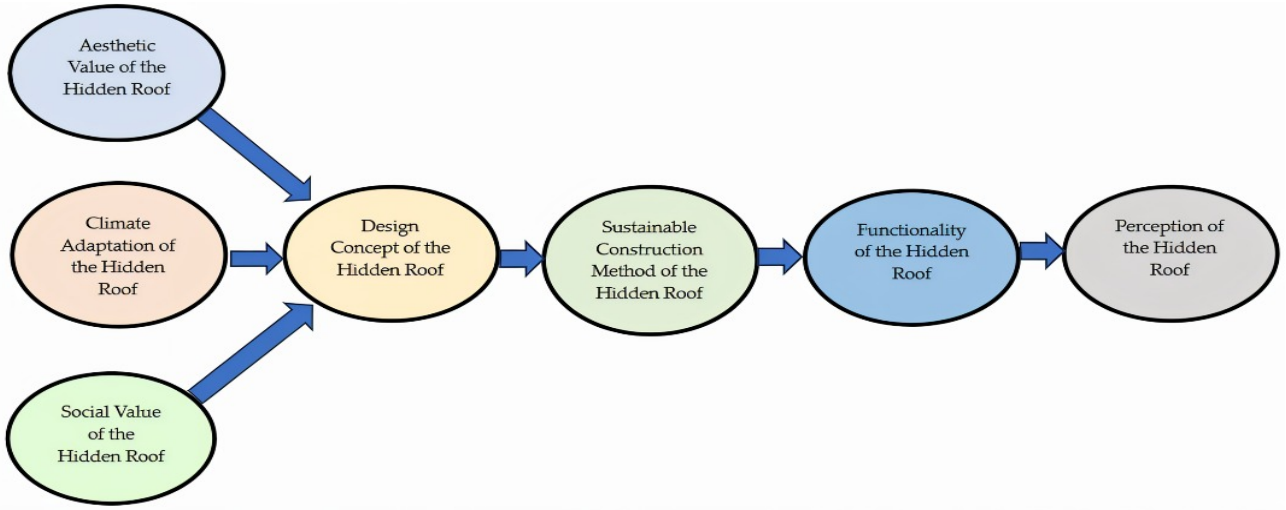

Figure 1. A conceptualised framework for hidden roof construction. Source: Authors' construction, 2025.

The Design Concept of Hidden Roof (DCHR) focuses on concealing the sloping elements of a traditional pitched roof within an outer flat wall or parapet. Featuring a

smooth, level exterior, this design offers the internal advantages of a sloped roof, such as effective water drainage and enhanced structural durability [3,4]. It combines the minimalist aesthetic of modern architecture with traditional roofing functions, making it ideal for urban environments that value creativity and visual harmony. Furthermore, it allows rooftop utilities like HVAC or solar panels to be incorporated without compromising the structure's overall visual appeal [3,4,14].

Climate Adaptation of the Hidden Roof (CAHR) refers to the ability to adapt to different climates, ensuring that hidden roofs perform effectively across a range of weather conditions, particularly in tropical or monsoon-prone areas. The concealed slope allows rainwater to drain more quickly, preventing leaks and stagnation [10,20,22]. In hot climates, energy efficiency and indoor comfort are enhanced by reducing heat gain through reflective roofing materials and adequate insulation. The ventilated cavities within the roof structure help maintain a cooler indoor environment. The design is adaptable to various climates, as it can also include thermal insulation to retain heat in colder conditions [13,23].

The Sustainable Construction Method of the Hidden Roof (SCMHR) emphasises using eco-friendly techniques in building hidden roofs. Sustainability can be enhanced by incorporating solar or green roofing technologies, utilising recycled or renewable materials, and installing rainwater harvesting systems [3,4,13,23]. Prefabricated roof components reduce construction time and minimise on-site waste. Furthermore, the energy efficiency of the design throughout the building's lifespan helps lower its carbon footprint. Proper design and implementation also extend the roof's lifespan and decrease the need for repairs or replacements [13,23].

The Aesthetic Value of the Hidden Roof (AVHR) offers a clean, unobstructed visual line, which is often preferred in modern and minimalist architecture, contributing to its aesthetic appeal. While functional slopes are concealed, the external facade looks flat or subtly contoured. This is especially true in commercial or urban developments where architectural harmony is essential, as it gives the building a more contemporary and uniform appearance [3,18]. Additionally, the building's smooth profile is enhanced by the absence of prominent roofing features, such as ridges and tiles, which supports architectural trends that focus on balance, form, and simplicity [13].

The Functionality of the Hidden Roof (FHR) remains robust despite its concealed nature. Similar to a standard sloped roof, it provides effective rainwater drainage, structural support, and protection against the weather. Drainage systems can be integrated into the parapet walls as part of the design, shielding them from external damage [3]. Moreover, hidden roofs often enable easy access to rooftop equipment, creating a practical utility area that stays out of sight from the public. Long-term maintenance needs are lower because the roof's hidden slope prevents the accumulation of water and debris [13].

Perception of the Hidden Roof (PHR) within architectural and user communities is generally positive. They are seen as innovative, progressive solutions that consider both practical and aesthetic factors [3]. Architects and clients often regard them as symbols of sophistication, modernity, and clever design [14]. The design helps create a forward-looking, refined image in commercial buildings, while homeowners appreciate the subtlety and clean lines in residential settings. Furthermore, the hidden roof is viewed as a way of honouring traditional building methods while adapting them to contemporary needs [3,18].

The Social Value of the Hidden Roof (SVHR) plays a significant role in urban and culturally sensitive environments. Hidden roofs can enhance functionality through modern techniques while preserving the external appearance of traditional structures in heritage zones or areas with strict architectural regulations [4,18]. This promotes architectural continuity and the preservation of cultural identity. Moreover, by enhancing the aesthetics of the built environment, they contribute to neighbourhood appearance and foster community

pride. As socially conscious design choices, they also support sustainability, aligning with the public's increasing concerns about environmental impact [5,6,19].

