Computational Analytical Mapping of Spatial Organization in Kano Metropolis: A Shape Grammar Approach to Traditional Hausa Houses

Olakanbi AbdulRaheem Bolaji[1], Aminu Lawan Abdullahi[2], Aliyu Zakari[3], Abdullahi Muhammad Yaradua[4], Ajibola Edidiong Nseabasi[5], Nusa Jubril Danlami[6] and Hassan, A. Tanimu[7]

[1,2,3,4,5&6]*Department of Architecture, Faculty of Environmental Sciences, University of Abuja, Nigeria*
[7]*Department of Industrial Design, Faculty of Environmental Sciences, University of Abuja, Nigeria*

Abstract | **Original Research Article**

This research, using the analytic shape grammar method, studies the specific spatial organization of the typical plan layouts of the Hausa traditional architecture found in Northern Nigeria with a view to provide a way of exploring feasible designs. Existing data (plan layouts) were collected from the corpus of surveyed works from 2005 to 2008 in Kano municipal of Northern Nigeria. Thirty–eight of the plan layouts were analyzed with an attempt to produce the Hausa architectural design grammar. The findings classified the spatial organization plan layout types into two major groups, according to the form of their courtyard: Hypo-courted type and Interconnect courted type of Hausa Traditional Architecture; sub-divided into five groups in terms of spatial organization and area: 3 - 6 Rooms Single type (100 sqm); 5-8 Rooms Single type (225 sqm); 2-3 Rooms of 3 Apartments type (486 sqm); 2-3 Rooms of 3 Row Houses type (900 sqm); Storey Building type. From the findings are recommendations such as studying a more stylistic range of Northern Nigerian (Hausa) Architecture, a formal description of the urban design space in terms of the Hausa traditional city shape, and the necessary development of a formal generative mechanism to be used for the computational component of this unique architectural style.

Keywords: Hausa Traditional Architecture, Northern Nigeria, Spatial Organization, Shape Grammar, Plan Layouts, Courtyard Types, Architectural Design Grammar, Urban Design, Generative Design, Computational Architecture.

INTRODUCTION

The study of spatial organization and architectural language elements in traditional houses has gained increasing global recognition due to its relevance in preserving cultural heritage and informing contemporary design practices. Across different parts of the world, spatial configurations in traditional dwellings reflect the socio-cultural, environmental, and technological contexts in which they evolve. In Europe and Asia, for instance, traditional architecture often adheres to geometric principles and shape grammar rules that define proportions, symmetry, and spatial connectivity (Alexander, 1977). These principles ensure a balance between aesthetics and functionality, reinforcing hierarchical spatial arrangements and privacy gradients. In Islamic and vernacular architecture, particularly in the Middle East and North Africa, courtyards play a central role in spatial configuration, functioning as climatic regulators and social spaces (Omer, 2019). Similarly, in sub-Saharan Africa, including Nigeria, indigenous architecture relies on spatial hierarchy and geometric elements to organize domestic and communal spaces.

On the African continent, traditional architectural forms reflect a deep connection between spatial organization and cultural identity. Indigenous African dwellings, including those of the Hausa people, demonstrate a spatial logic governed by cultural norms and environmental adaptation. The courtyard system, a key feature in many African and Middle Eastern traditional homes, serves as the nucleus of spatial organization, providing ventilation and a private space for family activities (Falola & Salami, 2020). The shape grammar of African architecture incorporates recurring motifs, proportions, and symmetry that not only enhance aesthetic appeal but also contribute to the

structural integrity of buildings (Gardi, 2014). Within the Hausa context, traditional houses in Kano Metropolis exhibit distinctive spatial elements such as the zaure (entrance hall), which mediates between public and private domains, reinforcing social norms and privacy hierarchies.

Regionally, Hausa architecture in northern Nigeria exemplifies a well-defined spatial configuration that integrates functional, cultural, and environmental considerations. The central courtyard is a prominent feature that organizes spatial relationships within the household, ensuring a clear separation of public and private spaces (Denyer, 1978). Additionally, the arrangement of rooms follows a structured hierarchy, with the male and female quarters reflecting gender-based spatial organization. The placement of the zaure, serving as a transitional space, plays a crucial role in defining access and movement patterns within the house. These elements align with broader architectural traditions in West Africa, where geometric principles and shape transformation rules dictate the layout and ornamentation of buildings (Oliver, 1997).

Architectural language elements of traditional Hausa houses, encompasses spatial configuration and geometric and shape grammar features. Spatial configuration, a fundamental aspect of architectural design, determines the arrangement and relationships between various spaces within a building. In Hausa traditional houses, spatial organization follows a structured hierarchy that accommodates privacy needs and functional requirements. The courtyard organization, a defining feature, influences airflow, temperature regulation, and social interactions (Edwards, 2005). Room connectivity determines the ease of movement between different sections of the house, ensuring logical spatial transitions that enhance usability and security. The hierarchical spatial arrangement dictates the placement of key rooms and functional spaces, reinforcing cultural values and traditional customs.

Within spatial configuration, the central courtyard (zaure) is a crucial element that integrates social and environmental functions. The zaure serves as a reception area for visitors while maintaining the privacy of inner residential spaces. Its placement aligns with the broader architectural principle of transitional spaces, a concept observed in Islamic and African vernacular architecture (Bianca, 2000). The entrance hall, another critical spatial feature, controls access to the inner courtyard and living quarters, reinforcing security and privacy. Privacy gradients further define the spatial hierarchy, ensuring that public, semi-private, and private spaces are clearly demarcated. These gradients reflect socio-cultural norms, where gender roles and family interactions influence the spatial organization of traditional Hausa homes (Nash, 2018).

Geometric and shape grammar features provide a systematic approach to understanding architectural design through visual and mathematical rules. Proportions and symmetry govern the overall aesthetic balance of traditional Hausa houses, ensuring that structures adhere to established design principles (Hillier & Hanson, 1984). Recurring motifs and patterns, observed in wall decorations and façade designs, reinforce cultural identity and artistic expression. The number of rooms within a house is another crucial parameter that influences spatial distribution and functional efficiency. Larger households require a complex spatial hierarchy, with designated spaces for different family members and activities.

The placement of the zaure is a vital aspect of spatial organization, dictating access and movement patterns within the house. In many traditional Hausa houses, the zaure is strategically positioned to control the interaction between public and private realms (Adamu, 2005). Courtyard division further refines spatial relationships, ensuring that spaces are allocated based on their intended function. For instance, separate courtyards may be designated for men and women, reflecting gendered spatial dynamics within Hausa society. The placement of staircases is another significant architectural consideration, influencing vertical movement and accessibility within multi-story dwellings.

Shape transformation rules play a critical role in the evolution of Hausa traditional architecture. These rules define how spatial elements can be modified or adapted while maintaining coherence with established design principles (Stiny & Mitchell, 1978). For example, variations in courtyard layouts, room configurations, and façade treatments illustrate the adaptability of Hausa architectural forms. Despite modern influences, traditional houses in Kano Metropolis continue to exhibit these shape grammar features, preserving their cultural and functional significance.

The interrelationships between spatial configuration and geometric and shape grammar features are evident in the holistic design of Hausa traditional houses. Courtyard organization, for instance, is directly influenced by proportionality and symmetry, ensuring a balanced and harmonious layout. Room connectivity aligns with shape grammar principles, where spatial transitions are defined by established transformation rules. Hierarchical spatial arrangements reinforce privacy gradients, which in turn dictate the placement of key architectural elements such as the zaure and entrance hall.

Moreover, the interplay between recurring motifs and spatial configuration highlights the cultural significance of architectural design. Decorative patterns and symbolic motifs not only enhance aesthetic appeal but also delineate spatial boundaries and hierarchical distinctions. The number of rooms and their placement within the house reflect both functional requirements and social hierarchies, ensuring that spatial organization adheres to traditional norms and values.

Statement of the Problem

Traditional Hausa houses in Kano Metropolis face several challenges that affect their spatial configuration and overall architectural integrity. One of the major problems is the disruption of courtyard organization due to increasing urban density and modernization. The traditional courtyard, which serves as the nucleus of spatial organization, is being replaced by

more compact housing units that lack adequate ventilation and privacy (Falola & Salami, 2020). Analytical mapping through shape grammar can help document and preserve traditional courtyard layouts, ensuring their integration into contemporary housing designs.

Another critical issue is the weakening of room connectivity in modern adaptations of Hausa architecture. The traditional spatial logic, which allows for smooth movement and hierarchical organization, is often compromised by irregular room placements (Gardi, 2014). Shape grammar principles can be applied to analyze and reconstruct efficient room connectivity patterns that maintain the functional and cultural essence of Hausa dwellings.

Hierarchical spatial arrangement is also under threat due to modern building practices that do not account for traditional social structures. The cultural emphasis on privacy and gendered spaces is being eroded, leading to layouts that do not align with Hausa cultural norms (Oliver, 1997). Shape grammar analysis can help identify and reintroduce hierarchical spatial arrangements to ensure that traditional values are retained in contemporary housing.

Privacy gradients are also being compromised due to modern housing designs that do not consider the traditional separation of public and private spaces. Analytical mapping using shape grammar can redefine privacy gradients, ensuring the continuity of cultural norms in spatial design.

The placement of staircases in modern adaptations often disrupts spatial flow and usability, deviating from traditional patterns. Shape grammar principles can guide staircase placement in ways that maintain efficient circulation within houses.

Lastly, the division of courtyards in contemporary housing developments often disregards traditional zoning principles, affecting the usability of shared spaces. Shape grammar can offer systematic guidelines for courtyard division that align with Hausa architectural traditions.

Stiny (1975) introduced shape grammar as a formal design approach to architecture based on the computational theory of formal language by Chomsky (1966), Chomsky in his primitive analytic and generative grammars, cited the significance of analytic grammars in the operation of natural language. Chomsky (1966) argued that natural language as involving a type of rule-governed creativity; "his theories about languages have influenced social and pure sciences; computer science and design theory, and philosophy. This language theory provided a blueprint for modelling the computational analytic and generative process of architecture (Coyne 1988). Analytic shape grammar were used to understands a given design style through decomposition of its elements, making design a problem-solving activity with space formulation for possible solutions. For optimal space solutions, shape grammars formally describe the shape of a design space and provide for the exploration of design possibilities.

Most published materials on shape grammar have been about formalizing established architectural design styles,

to analyze original designs in those styles. Among these works are shaped grammars for the architecture of Giuseppe Terragni by Flemming (1981), Frank Lloyd Wright by Koning and Eizenberg (1981), Glenn Murcutt by Hanson and Radford (1986), Christopher Wren by Buelinckx (1993), and Irving Gill by J.Gibbs (1981), for the vernacular styles of Japanese tearooms by Knight (1999), bungalows of Buffalo by Downing and Flemming (1981), Queen Anne houses by Flemming (1987), and Taiwanese traditional houses by Chiou and Krishnamurti (1996). Also are the landscape architecture of Mughul Gardens by G.Stiny and W.j.Mitchell (1980), and the development of shape grammar for Suakin city of Sudan (Olakanbi, Abdulraheem and O, Rayis 2016). Notably, the Wright Grammar is the first 3D architectural design style, influenced partly by Stiny's earlier work on kindergarten grammar, just like Froebel influenced Wright's architecture.

Flemming (1981) conducted a study on the formal characteristics of Terragni's Casa Giuliani Frigerio, utilizing parametric shape grammar to analyze its architectural composition. The study aimed to uncover the underlying design principles governing the structure, offering a systematic explanation of its form and spatial organization. The methodology involved applying parametric shape grammar to identify recurring geometric patterns and compositional rules, allowing for a deeper understanding of how the building's architectural elements relate to one another. The findings revealed that Casa Giuliani Frigerio follows a structured and rule-based design approach, demonstrating how formal elements can be generated and analyzed through parametric grammar. The study concluded that parametric shape grammar serves as a powerful analytical tool for decoding architectural styles, enabling a precise understanding of complex design systems. Flemming recommended further research on the application of shape grammars in modern and historical architecture, particularly for preserving, reconstructing, and innovating architectural designs based on established formal principles.

Downing and Flemming (1981) conducted a study on the architectural conventions of bungalows built between 1914 and 1926 in Buffalo, New York, focusing on how these houses relate to other popular house types. The study aimed to analyze the spatial organization of Buffalo bungalows and establish their underlying design conventions using a parametric shape grammar. The methodology involved measured drawings of seven bungalows, which were examined to identify common organizational patterns and geometric variations. The findings revealed that bungalows share a set of design rules, with differences arising from geometric variations within a common framework. The study concluded that shape grammar provides a systematic approach to understanding architectural styles, offering a way to explain variations within a shared set of conventions. The authors recommended further research on parametric shape grammar as a tool for analyzing and preserving traditional housing styles, with potential applications in architectural restoration and design adaptation.

Flemming (1994) conducted a study on the shape grammar

of Queen Anne houses, focusing on the historic Shadyside district in Pittsburgh, USA, where this architectural style was prevalent in the 1880s. The study aimed to define shape grammars that generate Queen Anne-style houses, illustrating how individual architectural components relate to the overall design. The methodology involved developing separate shape grammars for plan generation and three-dimensional articulation, emphasizing geometric relationships and design coherence. The findings revealed that Queen Anne houses follow specific architectural rules, where individual elements, such as turrets, gables, and asymmetrical facades, contribute to a unified aesthetic. The study concluded that shape grammars provide a systematic way to understand and generate Queen Anne-style houses, demonstrating their potential as tools for architectural analysis and preservation. Flemming recommended further exploration of shape grammars to facilitate the restoration, conservation, and adaptation of historical architectural styles in contemporary design practice.

Olakanbi Bolaji AbdulRaheem and Osama Abdulwahab Rayis (2016) conducted a study on the parametric shape grammar of traditional Suakin houses in the Red Sea State, Sudan. The study aimed to systematically generate appropriate plan arrangements that ensure the required functional relationships between spaces while preserving the architectural heritage of Suakin. The researchers employed an analytical methodology that examined the topological and geometrical properties of old Suakin houses, tracing their origins and integration into traditional Suakin buildings over the past ten centuries. The findings revealed that the shape rules, dimensional properties, and geometric and topological patterns of houses in the corpus serve as a generative model for the Suakin architectural language. The study concluded that parametric shape grammars hold significant creative and generative value, aiding in understanding the formal composition of Suakin's historical style. Additionally, it emphasized the potential for reviving and adapting Suakin's architectural principles in contemporary building designs. The authors recommended further exploration of parametric shape grammar as a tool for architectural preservation and innovation in traditional Sudanese architecture.

Olakanbi Bolaji AbdulRaheem and Osama Abdulwahab Rayis (2016) conducted a study on the generative mechanisms of Suakin architecture, emphasizing its creative ambiguity and diverse architectural influences, including Turkish, Anglo-Egyptian, Mamluk, and traditional styles. The study, carried out at the Design and Innovation Center, Africa City of Technology, Sudan, aimed to introduce shape grammar as a generative tool for Suakin architecture. The researchers employed a deductive analysis methodology, examining a corpus of five traditional Suakin architectural styles to extract and compose new Suakin plan layouts. Their findings highlighted the rich generative potential of Suakin architecture, demonstrating how architectural rule specifications contribute to style generation and transformation. The study concluded that Suakin's architectural diversity can be systematically analyzed and regenerated using shape grammar tools, providing insights

into its formal composition and structural evolution. The authors recommended further exploration and application of generative design tools to preserve and adapt Suakin's architectural heritage for contemporary and future use.

Shape grammars in art usually include the paintings of Richard Diebenkorn by Kirsch, Kirsch et al. (1988), Georges Vantonger loo by Knight (1989), and Fritz Glarner by T.W.Knight (1989), the chair designs of Hepplewhite by T.W.Knight (1989), the window designs of Frank Lloyd Wright by Rollo (1995), and ornamental designs on ancient Greek pottery by T.W.Knight (1986).

Knight (1980) conducted a study on the generation of Hepplewhite-style chair-back designs, focusing on the application of parametric shape grammar to systematically generate and analyze these designs. The study aimed to develop a formalized approach for understanding and replicating the stylistic elements of Hepplewhite chair-backs, which are known for their elegant and intricate geometric patterns. The methodology involved constructing a parametric shape grammar that defines the design rules governing the structure and ornamentation of Hepplewhite chair-backs, allowing for variations within a consistent stylistic framework. The findings revealed that shape grammar provides a systematic way to generate new chair-back designs while maintaining the defining characteristics of the Hepplewhite style. The study concluded that parametric shape grammars can serve as valuable tools for preserving historical design principles and facilitating the creation of stylistically coherent new designs. Knight recommended further exploration of shape grammars in furniture design and other decorative arts to aid in both historical analysis and contemporary design innovation.

The stylistic ranges illustrate the generosity of the shape grammar formalism as in Knight (1978). That means a style is analyzed with an inferring grammar, the rules of the grammar are transformed which in turn forms the basis of a new grammar and style. Therefore, this study is carried out with the objective of identifying the unique elements and stylistic range of the specific spatial organization of Hausa Architecture of Northern Nigeria.

LITERATURE REVIEW

The concept of geometric vocabulary elements and shape grammar features plays a crucial role in understanding spatial configuration within architectural discourse. Geometric vocabulary elements refer to the fundamental shapes, proportions, and patterns that define architectural compositions, while shape grammar features provide a rule-based framework for generating and modifying architectural forms (Stiny, 2006). These principles are integral in analyzing spatial configurations across different architectural traditions, particularly in traditional Hausa houses, where spatial hierarchy, connectivity, and privacy gradients are essential design considerations (Hillier & Hanson, 1984).

Spatial configuration is a fundamental aspect of architectural design that determines the organization and relationships between different spaces within a building.

Courtyard organization, for example, is a key feature in traditional Hausa houses, serving as the central space around which other rooms are arranged. The courtyard provides ventilation, social interaction space, and a controlled microclimate, reinforcing its importance in vernacular architecture (Oliver, 1997). Shape grammar principles can be used to systematically analyze and replicate courtyard designs, ensuring their continued relevance in contemporary adaptations (Mitchell, 1990).

Room connectivity is another critical aspect of spatial configuration, as it dictates movement flow and accessibility within a house. In traditional Hausa architecture, room connectivity is designed to balance social interaction and privacy, ensuring seamless movement between different functional areas (Adamu, 2005). Geometric principles, such as symmetry and proportion, play a role in structuring room connectivity, creating an organized and efficient spatial layout (Hillier, 1996).

Hierarchical spatial arrangement is a defining characteristic of traditional Hausa houses, where spaces are arranged according to cultural and functional priorities. This hierarchy ensures that public, semi-private, and private spaces are appropriately separated, aligning with the socio-cultural norms of Hausa society (Denyer, 1978). Shape grammar provides a structured approach to understanding these spatial hierarchies, facilitating their analysis and replication in contemporary architectural practices (Stiny & Mitchell, 1978).

The central courtyard, or zaure, is a prominent spatial feature in Hausa architecture, acting as a transitional space that regulates access to different parts of the house. Its placement and configuration follow geometric principles that enhance security, privacy, and environmental control (Bianca, 2000). By applying shape grammar rules, architects can analyze the transformation of zaure designs over time, ensuring that modern adaptations retain their functional and cultural significance (Nash, 2018).