3. Research Methodology

The research methodology utilised a quantitative approach to collect information from survey respondents using structured questionnaires. This approach facilitated the assessment of participants' opinions and perceptions regarding hidden roof construction in Ghanaian urban housing. Fellows and Liu [37] assert that the quantitative approach is more positivist in nature, aiming to gather factual information and analyse the connections between facts, as well as how these connections relate to theoretical assumptions and prior research findings. When measurements are taken using scientific methods, researchers can obtain factual data that can be used to test hypotheses, make informed decisions, and draw significant conclusions.

This study employed a cross-sectional survey design, collecting data from respondents at a single point in time to examine the factors influencing the adoption and utilisation of hidden roof construction.

The study population comprised construction professionals and stakeholders within the Kumasi Metropolitan area of Ghana's Ashanti Region. The Ashanti Region is one of the fastest-growing urban centres in the country, with diverse housing typologies such as storey buildings, flats, and apartments that are representative of Ghana's wider urban housing context [38]. Kumasi was purposively selected because it serves as a regional hub for construction activities and reflects architectural trends comparable to those in other urban areas of Ghana. While the findings primarily reflect the Kumasi context, they are reasonably generalisable to other Ghanaian cities with similar socio-economic and architectural conditions.

The study employed a non-probability sampling technique, specifically purposive and convenience sampling, to identify and select respondents with relevant expertise and experience in hidden roof construction. Participants included architects, civil engineers, quantity surveyors, contractors, and homeowners. The purposive approach ensured that only individuals with direct experience or professional involvement with hidden roofs were included, while convenience sampling facilitated access to participants willing to respond.

A total of 220 questionnaires were distributed, and 175 valid responses were retrieved, yielding a response rate of 79.5%. The sample size satisfies the requirements for Partial Least Squares Structural Equation Modelling (PLS-SEM) based on Hair et al.'s [39] "10× rule," which suggests that the minimum sample size should be at least ten times the largest number of structural paths directed at a construct in the model. Since the study model contains a maximum of six paths, a minimum of 60 responses would have been sufficient. Therefore, the final sample of 175 respondents exceeds the threshold for robust statistical analysis and ensures adequate statistical power for hypothesis testing.

A survey questionnaire was used to collect primary data from respondents. The instrument consisted of items measured on a 5-point Likert scale, ranging from "Strongly Disagree" (1) to "Strongly Agree" (5). The questions were designed to measure variables such as aesthetic value, social perception, climate adaptation, design concept, sustainable construction, functionality, and overall perception of hidden roofs.

The collected data were analysed using both descriptive and inferential statistical methods. Descriptive statistics (frequencies, percentages, means, and standard deviations) were employed to summarise respondents' demographic characteristics and general perceptions of hidden roof systems. Structural Equation Modelling (SEM) was then used to examine the relationships between the identified factors influencing adoption and utilisa-

tion. Data analysis was performed using SPSS (Version 25) for descriptive analysis and SmartPLS 4 for SEM, which is suitable for exploratory models with latent constructs such as perceived usefulness, usability, and intention to adopt.

The study involved human participants and adhered strictly to ethical research standards. Informed consent was obtained from all participants before data collection. Respondents were assured of anonymity and confidentiality, and participation was entirely voluntary. Participants were also informed of their right to withdraw from the study at any time without penalty. Figure 2 shows the flowchart of the research process used for the study.

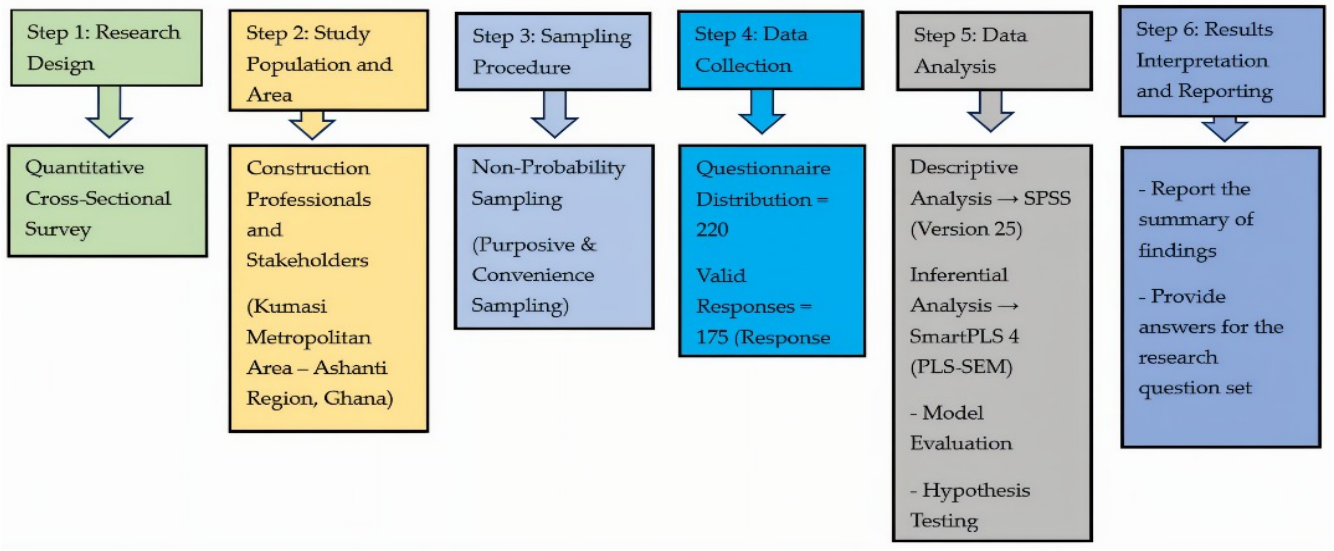

Figure 2. Flowchart of the research process. Source: Authors' construction, 2025.

4. Findings and Discussion

The analytical tools employed in this study were descriptive (frequency with percentages for background characteristics and mean scores with standard deviations for construct indicators), exploratory factor analysis, and partial least squares structural equation modelling (PLS-SEM). The estimations were conducted using SPSS version 27 and SmartPLS 4 [40].

4.1. Descriptive Statistics of Background Characteristics

In terms of responses, the study was male-dominated, representing 85.7% of the respondents. The majority of respondents held a Bachelor's degree, representing 57.1%. The next highest educational qualification was a Master's degree, representing 28.6%, and then a Diploma/Higher National Diploma (Table 2). The educational qualifications of the respondents in the study were high. The main roles identified in the study were clients and quantity surveyors, representing 37.1% and 33.7%, respectively. The other roles of the respondents in the study were project managers, architects, contractors and engineers (Table 2).

Table 2. Background Information of Respondents.

Background Information	Frequency	Percentage
Gender		
Male	150	85.7
Female	25	14.3
Total	175	100
Highest qualification		
Diploma/Higher National Diploma	25	14.3
Bachelor's Degree	100	57.1
Master's Degree	50	28.6
Total	175	100
Role in the construction industry		
Client	65	37.1
Constructor	5	2.9
Quantity Surveyor	59	33.7
Engineer	1	0.6
Architect	15	8.6
Project Manager	30	17.1
Total	175	100

Source: Fieldwork, 2025.

4.2. Descriptive Statistics of the Constructs' Indicators for the Hidden Roof Adoption and Utilisation

This section presents the descriptive statistics of the constructs' indicators in the study. These indicators have been ranked accordingly based on their mean scores and standard deviation. (Table 3). Indicators with the same mean scores were ranked based on the standard deviation, where lower deviation was ranked first.

Table 3. Factors influencing the adoption and utilisation of hidden roof construction.

Factors of Hidden Roof Adoption and Utilisation	Mean Scores	Std. Dev.	Rank
Functionality of the Hidden Roof			
A hidden roof design increases the property's market value due to its contemporary appearance.	3.97	1.243	1
Buildings with hidden roofs allow for more hidden incorporation of other systems (solar installation systems, service installations).	3.84	1.060	2
Urban environments are made more beautiful by the neat, flat-top design of hidden roofs.	3.81	1.095	3
The design gradient of the hidden roof makes installations more convenient.	3.78	1.099	4
Hidden roofs are more visually appealing than conventional roofs.	3.71	1.145	5
Design Concept of Hidden Roof			
The internal drainage system in hidden roofs is efficient and reliable when well-designed.	4.33	0.852	1
The building is successfully shielded from the elements (rain, sun, and wind) by hidden roofs.	4.20	0.727	2
Hidden roof systems are easier to integrate with modern utilities (e.g., solar panels, water tanks).	4.17	0.798	3
Hidden roofs enhance building security by preventing roof access.	4.09	0.811	4

Table 3. *Cont.*

Factors of Hidden Roof Adoption and Utilisation	Mean Scores	Std. Dev.	Rank
Aesthetic Value of the Hidden Roof			
Hidden roof offers modern appearance	4.22	0.921	1
Hidden roof enhances easy maintenance	4.17	0.906	2
Hidden roof increases roof space usage	3.98	0.934	3
Hidden roof has design flexibility	3.93	1.056	4
Hidden roof enhanced weather protection	3.88	0.818	5
Climate Adaptation of the Hidden Roof			
Properly built hidden roofs can prevent water leakage and dampness.	4.46	0.763	1
The design helps reduce heat absorption in buildings.	4.38	0.807	2
Hidden roofs are well-suited for tropical climates.	4.38	0.792	3
Hidden roofs offer better protection against storm damage than exposed pitched roofs.	4.23	0.861	4
Social Value of the Hidden Roof			
Hidden roof designs improve the visual appeal of communities.	4.13	0.821	1
The use of hidden roofs promotes architectural harmony in urban areas.	4.06	0.889	2
Hidden roofs encourage innovation in roof designs and construction.	4.00	0.994	4
Hidden roofs play a crucial role in preserving the cultural identity of buildings.	4.00	0.871	3
Hidden roofs are becoming more accepted than traditional roofs.	3.99	1.003	5
The incorporation of hidden roofs facilitates the contemporary development of cities.	3.81	1.126	6
Perception of the Hidden Roof			
I would recommend hidden roof systems for urban housing projects.	4.40	0.788	1
The ease of maintenance affects my willingness to use hidden roofs.	4.32	1.040	2
Hidden roofs are more secure as compared to traditional roofs.	4.22	0.872	3
I intend to use a hidden roof construction in my next project/building.	4.21	1.065	4
Social status and trends influence the preference for hidden roof design.	4.17	0.943	5
Hidden roofs are useful for modern housing projects.	4.16	1.103	6
Hidden roofs are more durable as compared to traditional roofs.	4.06	1.043	7
My decision to adopt a hidden roof is influenced by cost considerations.	3.95	1.092	8
Sustainable Construction Method of the Hidden Roof			
The hidden roof system can be integrated with solar energy solutions.	4.25	0.881	1
The design of a hidden roof reduces heat in the roof, which can affect indoor air quality.	4.24	0.864	2
The hidden roof system allows for the incorporation of a green roof system.	4.20	0.871	3
Hidden roofs support long-term sustainability in building maintenance.	4.11	0.874	4
Hidden roofs allow for efficient rainwater harvesting.	4.10	0.803	5
Hidden roof construction promotes the use of eco-friendly materials.	3.99	0.881	6
The construction process of hidden roofs reduces material waste.	3.78	0.857	7

Source: Fieldwork, 2025.