The entrance hall is another key spatial element that plays a role in defining the accessibility and security of traditional Hausa houses. It serves as a buffer between the external environment and private living areas, reinforcing the hierarchical spatial arrangement (Falola & Salami, 2020). Shape grammar allows for the systematic study of entrance hall configurations, offering insights into their evolution and potential modifications in contemporary housing developments (Gardi, 2014).

Privacy gradient is an essential consideration in Hausa architectural design, where spaces are arranged to ensure appropriate levels of privacy for occupants. This gradient dictates the transition from public to private spaces, influencing room placement, connectivity, and courtyard division (Edwards, 2005). Geometric principles, such as spatial depth and proportion, contribute to the effective implementation of privacy gradients, maintaining the integrity of traditional layouts (Hillier & Hanson, 1984).

Proportions and symmetry are fundamental geometric principles that govern the spatial organization of traditional Hausa houses. These principles ensure balance and harmony in architectural design, enhancing both functionality and aesthetic appeal (Stiny, 2006). Shape grammar provides a computational approach to analyzing proportions and symmetry, allowing architects to generate and modify designs based on established rules (Mitchell, 1990).

Recurring motifs and patterns are distinctive features of Hausa architecture, reflecting cultural identity and artistic expression. These motifs are often found in wall decorations, ceiling designs, and courtyard layouts, reinforcing the visual and symbolic coherence of traditional houses (Adamu, 2005). Shape grammar offers a methodological framework for cataloging and reproducing these motifs, ensuring their preservation in contemporary architectural practices (Oliver, 1997).

The number of rooms in traditional Hausa houses is an important spatial variable, influencing household organization and functionality. Larger households require more complex spatial configurations, with designated areas for different family members and activities (Denyer, 1978). Geometric principles help optimize room arrangements, ensuring efficient use of space while maintaining cultural norms and traditions (Bianca, 2000).

Zaure placement plays a crucial role in defining spatial transitions and access control within Hausa traditional houses. The strategic positioning of the zaure ensures that public and private spaces remain distinctly separated, aligning with cultural expectations of privacy and social interaction (Hillier, 1996). Shape grammar analysis can help document and refine zaure placements, allowing for adaptable yet culturally sensitive architectural solutions (Stiny & Mitchell, 1978).

Courtyard division is a critical spatial consideration, particularly in large traditional Hausa houses where multiple courtyards may be used for different functions. These divisions create distinct zones for family members, guests, and domestic activities, ensuring organized and functional spatial layouts (Oliver, 1997). Shape grammar provides a systematic approach to analyzing and designing courtyard divisions, enhancing their efficiency and cultural relevance (Gardi, 2014).

The placement of staircases in traditional Hausa houses is an architectural element that influences circulation and space utilization. In multi-story dwellings, staircases must be positioned strategically to optimize movement while preserving privacy gradients (Falola & Salami, 2020). Geometric principles help determine the most efficient staircase placements, ensuring accessibility and spatial coherence (Edwards, 2005).

Shape transformation rules govern the evolution of architectural forms, allowing for modifications while maintaining structural and cultural integrity. These rules dictate how spatial elements such as rooms, courtyards, and decorative features can be adapted over time, ensuring continuity in architectural traditions (Mitchell, 1990). By applying shape grammar principles, architects can study historical transformations and develop strategies for contemporary interpretations of Hausa architecture (Stiny, 2006).

The concepts of geometric vocabulary elements and shape grammar features provide valuable insights into the spatial organization of traditional Hausa houses. By analyzing courtyard organization, room connectivity, hierarchical spatial arrangement, and privacy gradients through shape grammar, architects can document, preserve, and adapt these traditional design principles in modern contexts. The integration of geometric principles ensures that spatial configurations remain functional, aesthetically coherent, and culturally relevant, contributing to the sustainability of Hausa architectural heritage in Kano Metropolis.

Noam Chomsky introduced the computational theory of formal language in 1956, later expanding on it in 1966. His theory classifies formal languages into a hierarchy known as the Chomsky Hierarchy, which consists of four levels: regular languages, context-free languages, context-sensitive languages, and recursively enumerable languages (Chomsky, 1966). The rationale behind this classification is to systematically describe the syntax of natural and artificial languages using formal grammars, where rules govern the structure and transformation of symbols. The computational aspect of this theory has been foundational in linguistics, computer science, and architectural modeling, particularly in understanding how rules shape structured systems.

Several scholars have supported Chomsky's theory, emphasizing its applicability in diverse fields. Hopcroft and Ullman (1979) argue that the formal language theory is crucial in computer science, particularly in compiler design and artificial intelligence, as it provides a structured way to define and manipulate symbols. Similarly, Stiny and Gips (1978) highlight the importance of formal grammars in shape grammar, a methodology for defining architectural patterns and transformations. They assert that the computational logic underlying Chomsky's framework can be adapted to analyze and generate spatial compositions in architecture. Moreover, Hillier and Hanson (1984) extend the applicability of formal grammars to spatial configuration, demonstrating how syntactic rules can model the spatial logic of built environments.

Despite its broad applicability, Chomsky's theory has faced criticism from scholars who argue that it oversimplifies the complexity of real-world systems. Pullum and Scholz (2002) contend that the strict hierarchical classification of languages does not fully capture the fluidity and contextual adaptability of natural languages. Additionally, Johnson (2004) critiques the deterministic nature of formal grammar, asserting that human cognitive processes and architectural spatial designs do not always adhere to rigid syntactic rules. Furthermore, Boden (2006) argues that Chomsky's approach lacks consideration for emergent design principles, particularly in creative disciplines such as architecture, where form and function evolve dynamically rather than through predefined syntactic structures.

Chomsky's computational theory of formal language justifies the current study on analytical mapping of spatial organization in Kano Metropolis by providing a structured methodology to define and analyze traditional Hausa

architectural elements. The study utilizes shape grammar, which is rooted in formal language theory, to identify and systematize the spatial configuration of Hausa traditional houses. By applying shape grammar rules, the study captures the geometric and spatial logic that governs courtyard organization, room connectivity, hierarchical spatial arrangements, and privacy gradients. This structured approach aligns with Chomsky's premise that formal rules can systematically define and manipulate complex structures, making it an effective tool for architectural analysis.

Furthermore, this study benefits from Chomsky's theory by leveraging computational models to explore feasible design adaptations while maintaining the integrity of traditional Hausa architecture. Just as formal languages provide a foundation for programming and artificial intelligence, shape grammar offers a rule-based framework to generate and evaluate spatial compositions. Through analytical mapping, this study contributes to the broader discourse on preserving architectural heritage while facilitating modern adaptations that retain cultural and spatial coherence. The application of formal grammars in spatial configuration ensures that Hausa architectural principles are systematically documented and reinterpreted in contemporary urban contexts.

George Stiny introduced the computational theory of shape grammar in 1975, revolutionizing the way architectural design is conceptualized through formal rule-based systems. Shape grammar provides a systematic method for generating and analyzing architectural forms using a set of transformation rules that define spatial compositions (Stiny, 1975). The rationale behind shape grammar theory lies in its ability to decompose complex architectural designs into fundamental geometric and spatial rules, allowing for the exploration of both traditional and novel design paradigms. By formalizing design languages, shape grammar offers a computational framework for preserving and adapting architectural heritage while facilitating creative spatial configurations.

Several scholars have supported Stiny's shape grammar theory, highlighting its applicability in various architectural and design contexts. Knight (1999) argues that shape grammar provides a generative system that enables architects to create design variations while maintaining stylistic coherence. Similarly, Duarte (2005) applies shape grammar to mass customization in housing, demonstrating its potential to balance traditional architectural principles with contemporary needs. Chase (2010) extends the argument by emphasizing shape grammar's role in computational design, particularly in automating pattern recognition and spatial transformation in architectural modeling. These studies reinforce the claim that shape grammar is a powerful tool for analyzing, reconstructing, and innovating within architectural traditions.

Despite its strengths, shape grammar theory has faced criticism, particularly regarding its computational complexity and applicability in non-rule-based design contexts. Agarwal and Cagan (1998) argue that the strict rule-based approach of shape grammar may be limiting in

cases where design intuition and fluidity are essential. Furthermore, Herr and Kvan (2007) criticize the difficulty in translating abstract architectural concepts into precise computational rules, questioning the practical usability of shape grammar in large-scale architectural projects. Additionally, McKay, Shea, and Chau (2012) point out that the reliance on predefined transformation rules restricts the emergence of organic, user-driven design evolutions, thereby reducing adaptability in dynamic architectural environments.

The computational theory of shape grammar justifies the current study on analytical mapping of spatial organization in Kano Metropolis by providing a structured method for analyzing the spatial composition of Hausa traditional houses. Hausa architecture follows established spatial hierarchies and geometric patterns, which can be systematically documented and replicated using shape grammar rules. By mapping out recurring spatial elements such as courtyard organization, room connectivity, and privacy gradients, shape grammar allows for a precise analysis of the underlying logic governing Hausa architectural forms (Stiny & Mitchell, 1978). This approach ensures that traditional design principles are not only preserved but can also be adapted for modern applications without losing cultural authenticity.

Furthermore, the analytical mapping shape grammar method provides a rule-based framework for exploring feasible designs in Hausa architecture while maintaining traditional spatial organization. Through computational modeling, this study formalizes the spatial rules governing the placement of zaure, courtyard divisions, and hierarchical arrangements, facilitating the generation of culturally responsive architectural solutions. As shape grammar enables both preservation and innovation, this study contributes to the sustainable development of Hausa traditional architecture in Kano Metropolis, ensuring that contemporary architectural adaptations respect the spatial logic and aesthetic coherence of historical Hausa dwellings.

Most recent buildings designs across Hausa regions in Nigeria have been built with imported styles, materials and the construction techniques tailored to satisfy the modernity self-ego and aspirations. Thus, traditional architecture styles ought not to be abandoned and forgotten, hence; experts' awareness should be tailored to the understanding of its original essence. Oluwagbemiga P. A and Modi S.Z. (2014).

The debate on Hausa Architecture of Northern Nigeria has concentrated on the development and incorporation of Hausa traditional elements and principles, several studies examined the cognizance of local materials, method of construction, another study investigated the methods of its lay-out, social, cultural factors, and environmental factors of Hausa context amongst others (O.P. Agboola and M. S. Zango 2014)(J. Lodson and J. E. Ogbeba, U. K. Elinwa 2018)(K.G. Umar 2019). There are also studies on form and spatial configuration (B. A. Danjuha 1988), socio-cultural effect on special organization of Hausa context (U. H. Bamalli 2020), conservation, preservation, and restoration of Hausa traditional architecture by highlighting the spatial morphology and technique (K.G. Umar 2019) (D. A. Yusuf , G. K. Umar , A. Ahmeda, A. M. Usmana 2019), Hausa traditional forms of housing and the organization of the domestic groups (F. W. Schwerdtfeger 2018) and the old Hausa builders in traditional design and decoration (M.B. Shehu 2016). However, little attention is given to the analytic computation aspect of this space, now that new technology of twenty century has transformed the design landscape in a profound and indelible manner. It is relevant to examine and analyse the computational composition of this unique architectural style so that designers and researchers can learn the capacity of shapes grammar to describe and generate complex urban form.

Hausa traditional architectural design represents one of the most culturally and aesthetically significant aspects of Nigeria's architectural heritage. The Hausa people, primarily inhabiting Northern Nigeria and parts of Niger, have developed a distinctive architectural style that reflects their cultural, religious, and environmental context. Hausa architecture is characterized by adobe (mud) structures, intricate geometric patterns, and adaptive techniques that respond to the arid climate of the Sahel region. This literature review explores Hausa traditional architecture through its historical evolution, materials and construction techniques, spatial organization, aesthetic principles, and contemporary relevance.

Hausa traditional architecture traces its roots back centuries, influenced by various Islamic and indigenous African styles, especially as Islam spread through Northern Nigeria around the 11th century. The region was part of ancient trans Saharan trade routes, which facilitated the exchange of ideas, goods, and cultural practices, including architectural styles (Hiskett, 1984). Historical accounts of Hausa architecture, such as the Hausa city states of Kano, Katsina, and Zaria, describe them as fortified cities with palaces, mosques, and residential compounds, all reflecting a cohesive architectural language.

According to Bugaje (1991), Islamic architectural influence introduced unique elements such as domes, arches, and minarets, integrating seamlessly into the indigenous building traditions. The interaction between indigenous practices and Islamic architecture shaped a unique, region specific design language that evolved into what is now recognized as traditional Hausa architecture.

One of the hallmarks of Hausa architecture is the use of locally sourced materials, particularly adobe, a mixture of mud and straw. The mud used in Hausa architecture is typically molded into large bricks and left to dry in the sun, forming robust walls that are well suited to the arid Sahel climate (Maishanu, 2012). The mud walls are often several feet thick, providing excellent insulation that helps regulate indoor temperatures.

Construction techniques have evolved to include advanced plastering methods, often involving layers of a smooth, fine plaster made from a mix of sand and animal dung, which both strengthens the walls and provides a smooth surface for intricate decorations (Denyer, 1978). The use of wooden beams, or "zannah," enhances structural

integrity and enables the construction of larger, taller buildings without compromising stability (Bako, 2013).

Hausa architectural spaces are organized with distinct separations for privacy, religious observance, and social interaction, aligned with Islamic principles and cultural values. Hausa compounds are typically organized around a central courtyard, known as the "zaure," which functions as an entrance hall and a space for public interaction. The zaure serves as a meeting area and often leads to more private spaces within the household, reflecting the emphasis on privacy and family structure in Hausa society (Prussin, 1986).

In a typical Hausa residential compound, rooms are arranged to accommodate gender roles and familial hierarchies. Private quarters are designated for women, while spaces for guests and communal areas are open to male visitors. The mosque, usually placed in the central part of the compound, serves as a religious focal point, emphasizing the integration of religious practice into daily life (Renner, 2017).

Aesthetic considerations in Hausa architecture are closely tied to cultural symbolism and religious motifs. The Hausa are known for intricate, geometric wall decorations created through the "zane" technique, which involves carving patterns into the wet mud surface. These designs often reflect Islamic themes, such as the use of nonrepresentational art (abstraction) due to the prohibition of figural images in Islamic art (Fagg, 1983).

In addition to geometric patterns, Hausa architecture incorporates symbolic motifs, often inspired by plants, animals, and cosmic elements, each carrying particular meanings within Hausa culture. For instance, the "daki" motif represents the sun, symbolizing vitality and divine presence (Suleiman, 1998). Decorative elements are not only aesthetically appealing but also serve as identifiers of social status, as more elaborate designs are often reserved for religious buildings or the homes of wealthy individuals (Hausa Arts, 2019).

The climatic conditions of Northern Nigeria's Sahel region heavily influence Hausa architecture. The thick adobe walls help retain cool air within buildings, countering the intense daytime heat and reducing the need for additional cooling measures. Additionally, narrow windows and limited openings reduce sunlight penetration, keeping interiors cool and limiting exposure to dust storms common in the region (Eziyi et al., 2017).

Roofs in Hausa architecture are traditionally made with domes or flat surfaces to manage rainfall, a critical consideration in this semiarid environment. Dome construction, influenced by Islamic architecture, allows rainwater to flow off efficiently and minimizes pooling on flat roofs, which would otherwise erode the mud walls over time (Sa'idu, 2014). The architectural design thus showcases adaptive strategies that reflect a deep understanding of and respect for the local environment.

While Hausa traditional architecture remains a cultural symbol, modern materials and techniques are replacing traditional methods in urban areas. Concrete and metal roofing are gradually replacing mud and thatch due to their durability and reduced maintenance. However, efforts to preserve and adapt traditional styles to contemporary needs are evident in projects by architects and scholars who advocate for sustainable and culturally rooted practices (Olotuah, 2019).

Several conservation initiatives aim to preserve Hausa architecture in cities like Kano and Zaria, recognizing its heritage value and sustainable design. The adaptation of traditional techniques for modern contexts could offer valuable lessons in sustainability, particularly in areas facing similar environmental challenges (Sani et al., 2020).

Analytic Shape Grammar of 2D (Plan Layouts) and 3D Spatial Organization

Koning and Eizenberg (1981), developed a shape grammar integrating design principles specified by Frank Lloyd Wright, to generate prairie-style houses in 2D. Duarte, Rocha et al. (2006) developed a grammar to illustrate the informal structure of the zaoulat-lakhdat quarter both in a top–down and bottom–up fashion; the latter seems sufficient to simplify the chaotic urban structure through the interior development of the Serbs. The designs are decomposed into shapes and arrangements of spatial relations of vocabulary elements (Knight, 1998b: 88), and defined by shape grammar with a language of designs, which generates the descriptions by use of a recursive schema based on this shape grammar (Stiny, 1981: 257). A study carried out by Mitchell (1986: 154) stated that some existing works as a result of attempts to produce a grammar of replication, with other designs, are recognized as of the same style. The rules are inferred from sets of examples. As a result, they share the same characteristic features of the style and they can have their own particular characteristics. A functional type is differentiated from similar functional types by virtue of its style. For example, a Hausa traditional house is different from a Yoruba traditional house or an Igbo house by virtue of its style. Therefore, the Mitchell (1986) methods are to be adopted in this paper.

METHODOLOGY

The research design for this study adopts the Analytical Shape Grammar Method, which is a systematic approach used to map and analyze the spatial organization of traditional Hausa houses in Kano Metropolis. This method involves the decomposition of architectural forms into a set of defined rules and geometric transformations, allowing for an in-depth understanding of how traditional Hausa architectural elements are structured and organized. The study follows a qualitative and computational approach, where spatial configurations are examined using shape grammar rules that define relationships between elements such as zaure (entrance hall), courtyard divisions, foreyard, inner yard, and stair placement. The methodology includes data collection through measured drawings, historical records, and spatial analysis, followed by the development of a shape grammar rule set to identify and classify architectural patterns. By employing an analytic mapping technique, this study aims to systematically document and interpret the spatial logic underlying Hausa traditional houses, preserving their

architectural identity and informing contemporary architectural practices.

Choosing the Analytic Shape Grammar Method has significant implications for this research. First, it ensures an objective and rule-based analysis of traditional Hausa house structures, making it possible to identify recurrent spatial configurations and variations across different house typologies in Kano Metropolis. Second, this method allows for a computational representation of traditional spatial organization, which can be adapted for digital reconstruction, architectural conservation, and generative design applications. By mapping spatial arrangements analytically, this research contributes to the preservation of indigenous Hausa architectural heritage, ensuring that its principles can be integrated into modern architectural practices while maintaining cultural authenticity. Furthermore, the shape grammar approach enables comparative analysis with other architectural styles, providing insights into universal spatial design principles and facilitating cross-cultural architectural studies. Thus, this research design offers a systematic, replicable, and computationally efficient approach to studying the spatial organization of Hausa traditional houses.

In this direction, the method of analysis adopted for this study is shape grammar analytical in nature for describing formal compositional aspects of traditional Hausa houses that have been built in Kano metropolitan for the past centuries.