The mean score ranking was used to evaluate how the respondents rated the indicators of the constructs. The mean scores of the indicators of the hidden roof's functionality ranged from 3.71 to 3.97, with a deviation ranging from 1.060 to 1.243. The first three functionalities of the hidden roof were: "Hidden roof design increases the property's market value due to its contemporary appearance", "Buildings with hidden roofs allow for more hidden incorporation of other systems (solar installation systems, service installations)", and "Urban environments are made more beautiful by the neat, flat-top design of hidden roofs.". The perception that hidden roof design increases a property's market value (Mean = 3.97) reflects a growing recognition of its functional and economic benefits. Although not overwhelmingly rated, this supports the literature by Urbanik & Tomaszewicz [13] and Guzmán-Sánchez et al. [3], who contend that modern architectural features, such as concealed roofs, enhance real estate value due to their sleek aesthetics, space efficiency, and potential for system integration. However, the moderate level of agreement suggests that functionality alone may not be the only factor driving adoption, as practical performance and maintenance considerations might influence expectations [13]. Implication: Functionality is well recognised, but mean scores below 4 suggest moderate, not overwhelming, agreement.

The design concept of the hidden roof had mean scores ranging from 4.33 to 4.09 with standard deviations from 0.727 to 0.852 (relatively low). These indicators were rated with high consistency of responses. The first two most highly rated were: "The internal drainage system in hidden roofs is efficient and reliable when well-designed" and "The building is successfully shielded from the elements (rain, sun, and wind) by hidden roofs." The highest-rated item in the entire study, efficient internal drainage systems (Mean = 4.33), confirms that technical functionality is a priority among professionals. This aligns with the findings of Guzmán-Sánchez et al. [3], Andreescu et al. [4], and Forehand [14], who highlight that improper drainage is a common failure point in flat or hidden roof systems. The ability to channel rainwater effectively is especially critical in tropical regions, where intense rainfall can lead to structural damage if poorly managed. The strong agreement emphasises that when well-designed, hidden roofs are not only visually modern but also technically robust, validating building science principles of performance-based roof design [3,4]. Implication: Technical design aspects of hidden roofs are highly valued, especially functional infrastructure like drainage and weather resilience.

Under the aesthetic values of the hidden roof, indicators such as "Hidden roof offers modern appearance" and "Hidden roof enhances easy maintenance" were rated the highest, with mean scores of 4.22 (SD = 0.921) and 4.17(SD = 0.906), respectively. The high score for modern appearance (Mean = 4.22) supports research by Guzmán-Sánchez et al. [3] and Vasiliu [18], which emphasises aesthetics as a major driver of architectural innovation in residential design. The hidden roof's clean lines, flat profiles, and minimalistic look appeal to contemporary tastes, particularly in urban developments aiming for modern, high-end visual identity. Low maintenance further strengthens the appeal, reflecting a convergence of beauty and practicality [13]. Implication: Aesthetic appeal and low maintenance are strong motivators for hidden roof adoption.

Climate adaptation of the hidden roof was rated with mean scores from 4.46 to 4.23 and with deviations from 0.763 to 0.861 (high consistency). The first three most relevant climate adaptations of the hidden roof were: "Properly built hidden roofs can prevent water leakage and dampness", "The design helps reduce heat absorption in buildings" and "Hidden roofs are well-suited for tropical climates". With the highest mean score overall (4.46), the view that well-constructed hidden roofs prevent water leakage and dampness underscores their perceived resilience in tropical climates, where moisture control is a critical concern. Studies by Perovic et al. [20], Cascone [21], and Tam [22] show that proper roof insulation

and drainage are essential in warm, humid regions to reduce heat gain and water intrusion. The findings reaffirm the importance of hidden roofs as a climate-responsive solution, capable of reducing energy loads and improving occupant comfort [13,23]. Implication: Hidden roofs are widely seen as effective in managing climate challenges, particularly water resistance and heat reduction, which are critical for tropical regions.

From the social value indicators, the mean scores ranged from 4.13 to 3.81. The top four indicators under this construct were "Hidden roof designs improve the visual appeal of communities", "The use of hidden roofs promotes architectural harmony in urban areas", "Hidden roofs encourage innovation in roof designs and construction" and "Hidden roofs play a crucial role in preserving the cultural identity of buildings", with mean scores of 4.13 (SD = 0.821), 4.06 (SD = 0.889), 4.00 (SD = 0.994) and 4.00 (SD = 0.871), respectively. Respondents recognised the architectural harmony, cultural preservation, and innovative potential of hidden roofs (Mean > 4.00), indicating a growing social acceptance. While not as dominant as technical or environmental dimensions, this aligns with Wibaut et al. [5], Ibrahim & Nassef [6], and Wang & Guo [19], who suggest that roof forms contribute to community identity and architectural coherence. However, the slightly lower ranking of this construct suggests that social value is appreciated but may still lag behind more tangible benefits like climate adaptation and functionality [4,18]. Implication: While hidden roofs are seen as culturally and socially beneficial, the social impact is not as strong as climate- or design-related benefits.