BRIEF HISTORY OF (KANO STATE) STUDY AREA

Kano was one of the 12 states carved out of the former Northern Region in May 1967. The state was whole until Jigawa State was split off of it on August 27, 1991. It is situated in Nigeria's northwest geopolitical region. Kano State is inhabited by Muslim-majority Hausa and Fulani. The 2006 census put the population of Kano State at 9,383,682, making it one of the most populous states in Nigeria. It covers an area of 20,479.6 square kilometers and has 44 local governments.

There are roughly 458 people per square kilometer in the area. The commercial hub of Kano State is the walled city of Kano, which also serves as the state capital. It is a home to numerous immigrants, primarily Yoruba and Igbo. Kano metropolis, has six local government areas (Fagge, Gwale, Tarauni, Kano Municipal, Nassarawa, and Dala). Hausa is the state of Kano's official language, although majority of locals can read Arabic literature.

An Architectural Language for Hausa Traditional Architecture

It is acknowledged that the development of Hausa traditional architecture has shown a thorough comprehension and meaningful response, in which the styles are linked to collective neighborhood design rather than just individual structures. Consequently, it is essential to fully preserve, safeguard, and advance the discipline of Hausa traditional residential architecture (Umar et al.,

2019).

This part reveals an architectural language for the Hausa traditional architecture based on the works of G.K. Umar (2008), who described particular these kinds of architecture in some written sources, survey sketched plans, sections, and photographs. Using these documents, common elements are extracted and used to define the vocabulary elements of Hausa architectural grammar. This typical architecture devises the courtyard being a seclusion and hierarchy between spaces, like the acceptance of Islam which declares wives to be in "purdah". The adoption of a courtyard with boundary high walls ensures larger shaded 'Dakali' for relaxation, evening gatherings, air circulation and communal habitation.

Hausa traditional architecture can be stated as an introverted style. Its exterior form has very high principle and properties of order in triple heritage element and concept, whereas the interior space is arranged around a rectangular or square court or interconnected court yard articulated with postulated and recessed parts (Zaure) in between the outer rooms around the inner court. It is usually compounded with wall fence of one storied building. Although some of the Hausa traditional architecture may have one upper floor, the same plans of ground floors are used for those upper floors. Therefore, in this study, the main ground floor plans are taken into consideration with few on upper floors types. The plan compositions can be used to create an architectural language to describe the style of Hausa traditional architecture. Various buildings of the Hausa architectural styles are built across different states in northern Nigeria (G.K. Umar 2008; A. Mustapha, G. K. Umar, D.A. Yusuf 2019), yet there exists an original style with unique features common to all these buildings (B. A. Danjuha 1988).

Analytic Shape Grammar Representation for Hausa Traditional Architecture Plan Layouts

Shape grammars have a common analytic character. In representing a shape grammar, it is necessary to formulate the vocabulary elements, spatial relations, and shape rules of the shape grammar. In the context of this paper, the vocabulary elements and spatial relations are determined for shape grammar representation of Hausa traditional architecture plan layouts.

The shape grammar developed as specify in figure 1.0 for Hausa traditional architecture, is based on the plan layouts of these studies by G.K. Umar (2008). Architectural organization of the Hausa traditional architecture stems from the relationship between the court (fore court (FY) and inner court (IY)), the Room Space (RS), the Zaure (Z) and a courtyard (CY) serves as circulation space in and out of the Room Space (RS), the toilet and internal staircase (SC) is included at the court-yard (CY) for storey type of Hausa traditional architecture. These constitute the key vocabulary elements in the typology of Hausa traditional architecture as in figure 1.0

Vocabulary Elements of the Hausa Traditional Architecture

- The Court (Fore and Inner Courts).
- The Room Space.
- The Zaure.
- Stair Case
- Ground-Room-Space
- Floor-Room-Space
- Compound-Wall
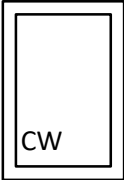
Vocabulary Elements of Hausa Architectures									Description
Room Space	Zaure	Court-Yard	Fore-yard	Inner-Yard	Stair-Case	Ground-Room-Space	Floor-Room-Space	Compound-Wall	Description
RS	Z	CY	FY	IY	SC	GRS	FRS	CW	Symbol
RS	Z	CY	FY	IY	SC	GRS	FRS	CW	Label

Figure 1.0: Hausa traditional architecture Vocabulary Elements
Source: Author's analytical work (2023)

This table systematically categorizes Hausa traditional house elements based on spatial arrangement and architectural grammar. In summary, the table provides an illuminating glimpse into the architectural elements of Hausa traditional architectural styles and buildings in Kano metropolitan Nigeria. These elements, from the distinctive Zaure (reception) to the intricate Shikin-Gida (Inner-Yard), collectively contribute to the Hausas' cultural and spiritual significance while also serving as striking examples of Hausa architectural mastery.

The table presents a structured classification of architectural elements fundamental to traditional Hausa houses in Kano Metropolis, Nigeria. Each element, represented by a symbol, plays a crucial role in shaping the spatial organization of Hausa architecture. Room Space (RS) refers to enclosed living areas that provide functional spaces for various household activities, while the Zaure (Z) serves as an entrance hall or transition space between the exterior and the private areas of the house. Courtyard (CY) is a central open space crucial for ventilation and social interactions, often divided into Foreyard (FY) and Inner Yard (IY) to create hierarchical spatial arrangements. The Staircase (SC) is essential in multi-level houses, facilitating vertical circulation. Ground Room Space (GRS) and Floor Room Space (FRS) distinguish between living areas at different levels, indicating the adaptation of

Hausa architecture to multi-story configurations. Finally, the Compound Wall (CW) defines the house perimeter, offering security and privacy, which are fundamental to traditional Hausa living patterns.

The architectural elements outlined in the table highlight the intricate spatial hierarchy and organization in Hausa traditional architecture, shaped by cultural, environmental, and functional considerations. The strong emphasis on courtyards underscores the importance of open-air spaces in facilitating natural ventilation, cooling, and social interactions, which are essential for adapting to Kano's hot climate. The presence of Zaure as a semi-public transitional space reflects Hausa societal norms of privacy and hospitality. Understanding these spatial components through an analytic shape grammar approach allows for a systematic mapping of their configurations and variations, which has significant implications for the study. By analyzing the spatial organization using shape grammar rules, this research will contribute to the documentation, preservation, and potential adaptation of Hausa architectural principles in contemporary designs. Moreover, the findings will provide a framework for integrating traditional spatial logic into modern urban planning and housing developments, ensuring that indigenous architectural identity is maintained in the face of rapid urbanization in Kano Metropolis.

NO S	Sample	Area	Plot Size	No of Room	No of Resident	Category	PARAMETRIC SHAPE		Location
1	YLW 623I	25*25	56.25	3-2.7	10-5.6	A	RECTANGLE	ATTARCHED	-
2	YLW 624J	30*30	225	5-15	3-7	A	RECTANGLE	ATTARCHED	
3	YLW 625K	25*25	56.25	3		A	RECTANGLE	ATTARCHED	
4	HTR 101C		675		20	C	RECTANGLE	APARTMENT	
5	HTR 112D		40	3	6	A	SQUARE	APARTMENT	
6	HTR 112E		162	6	17	A	SQUARE	APARTMENT	
7	LKM 175F		48	1	4	A	SQUARE	APARTMENT	
8	LKM 184G		24	2	11	A	RECTANGLE	APARTMENT	
9	LKM 185H		48	3-4.5	6-8	A	RECTANGLE	APARTMENT	MAI YA'U HOUSE
10	010 D		225	7	14	B	PARAMETRIC SHAPE	APARTMENT	UNGUWA UKU
11	003 D		225	7	21	B	RECTANGLE	COMPOUND	UNGUWA UKU
12	1006 G		225	5	2	B	SQUARE	COMPOUND	NAIBAWA
13	1010B H		100	8	4	B	SQUARE	COMPOUND	NAIBAWA
14	013 I		225			B	SQUARE	COMPOUND	
15	JJB317 J		225	5	7	B	SQUARE	COMPOUND	
16	JJB323 K		330	6	13	B	SQUARE	COMPOUND	
17	1005 C		486	4	15	C	RECTANGLE	COMPOUND	NAIBAWA
18	KBT985 H		486	7	12	C	RECTANGLE	COMPOUND	
19	DL570		900	3	20	D	RECTANGLE	ATTARCHED	DALA
20	DL571		900	6	18	D	RECTANGLE	ATTARCHED	DALA
21	DL572		900	3	6	D	RECTANGLE	ATTARCHED	DALA
22	DL573		900	6	18	D	RECTANGLE	ATTARCHED	DALA
23	JKR 422		900	3	10	D	RECTANGLE	ATTARCHED	MASUKWANI WARD
24	JKR 443		900	3	22	D	RECTANGLE	ATTARCHED	MASUKWANI WARD
25	JKR 446		900	2	8	D	RECTANGLE	ATTARCHED	MASUKWANI WARD
26	JKR 447		900	2	2	D	RECTANGLE	ATTARCHED	MASUKWANI WARD
27	FGE 246 I		486	10		D	RECTANGLE	COMPOUND	FEGGE
28	FGE 246 J		486	10		D	RECTANGLE	COMPOUND	FEGGE
29	001A		486			C	RECTANGLE	COMPOUND	UNGUWA UKU

Table 2.0: Sample houses' Parameters for the plan type of Hausa Traditional Architectures
Source: G.K. Umar (2008

The table presents a structured analysis of Hausa traditional architectural styles in Kano Metropolis, Nigeria, categorized based on plot size, number of rooms, number of residents, shape, and location. The data highlights the dominance of rectangular and square parametric shapes, with buildings classified into different categories (A, B, C, and D), which may represent varying socio-economic or functional typologies. The attached housing style is prevalent, particularly in locations like Dala and Masukwani Ward, reflecting the high-density settlement patterns in urban Kano. Compound housing, another prominent typology, is distributed in areas like Naibawa, Fegge, and Unguwa Uku, signifying traditional spatial arrangements that support extended family living and privacy. The variation in plot sizes, ranging from 24m² to 900m², indicates a spectrum of housing densities, with some areas accommodating more residents per unit, reflecting the urban pressures and adaptive housing solutions in Kano's metropolitan setting.

The architectural elements in Hausa traditional houses, as shown in the table, reflect a deep-rooted cultural and environmental adaptation. The compound housing typology, characterized by enclosed spaces and central courtyards, provides natural ventilation and thermal comfort, crucial for Kano's hot climate. The attached housing pattern, often seen in high-density areas, represents a response to land scarcity and population growth, balancing communal living with privacy. The predominance of rectangular structures suggests efficiency in space utilization and construction simplicity, which is a hallmark of Hausa vernacular architecture. The study's implication is significant, as it helps in mapping spatial organization patterns, preserving indigenous building techniques, and informing contemporary urban housing development. By employing a shape grammar approach, this research can systematically analyze and propose sustainable housing models that integrate traditional Hausa architectural principles with modern urban demands, ensuring cultural continuity and spatial efficiency in Kano Metropolis.

Table 3.0: Classification of Hausa Traditional House Shape Grammar Elements

Primary Node	Subcategories	Further Branching	Shape Grammar Elements
Number of Rooms (RS)	1–2 Rooms	- Zaure Placement: Front (Entrance)	RS, Z, CY, SC, CW
		- Courtyard Division: Single	
		- Staircase Location: Near the Wall	
	3–4 Rooms	- Zaure Placement: Central	RS, Z, CY, FY, IY, SC, CW
		- Courtyard Division: Divided (Fore-Yard & Inner-Yard)	
		- Staircase Location: Near Inner Yard	
	5+ Rooms	- Zaure Placement: Side/Separate	RS, Z, CY, FY, IY, SC, GRS, FRS, CW
		- Courtyard Division: Multiple Sections	
		- Staircase Location: Attached to a Room	
		- Additional Features: Ground Room Space, Floor Room Space	
Zaure Placement (Z)	Front	- Common in small and medium houses	Z
	Central	- Typical in medium-sized compounds	Z
	Side/Separate	- Found in larger, multi-sectional houses	Z
Courtyard Division (CY)	Single	- One open space in the compound	CY
	Divided (Fore-Yard & Inner-Yard)	- Outer space for guests, inner for family privacy	CY, FY, IY
	Multiple Sections	- Found in larger houses with separate activity areas	CY, FY, IY
Fore Courtyard Placement (FY)	Front	- Public or guest space	FY
	Side	- Additional open space for various uses	FY
Inner Courtyard Placement (IY)	Central	- Private family space	IY
	Rear	- Separate from main entrance	IY
	Adjacent to Rooms	- Integrated into the residential layout	IY

Primary Node	Subcategories	Further Branching	Shape Grammar Elements
Ground Room Space Placement (GRS)	Near Entrance	- Typically used for storage or additional rooms	GRS
	Near Courtyard	- Provides easy access to open-air spaces	GRS
	Near Outer Wall	- Ensures security and privacy	GRS
Location of Staircase (SC)	Near Wall	- Common in compact houses	SC
	Near Inner Yard	- Found in larger houses for easy upper-floor access	SC
	Inside a Room	- Adds security and privacy	SC
Placement of Floor Space (FRS)	Above Zaure	- Uses entrance space efficiently	FRS
	Above Courtyard	- Provides shade and ventilation	FRS
	Separate Structure	- Found in larger multi-story buildings	FRS
	Extended Balcony	- Enhances airflow and visibility	FRS

Source: Author's analytical work (2023)

The table provides a structured breakdown of the architectural elements of Hausa traditional houses in Kano Metropolitan, Nigeria, using a shape grammar approach to categorize spatial organization. The primary architectural components include the number of rooms, courtyard divisions, staircase placements, and room arrangements, each influencing the spatial hierarchy and functional zoning within a Hausa compound. Houses with 1–2 rooms typically place the Zaure (entrance hall) at the front, have a single courtyard, and position the staircase near the wall, reflecting a compact and functional layout for smaller households. In contrast, compounds with 3–4 rooms exhibit a central Zaure, a divided courtyard (foreyard and inner yard) for guest and family separation, and a staircase near the inner yard, enhancing spatial organization and privacy. Larger compounds with 5+ rooms adopt a side or separate Zaure, multiple courtyards, and additional features such as ground and floor room spaces, indicating a more complex spatial structure that accommodates extended family living and hierarchical zoning of activities. The placement of courtyards (single, divided, or multiple sections) determines the degree of social interaction, privacy, and ventilation, while the location of staircases and floor spaces further dictates movement patterns and structural efficiency.

These architectural elements highlight the deep-rooted cultural, environmental, and functional influences on Hausa traditional architecture. The Zaure's placement varies by house size, functioning as a transitional space between public and private areas, reinforcing social norms of privacy and hospitality. The courtyard system is central to Hausa homes, providing natural ventilation, social gathering spaces, and climate adaptability. The parametric nature of the shape grammar elements suggests a rule-based design framework, where traditional building practices evolve systematically while maintaining core spatial principles. This study's implication lies in its ability to map and preserve indigenous Hausa architectural styles while informing modern housing policies and urban planning in Kano. By understanding these spatial configurations through shape grammar analysis, future designs can integrate sustainable, culturally sensitive housing solutions that maintain the essence of Hausa architectural identity while adapting to contemporary urban demands.

Table 4.0: Decision Tree Classification of Hausa Traditional House Shape Grammar Elements

Root Node	Branching Criteria	Sub-Categories	Shape Grammar Elements (Symbols)
Number of Rooms (RS)	1–2 Rooms	-	RS, Z, CY, SC, CW
	3–4 Rooms	-	RS, Z, CY, FY, IY, SC, CW
	5+ Rooms	-	RS, Z, CY, FY, IY, SC, GRS, FRS, CW
Zaure Placement (Z)	Front (Entrance)	-	Z
	Central	-	Z
	Side/Separate	-	Z

Root Node	Branching Criteria	Sub-Categories	Shape Grammar Elements (Symbols)
Courtyard Division (CY)	Single	-	CY
	Divided (Inner & Fore)	-	CY, FY, IY
	Multiple Sections	-	CY, FY, IY
Fore Courtyard Placement (FY)	Front	-	FY
	Side	-	FY
	Enclosed	-	FY
Inner Courtyard Placement (IY)	Central	-	IY
	Rear	-	IY
	Adjacent to Rooms	-	IY
Ground Room Space Placement (GRS)	Near Entrance	-	GRS
	Near Courtyard	-	GRS
	Near Outer Wall	-	GRS
Location of Staircase (SC)	Near Wall	-	SC
	Near Inner Yard	-	SC
	Inside a Room	-	SC
Floor Space Placement (FRS)	Above Zaure	-	FRS
	Above Courtyard	-	FRS
	Separate Structure	-	FRS
	Extended Balcony	-	FRS

Source: Author's analytical work (2023)

This structured table clearly organizes Hausa traditional house architectural elements by their spatial configuration and shape grammar symbols.

The table presents a shape grammar-based classification of the spatial organization of Hausa traditional architecture in Kano Metropolitan, Nigeria, emphasizing the hierarchical arrangement of rooms, courtyards, staircases, and transitional spaces like the Zaure (entrance hall). The number of rooms determines the spatial complexity, where 1–2 room houses typically feature a front Zaure, single courtyard, and staircase near the wall, maintaining a simplistic and compact layout suited for smaller households. 3–4 room houses introduce a divided courtyard (foreyard and inner yard), allowing functional separation between public and private spaces, while 5+ room houses integrate multiple courtyards, ground and floor room spaces, enhancing hierarchical spatial organization for extended families. The Zaure's placement varies from front (common in smaller homes) to central or separate (for larger homes), reflecting the cultural significance of controlled accessibility and privacy. Courtyards, a defining feature, range from single to multiple sections, ensuring ventilation, lighting, and organized movement. Additionally, the staircase and floor space placements influence the vertical hierarchy, where staircases are typically near walls or inner courtyards, while upper floors serve as shaded areas or extensions for ventilation and privacy.

These architectural elements emphasize the deep integration of Hausa cultural values, environmental adaptation, and spatial efficiency in traditional housing. The Zaure and courtyard system uphold the sociocultural need for guest reception, family privacy, and climate control, while the staircase and floor space placement reflect security and hierarchical use of space. The shape grammar approach provides a systematic framework for understanding the inherent rules governing traditional Hausa architecture, offering valuable insights for modern architectural adaptations. By analyzing these spatial patterns, the study contributes to the preservation of Hausa architectural identity while informing contemporary urban housing policies. Future designs can incorporate culturally sensitive, sustainable solutions that respect traditional spatial logic while addressing modern urbanization challenges in Kano.