Perception of the hidden roof was rated with mean scores ranging from 4.40 to 3.95, showing a high level of agreement with the indicators. The first four top-rated indicators were: "I would recommend hidden roof systems for urban housing projects", "The ease of maintenance affects my willingness to use hidden roofs", "Hidden roofs are more secure as compared to traditional roofs" and "I intend to use a hidden roof construction in my next project/building". The means for these first four were 4.4 (SD = 0.788), 4.32 (SD = 1.040), 4.22 (SD = 0.872) and 4.21 (SD = 1.065), respectively. Strong agreement with recommending hidden roofs for urban housing projects (Mean = 4.40) reflects growing stakeholder confidence, echoing Guzmán-Sánchez et al. [3] and Vasiliu [18], who observed increasing adoption of integrated roofing systems in city developments. While cost and durability concerns were noted, this supports the idea that perceptions are largely positive when the roof system is associated with modernity, security, and utility integration. It also reinforces the need for cost-effective design innovations to support wider adoption [14]. Implication: Stakeholders view hidden roofs as favourable, especially in modern, urban contexts, but cost and long-term durability raise minor concerns.

Sustainable construction method of the hidden roof was rated with mean scores ranging from 4.25 to 3.78, showing a high level of agreement with the indicators. The top four rated indicators were: "The hidden roof system can be integrated with solar energy solutions", "The design of hidden roof reduces heat in the roof, which can affect indoor air quality" and "The hidden roof system allows for the incorporation of a green roof system". The means for these first four were 4.25 (SD = 0.881), 4.24 (SD = 0.864) and 4.20 (SD = 0.871), respectively. Perceptions around solar integration (4.25), heat reduction (4.24), and green roofing (4.20) affirm hidden roofs' compatibility with sustainable design goals. According to Wicker et al. [23], Guzmán-Sánchez et al. [3], Andreescu et al. [4], Urbanik & Tomaszewicz [13], roof design plays a pivotal role in energy efficiency and environmental performance. The lower ratings for eco-material use and waste reduction suggest that while hidden roofs are seen as sustainability enablers, stakeholders may be less aware of or less confident in their full environmental lifecycle benefits. These highlight an opportunity for further education and innovation in sustainable material selection and green construction practices [13,23]. Implication: Hidden roofs are strongly associated with

sustainability and energy efficiency, though perceptions about environmental materials and construction waste are less emphasised.

4.3. Measurement Model Evaluation of Hidden Roof

Following Hair [41], the measurement model was assessed for both reliability and validity. Reliability was evaluated using Cronbach's alpha, composite reliability, and factor loadings, all of which met acceptable thresholds. Validity assessment included Average Variance Extracted (AVE) for convergent validity and the Fornell–Larcker criterion for discriminant validity. Table 4 and Figure 3 detail the constructs along with their associated items, loadings, weights, reliability coefficients, and AVE values, confirming the robustness of the measurement model.

Table 4. Reliability and Validity of the Hidden Roof Model.

Constructs	Items	Weight	Factor Loading	CR	CA	AVE
Aesthetic Value of the Hidden Roof	AVHR1	0.218	0.803	0.908	0.874	0.664
	AVHR2	0.234	0.833			
	AVHR3	0.275	0.814			
	AVHR4	0.218	0.836			
	AVHR5	0.284	0.788			
Climate Adaptation of the Hidden Roof	CAHR1	0.228	0.847	0.939	0.914	0.795
	CAHR2	0.346	0.936			
	CAHR3	0.266	0.900			
	CAHR4	0.276	0.882			
Social Value of the Hidden Roof	SVHR1	0.185	0.828	0.926	0.905	0.677
	SVHR2	0.217	0.829			
	SVHR3	0.173	0.838			
	SVHR4	0.188	0.812			
	SVHR5	0.201	0.801			
	SVHR6	0.253	0.825			
Design Concept of Hidden Roof	DCHR1	0.228	0.812	0.91	0.876	0.67
	DCHR2	0.240	0.772			
	DCHR3	0.270	0.891			
	DCHR4	0.273	0.833			
	DCHR5	0.208	0.779			
Sustainable Construction Method of the Hidden Roof	SCMHR1	0.120	0.729	0.931	0.914	0.66
	SCMHR2	0.164	0.864			
	SCMHR3	0.185	0.795			
	SCMHR4	0.233	0.878			
	SCMHR5	0.174	0.770			
	SCMHR6	0.176	0.825			
	SCMHR7	0.170	0.818			
Functionality of the Hidden Roof	FHR1	0.308	0.873	0.899	0.851	0.691
	FHR2	0.263	0.804			
	FHR3	0.334	0.834			
	FHR4	0.297	0.812			

Table 4. *Cont.*

Constructs	Items	Weight	Factor Loading	CR	CA	AVE
Perception of the Hidden Roof	PHR1	0.160	0.853	0.956	0.947	0.729
	PHR2	0.151	0.874			
	PHR3	0.163	0.862			
	PHR4	0.141	0.802			
	PHR5	0.144	0.873			
	PHR6	0.120	0.884			
	PHR7	0.150	0.843			
	PHR8	0.143	0.837			

CR: Composite Reliability; CA: Cronbach's Alpha; AVE: Average Variance Extracted. Source: Fieldwork, 2025.

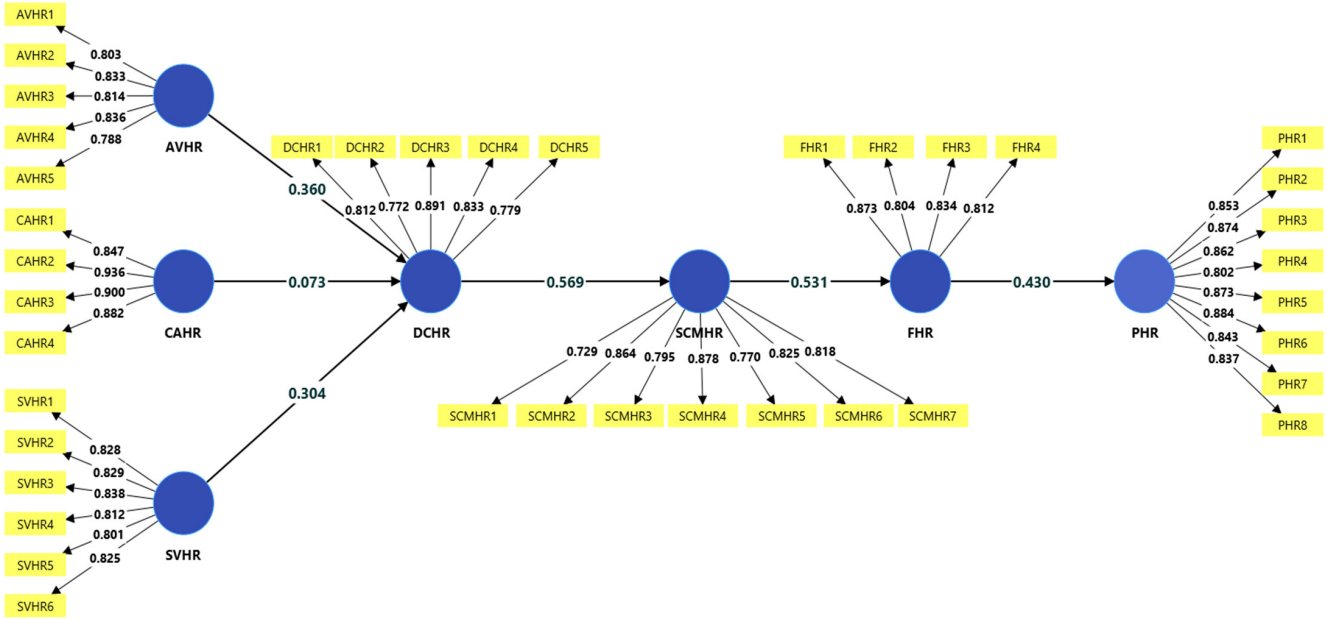

Figure 3. Measurement Diagram. Source: Fieldwork, 2025.

Table 5 presents the reliability and convergent validity statistics of the estimated model. Indicator loadings ranged from 0.729 to 0.936, exceeding the 0.70 threshold, confirming strong indicator reliability. Both composite reliability (0.899 to 0.956) and Cronbach's alpha (0.851 to 0.947) surpassed recommended thresholds, indicating high internal consistency across constructs. Convergent validity was confirmed, with Average Variance Extracted (AVE) values ranging from 0.660 to 0.795, above the 0.50 threshold, demonstrating that each construct explained over 50% of the variance in its indicators [41]. Discriminant validity, assessed using the Fornell–Larcker criterion, further supported the model's robustness.

Table 5. Discriminant Validity Using Fornell–Larcker Criterion.

	AVHR	CAHR	SVHR	DCHR	SCMHR	FHR	PHR
AVHR	0.815						
CAHR	0.474	0.892					
SVHR	0.477	0.517	0.823				
DCHR	0.54	0.401	0.514	0.819			
SCMHR	0.647	0.537	0.529	0.569	0.813		
FHR	0.524	0.471	0.509	0.463	0.531	0.831	
PHR	0.494	0.219	0.19	0.278	0.492	0.43	0.854

Source: Fieldwork, 2025.

Using the Fornell–Larcker criterion, discriminant validity was confirmed by comparing the square roots of the Average Variance Extracted (AVEs) with the inter-construct correlation coefficients. The square roots of the AVEs, placed on the diagonal in Table 5, were all higher than the corresponding correlation coefficients, indicating that each construct shared more variance with its indicators than with other constructs. This result supports the presence of discriminant validity in the model [42].

4.4. Structural Model Evaluation

After confirming that the measurement model met reliability, convergent validity, and discriminant validity standards, the structural model was assessed to explore relationships among hidden roof latent variables [41]. Key parameters evaluated included the constructs' coefficients of determination (R^2), predictive relevance (Q^2), path coefficients, and the statistical significance of each relationship [42,43].

From the results (Table 6), the coefficient of determination (average variance), the R-square, and adjusted R-square were 0.380 and 0.369, 0.323 and 0.319, 0.282 and 0.278 and 0.185 and 0.180 for design concept, sustainable construction method, functionality and perception of the hidden roof, respectively. The Q-square value measured the predictive relevance of the model as shown in Figure 4. According to Cohen [43] and Hair et al. [42], a construct's predictive relevance is small if $0.02 \leq Q^2 < 15$ and medium if $15 \leq Q^2 < 35$ and $Q^2 > 0.35$. The path from AVHR, CAHR and SVHR to DCHR had large predictive relevance (thus, $Q^2 > 0.35$). The Q^2s from DCHR to SCMHR, from SCMHR to FHR, and FHR showed moderate predictive relevance (thus, within $18 \leq Q^2 < 0.35$), while PHR was <18, indicating small predictive relevance.

Table 6. Quality Criteria of the Model.

Dependent Var.	R-Square	Adjusted	Q^2 Predict
DCHR	0.38	0.369	0.348
SCMHR	0.323	0.319	0.360
FHR	0.282	0.278	0.180
PHR	0.185	0.180	0.053

Source: Fieldwork, 2025.