Decision Tree Classification of Hausa Traditional House Shape Grammar Elements

◆ **Root Node: Number of Rooms (RS)**

▼ **Branching out based on the spatial and architectural elements**

- **1–2 Rooms**

Zaure Placement (Z): Front (Entrance)

- **Courtyard Division (CY):** Single
  - **Staircase Location (SC):** Near the Wall
    - **Shape Grammar Features:**
      ✔ **RS** (Room Space)
      ✔ **Z** (Zaure - Entrance)
      ✔ **CY** (Courtyard)
      ✔ **SC** (Staircase)
      ✔ **CW** (Compound Wall)

The decision tree illustrates the hierarchical spatial organization of Hausa traditional architecture in Kano Metropolitan, Nigeria, focusing on the relationship between the number of rooms and key architectural elements. For 1–2 room houses, the Zaure (entrance hall) is positioned at the front, serving as both a transition space and a reception area for visitors while maintaining privacy for inner rooms. The courtyard is singular, reinforcing its role as the central open-air space for ventilation, domestic activities, and social interactions. The staircase is placed near the wall, optimizing space efficiency and movement within compact dwellings. The compound wall (CW) encloses the entire structure, providing security, territorial definition, and climate control. These elements reflect Hausa cultural values of privacy, controlled access, and environmental adaptability, ensuring thermal comfort and airflow regulation in the region's hot climate.

This classification has significant implications for architectural studies and urban planning in Kano. The shape grammar approach used in the decision tree systematically codifies spatial relationships, offering insights for heritage conservation and modern architectural adaptations. By understanding how traditional Hausa homes are structured, urban designers and policymakers can incorporate these principles into contemporary housing solutions that respect cultural identity while addressing modern urbanization challenges. The decision tree framework serves as a blueprint for preserving indigenous knowledge, guiding future designs that balance tradition with functional modernity.

- **3–4 Rooms**

Zaure Placement (Z): Central

- **Courtyard Division (CY):** Divided into:
  ⚖ **Fore-Yard (FY)** (Outer Guest Area)
  ⚖ **Inner-Yard (IY)** (Private Family Area)
- **Staircase Location (SC):** Near Inner Yard
  - **Shape Grammar Features:**
    ✔ **RS** (Room Space)
    ✔ **Z** (Zaure)
    ✔ **CY** (Courtyard)
    ✔ **FY** (Fore-Yard)
    ✔ **IY** (Inner-Yard)
    ✔ **SC** (Staircase)
    ✔ **CW** (Compound Wall)

The decision tree for 3–4 room houses in Hausa traditional architecture highlights a more complex spatial organization, reflecting the increasing functional and social needs of larger households in Kano Metropolitan, Nigeria. The Zaure (entrance hall) is centrally positioned, enhancing accessibility and hierarchical separation between public and private spaces. The courtyard is divided into a Fore-Yard (FY), which serves as a guest reception area, and an Inner-Yard (IY), reserved for private family activities, reinforcing the Hausa cultural emphasis on privacy and controlled access. The staircase is placed near the Inner Yard, ensuring ease of movement between floors while maintaining security and spatial efficiency. The compound wall (CW) continues to serve as a boundary, offering protection, privacy, and climate control.

This architectural model has profound implications for both historical preservation and contemporary design. The use of shape grammar to analyze spatial configurations provides a systematic framework for documenting and revitalizing traditional Hausa housing principles. By integrating these adaptive design strategies, modern urban housing projects can incorporate culturally responsive layouts that balance privacy, social hierarchy, and environmental adaptation. Furthermore, understanding these spatial patterns supports sustainable architectural solutions, ensuring that new developments respect indigenous heritage while meeting modern living standards.

- **5+ Rooms**

Zaure Placement (Z): Side/Separate

- **Courtyard Division (CY):** Multiple Sections
  ⚖ **Fore-Yard (FY)** for visitors
  ⚖ **Inner-Yard (IY)** for family use
- **Staircase Location (SC):** Attached to a Room
  - **Additional Features:**
    ✔ **GRS** (Ground Room Space)
    ✔ **FRS** (Floor Room Space - Upper Level)
    ✔ **CW** (Compound Wall)
    ✔ **Decorative Elements**: Ornamental wall designs, niches, and carved wooden doors

The decision tree for houses with 5+ rooms in Hausa traditional architecture reflects the most elaborate spatial organization, emphasizing hierarchical separation, privacy, and multifunctionality. Unlike smaller homes, the Zaure (entrance hall) is placed separately or to the side, reducing direct access to private family spaces while enhancing guest reception and security. The courtyard is divided into multiple sections, with a Fore-Yard (FY) designated for visitors and an Inner-Yard (IY) reserved for family activities, reinforcing cultural norms of privacy and controlled interaction. The staircase is attached to a room, ensuring secure and discreet vertical movement between levels. Additional architectural features, such as Ground

Room Space (GRS) and Floor Room Space (FRS), indicate an upper-level extension, reflecting both functional expansion and social status. The compound wall (CW) remains a defining element, providing security, privacy, and climate regulation, while ornamental wall designs, niches, and carved wooden doors highlight the artistic and cultural identity of Hausa architecture.

The architectural elements in these larger houses demonstrate advanced spatial planning and socio-cultural influences in Kano's urban fabric. The integration of shape grammar analysis in studying these structures offers a systematic approach to understanding traditional housing patterns, aiding in heritage preservation and modern adaptation. The presence of decorative elements signifies a shift beyond functional design to aesthetics and status representation, influencing contemporary housing projects to incorporate both tradition and modernity. These findings underscore the importance of spatial organization in Hausa architecture, ensuring that future urban developments respect indigenous design principles while addressing modern housing needs.

Table 5.0: Decision Tree Classification of Shape Grammar Elements in Hausa Traditional Houses

| Number of Rooms	Zaure Placement (Z)	Courtyard Division (CY)	Location of Staircase (SC)	Shape Grammar Element (Symbol)
1–2 Rooms	Front (Entrance)	Single	Near the Wall	RS, Z, CY, SC, CW
3–4 Rooms	Central	Divided (Inner & Fore)	Near Inner Yard	RS, Z, CY, FY, IY, SC, CW
5+ Rooms	Side/Separate	Multiple Sections	Attached to a Room	RS, Z, CY, FY, IY, SC, GRS, FRS, CW

Source: Author's analytical work (2023)

The table presents a structured hierarchy of Hausa traditional architectural styles in Kano metropolitan Nigeria, emphasizing the relationship between spatial organization and cultural functionality. As the number of rooms increases, the Zaure (entrance hall) placement, courtyard division, and staircase location evolve to accommodate social interactions, privacy, and security needs. For smaller houses (1–2 rooms), the Zaure is positioned at the front, leading into a single courtyard (CY), with a staircase near the wall, reflecting a compact and functional layout suitable for small families or individuals. In medium-sized houses (3–4 rooms), the Zaure is centrally placed, and the courtyard is divided into a Fore-Yard (FY) and Inner-Yard (IY), ensuring a clear distinction between guest and family spaces. The staircase moves closer to the inner yard, enhancing connectivity to upper spaces while maintaining privacy. In larger houses (5+ rooms), the Zaure becomes detached or placed to the side, the courtyard is divided into multiple sections, and the staircase is integrated into a room, ensuring controlled movement between floors.

These spatial patterns align with Hausa cultural norms, where social hierarchy, gender roles, and hospitality traditions dictate architectural arrangements. The incorporation of shape grammar elements such as Room Space (RS), Zaure (Z), Courtyard (CY), Ground Room Space (GRS), and Floor Room Space (FRS) demonstrates a systematic design approach, ensuring flexibility in expansion while preserving traditional values. The study's implication highlights the need for urban planners and architects to integrate Hausa architectural principles in modern housing designs, maintaining heritage elements while adapting to contemporary spatial demands. Understanding this architectural evolution provides insights into sustainable and culturally appropriate housing solutions for Kano's growing urban population.
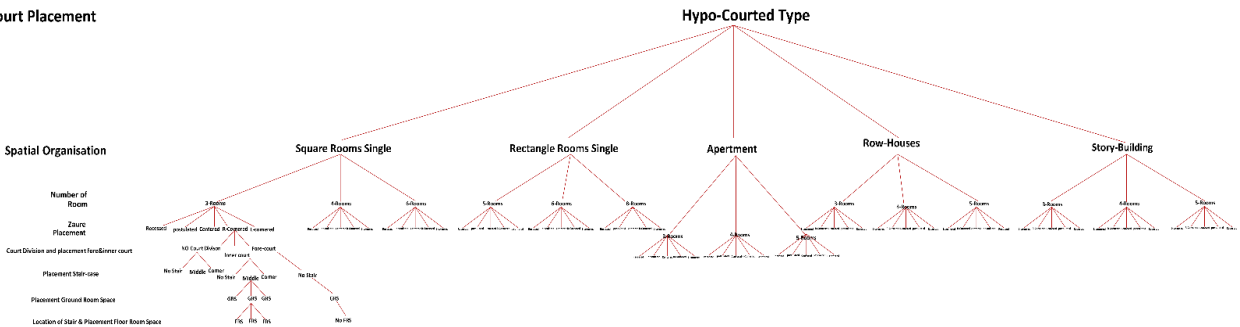
Figure 1.0: Classification tree for the plan type of Hausa Traditional Architectures
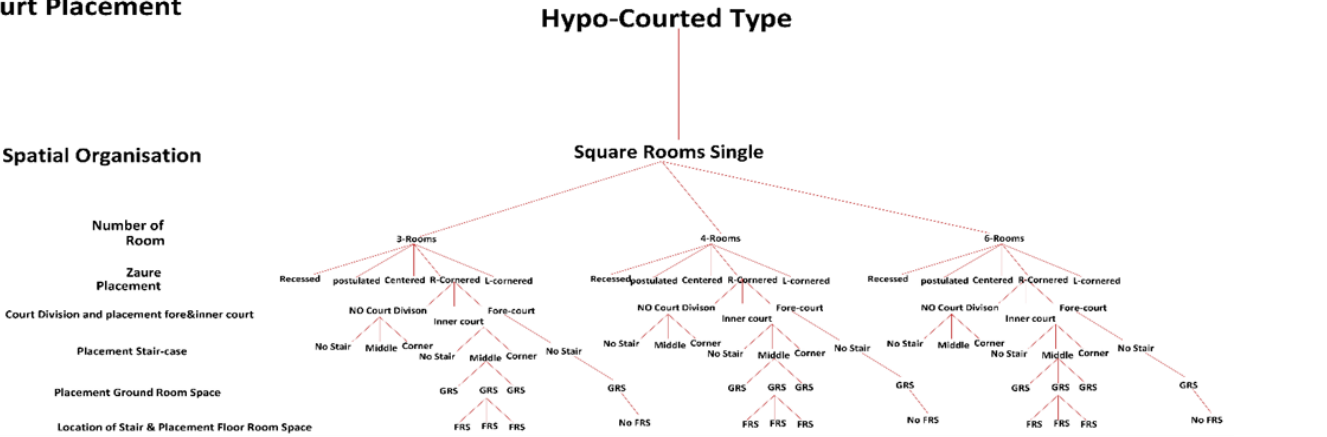
Source: Author's analytical work (2023)