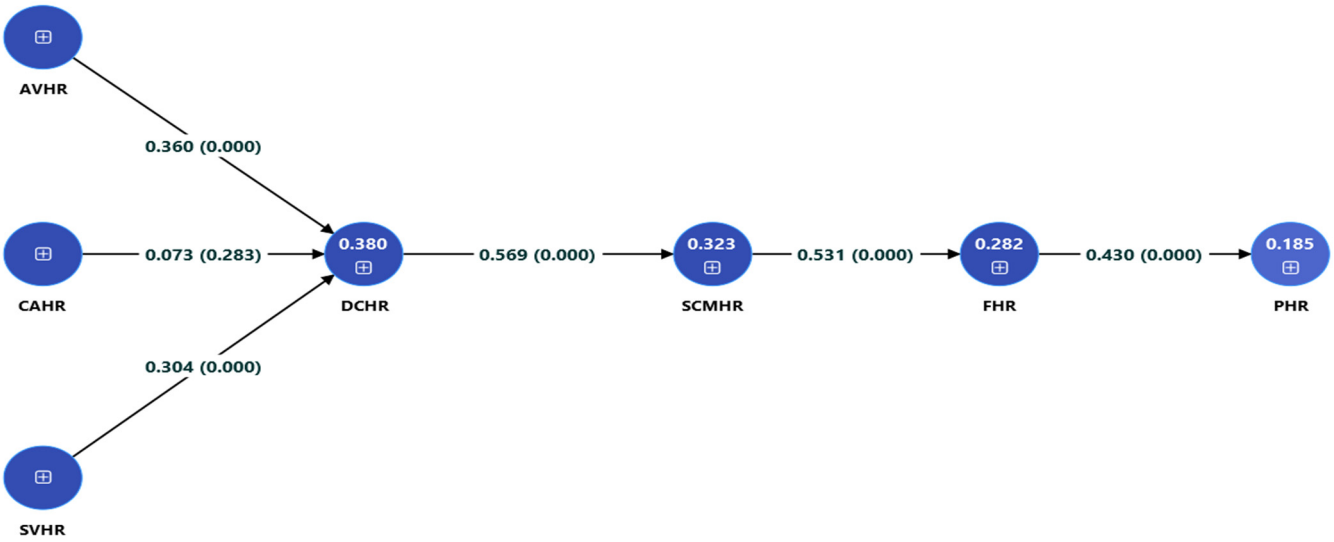

Figure 4. Structural Model Diagram. Source: Fieldwork, 2025.

The relationships among the latent constructs were measured, and the results are presented in Table 7. The analysis revealed that the aesthetic value of the hidden roof had

a significant positive relationship with the design concept of the hidden roof. The path coefficient between aesthetic value and the design concept of hidden roof was 0.360, the t-value was 4.458 and the *p*-value < 0.05. The strong positive relationship between aesthetic value and the design concept of hidden roofs (β = 0.360, t = 4.458, p < 0.05) reinforces the role of visual appeal in shaping perceptions of architectural quality. Aesthetic value, characterised by modern appearance, clean lines, and minimalism, contributes significantly to how stakeholders interpret the overall design logic. As noted by Guzmán-Sánchez et al. [3] and Vasiliu [18], in modern urban architecture, a structure's aesthetic integration with its environment enhances user satisfaction and community acceptance. Moreover, Urbanik & Tomaszewicz [13] emphasise that design aesthetics go beyond visual appeal, often serving as signals of quality, innovation, and functionality, especially in residential and commercial real estate.

Table 7. Path Coefficients and Significance.

	Path Coefficient	**Sample Coefficient**	**Std Dev.**	**t-Value**	***p*-Value**
AVHR -> DCHR	0.360	0.362	0.081	4.458	0.000
CAHR -> DCHR	0.073	0.072	0.068	1.073	0.283
SVHR -> DCHR	0.304	0.310	0.075	4.078	0.000
DCHR -> SCMHR	0.569	0.570	0.070	8.127	0.000
FHR -> PHR	0.430	0.433	0.071	6.027	0.000
SCMHR -> FHR	0.531	0.532	0.073	7.238	0.000

Source: Fieldwork, 2025.

The analysis revealed that the social value of the hidden roof had a significant positive relationship with the design concept of the hidden roof. The path coefficient between the social value of the hidden roof and the design concept of the hidden roof was 0.304, the t-value was 4.078 and the *p*-value < 0.05. The positive relationship between social value and the design concept (β = 0.304, t = 4.078, p < 0.05) indicates that perceptions of cultural relevance, architectural harmony, and communal identity significantly influence how hidden roofs are evaluated. According to Andreescu et al. [4] and Vasiliu [18], design practices that resonate with local cultural narratives and promote social cohesion tend to have greater acceptance and longevity. Hidden roofs, by supporting architectural uniformity and fostering innovative designs, may serve as symbols of progressive yet culturally grounded urban development. This finding also echoes Wibaut et al. [5], Ibrahim & Nassef [6], and Wang & Guo [19]'s assertion that socially responsive design enhances the perceived legitimacy and desirability of built forms.

The analysis revealed that the design concept of the hidden roof had a significant positive relationship with the sustainable construction method of the hidden roof. The path coefficient between the design concept of the hidden roof and the sustainable construction method of the hidden roof was 0.569, the t-value was 8.127 and the *p*-value < 0.05. The robust link between design concept and sustainable construction method (β = 0.569, t = 8.127, p < 0.05) highlights how good design directly facilitates sustainability outcomes. This supports the perspective of Urbanik & Tomaszewicz [13], who emphasise that sustainability is not an add-on but should be embedded in design thinking from the outset. Hidden roofs, with their compatibility with solar panels, green roofs, and rainwater harvesting systems, exemplify design approaches that align form with ecological function. Moreover, Guzmán-Sánchez et al. [3], Andreescu et al. [4] advocate for systems thinking in sustainable architecture, where design decisions anticipate energy, water, and material efficiency across the building lifecycle.

The analysis revealed that the sustainable construction method of the hidden roof had a significant positive relationship with the functionality of the hidden roof. The path coeffi-

cient between the sustainable construction method of the hidden roof and functionality of the hidden roof was 0.531, the t-value was 7.238 and the *p*-value < 0.05. The finding that sustainable construction methods positively influence functionality (β = 0.531, *t* = 7.238, *p* < 0.05) underscores the dual benefit of sustainable design: enhanced performance and reduced environmental impact. Features such as thermal insulation, efficient drainage, and weather resilience not only lower operational costs but also improve the daily usability of buildings. Studies by Perovic et al. [20], Cascone [21], and Tam [22] confirm that sustainability interventions, when properly implemented, enhance structural integrity, indoor comfort, and durability. The hidden roof system's capability to reduce heat absorption and support energy-saving technologies contributes directly to its functional performance, especially in tropical climates.

The analysis revealed that the functionality of the hidden roof had a significant positive relationship with perception of the hidden roof. The path coefficient between perception of the hidden roof and functionality of the hidden roof was 0.430, the t-value was 6.027 and the *p*-value < 0.05. Lastly, the significant relationship between functionality and perception (β = 0.430, *t* = 6.027, *p* < 0.05) suggests that practical utility plays a pivotal role in shaping overall stakeholder acceptance. This resonates with findings from Wicker et al. [23], who argue that end-users, developers, and regulators assess building components based on performance criteria such as reliability, ease of maintenance, and cost-effectiveness. Functional performance, particularly in terms of water resistance, space utilisation, and structural safety, directly informs whether a roof system is considered viable for modern housing [14]. As Guzmán-Sánchez et al. [3], Vasiliu [18] and Urbanik & Tomaszewicz [13] highlight, user satisfaction in built environments is closely tied to how well-designed features align with operational needs.

4.5. Hypotheses Evaluation

The six hypotheses evaluation is presented in Table 8. All (H1, H3–H6) were significant and supported, except H2.

Table 8. Hypotheses Evaluation based on Path Analysis Results.

H_i	Hypothesis Statement	Sign	Level	Comment
H_1	The aesthetic value of the hidden roof has a significant influence on the design concept of the hidden roof	+	Significant	Supported
H_2	Climate adaptation of the hidden roof has a significant influence on the design concept of the hidden roof	+	Not Significant	Not Supported
H_3	The social value of the hidden roof has a significant influence on the design concept of the hidden roof	+	Significant	Supported
H_4	The design concept of the hidden roof has a significant influence on the sustainable construction method of the hidden roof	+	Significant	Supported
H_5	The sustainable construction method of the hidden roof has a significant influence on the functionality of the hidden roof	+	Significant	Supported
H_6	Functionality of the hidden roof has a significant influence on the perception of the hidden roof	+	Significant	Supported

5. Conclusions

This study investigated stakeholders' perceptions of hidden roof systems by evaluating various dimensions such as functionality, design concept, aesthetic and social value, climate adaptation, sustainability, and overall user perception. The results demonstrate a strong appreciation for hidden roofs, particularly due to their climate adaptability, most notably their ability to prevent water leakage and reduce heat absorption. These qualities make them especially suitable for tropical environments, where extreme weather conditions demand resilient roofing solutions.

The design concept, with an emphasis on efficient internal drainage systems, received the highest ratings, reflecting the significance of technical reliability and modern utility integration, such as solar panels and service installations. Aesthetic value was also rated highly, with respondents praising the modern, flat-top appearance of hidden roofs and their contribution to visual coherence in urban environments. Social value indicators, including cultural relevance, architectural harmony, and innovative appeal, further contributed to the broader acceptance of hidden roofs in residential and commercial developments. From a sustainability perspective, features such as integration with solar energy systems, improved indoor air quality through heat reduction, and green roofing options were perceived positively. However, areas such as material waste reduction and the use of eco-friendly materials were rated moderately, indicating potential areas for improvement.

The structural analysis of the relationships between constructs confirmed that aesthetic and social values significantly influence the design concept, which in turn drives the adoption of sustainable construction practices. These practices then enhance the functionality of the roofing system, ultimately shaping positive perceptions among stakeholders. Overall, the study underscores the importance of a holistic design approach that balances technical performance, environmental responsibility, and contextual aesthetics. The insights are valuable for architects, builders, and policymakers aiming to promote sustainable, climate-resilient, and visually appealing roofing solutions in urban housing.

This study contributes to the growing body of knowledge on sustainable roofing by providing empirical evidence on stakeholder perceptions of hidden roof systems, highlighting their functional, aesthetic, social, and environmental benefits. It introduces an integrated framework showing how aesthetic and social values influence design, which in turn drives sustainability and functionality, ultimately shaping user perception. Based on these findings, the study recommends that policymakers promote hidden roof systems through updated standards and incentives, while architectural and construction training programmes incorporate hidden roof design principles. Practitioners are encouraged to adopt hidden roofs for their climate adaptability and integration with modern infrastructure.

Limitations and Future Research Directions

Despite its contributions, this study is not without limitations. Firstly, the research was geographically limited to the Kumasi Metropolitan area, which, although representative of Ghana's urban context, may not fully capture regional variations in architectural practices, socio-economic conditions, or climate adaptation strategies. Secondly, the study relied primarily on self-reported perceptions from professionals and homeowners, which may introduce subjective bias or overestimation of positive attributes. Additionally, the cross-sectional design restricts the ability to observe how perceptions and adoption behaviours evolve.

Future studies should therefore consider expanding the geographical scope to include other urban areas such as Accra, Takoradi, and Tamale to provide comparative insights into regional variations in hidden roof adoption. Further research could also employ

mixed-method or longitudinal approaches to capture deeper behavioural and temporal dynamics associated with hidden roof utilisation. Moreover, a cost–benefit or life cycle analysis would be valuable to assess the economic feasibility and long-term performance of hidden roofs relative to conventional roofing systems. These avenues will deepen understanding and support evidence-based innovation in sustainable urban housing across Ghana and beyond.

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Data Availability Statement: The data collected for the research study are available upon reasonable request due to no permission for online publication was obtained from the data owners at the time of data collection. Researchers interested in accessing the data must submit a request outlining their research intentions and how they plan to use the data. Access will be granted at the discretion of the research team, provided that the proposed use aligns with ethical research standards and respects the confidentiality of the participants.

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