The figure illustrates a hierarchical decision tree for Hausa traditional architectural styles in Kano metropolitan Nigeria, focusing on court placement and hypo-courted building types. The spatial organization begins with the

number of rooms, followed by Zaure (entrance hall) placement, courtyard division, staircase positioning, and additional spatial elements such as ground and upper floor rooms. The tree further categorizes housing typologies into square rooms, rectangular rooms, apartments, row houses, and story buildings, highlighting the variation in spatial arrangement based on household size and function. The traditional Hausa courtyard system is central to this classification, ensuring privacy, ventilation, and social hierarchy, with Zaure placement and courtyard sections reflecting cultural norms of hospitality and segregation. The architectural elements such as Zaure (Z), Courtyard (CY), Ground Room Space (GRS), and Floor Room Space (FRS) reinforce Hausa construction principles, emphasizing thermal comfort, spatial adaptability, and security. The study's implication suggests that Hausa vernacular architecture balances cultural heritage with functional urban housing needs, demonstrating a structured spatial grammar adaptable to modern housing development. Understanding these traditional spatial patterns is essential for urban planning and sustainable housing solutions in Kano, ensuring that modern buildings integrate indigenous principles for efficient space utilization and cultural preservation.
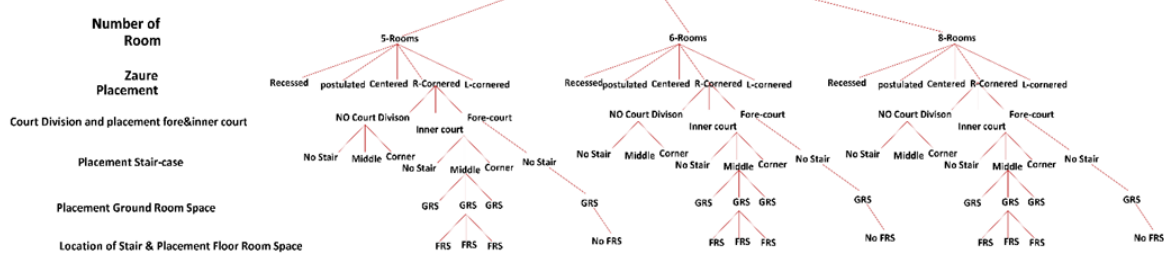

Figure 2.0: Classification tree for the Square Rooms Single Plan of Hausa Traditional Architectures. **Source**: Author's analytical work (2023)

The figure represents a decision tree analyzing Hausa traditional architectural styles in Kano, Nigeria, focusing on court placement within single-square room structures. The classification starts with the number of rooms (3, 4, or 6), influencing the Zaure (entrance hall) placement, which can be recessed, postulated, centered, right-cornered, or left-cornered. The next level determines courtyard division, either as no court division, an inner court, or a forecourt, reflecting the spatial hierarchy between public and private spaces. Staircase placement follows, categorized as middle, corner, or absent, impacting accessibility and spatial organization. Additional considerations include the ground room space (GRS) placement and floor room space (FRS), ensuring efficient land use and multi-functional design.

These architectural elements align with Hausa vernacular building principles, emphasizing climate responsiveness, privacy, and social function. The Zaure serves as an entrance and transitional space, while courtyards regulate airflow and enhance security. The classification highlights how different spatial configurations accommodate varied household sizes and needs, making the Hausa housing style adaptable. The implication for the study suggests that urban planning and modern housing designs in Kano can integrate traditional Hausa spatial organization to enhance thermal comfort, cultural continuity, and sustainable architecture. This approach fosters heritage conservation while addressing contemporary urban housing challenges.

Figure 3.0: Classification tree for the Rectangular Rooms Single Plan of Hausa Traditional Architectures.
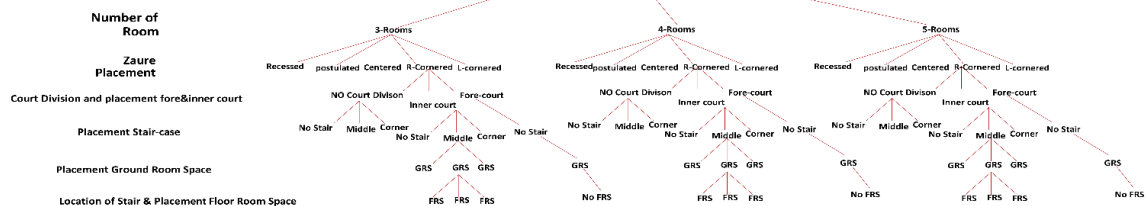**Source**: Author's analytical work (2023)

The figure illustrates a decision tree representing the spatial organization of rectangular room single-unit Hausa traditional houses within the hypo-courted type in Kano, Nigeria. The hierarchy begins with the number of rooms (5, 6, or 8), influencing the Zaure (entrance hall) placement, which can be recessed, postulated, centered, right-cornered, or left-cornered. Further divisions categorize courtyard integration, which may be absent (no court division), an inner court, or a forecourt, reflecting privacy needs and hierarchical zoning. The placement of the staircase (middle, corner, or none) and additional elements like ground room space (GRS) and floor room space (FRS) contribute to optimizing spatial usage while ensuring ventilation and accessibility. These architectural elements demonstrate the adaptability of Hausa traditional housing to family size, privacy, and climate control. The Zaure acts as a transitional space, while courtyards facilitate airflow and cultural interactions. The variability in courtyard placement shows the importance of modularity in Hausa dwellings, accommodating social and functional needs. The study's implication is significant for sustainable urban planning, as integrating Hausa architectural principles into modern housing design can improve thermal comfort, social cohesion, and cultural preservation in Kano's rapidly urbanizing areas.

Figure 4.0: Classification tree for the Apartment Plan of Hausa Traditional Architectures
Source: Author's analytical work (2023)

The figure presents a decision tree outlining the spatial organization of apartment-style Hausa traditional houses within the hypo-courted type in Kano, Nigeria. The classification begins with the number of rooms (3, 4, or 5), which influences the Zaure (entrance hall) placement—it may be recessed, postulated, centered, right-cornered, or left-cornered. The court division varies between no courtyard division, an inner court, or a forecourt, demonstrating hierarchical zoning for privacy and ventilation. Additionally, the staircase placement (middle, corner, or none) impacts vertical circulation, while ground room space (GRS) and floor room space (FRS) define functional and spatial adaptability.

These elements reflect Hausa architectural ingenuity,

where courtyards regulate airflow, staircases optimize space, and the Zaure provides a transitional zone for guests and residents. The variation in court placements and staircase positions signifies customization based on family size, privacy, and cultural practices. The study's implications highlight sustainability in urban housing, where Hausa traditional principles can enhance climate-responsive design, social cohesion, and efficient space utilization in modern housing developments across Kano.
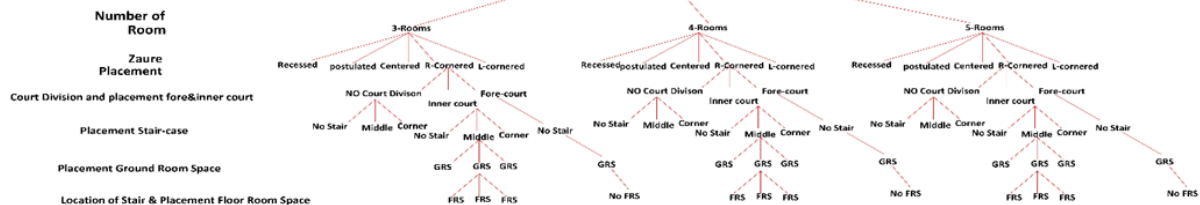
Figure 5.0: Classification tree for the Row-Houses Plan of Hausa Traditional Architectures
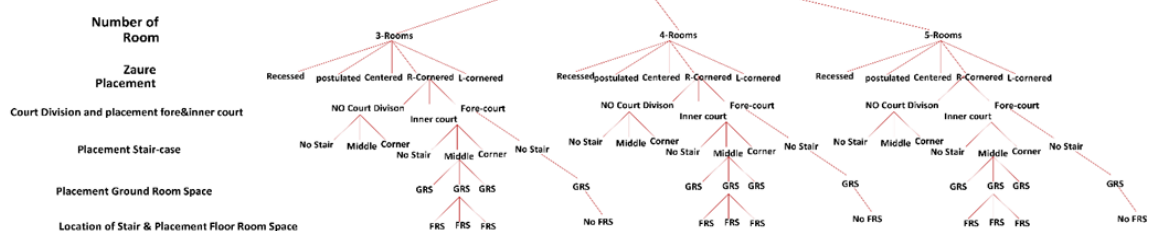**Source**: Author's analytical work (2023)

The figure illustrates the decision tree for the spatial organization of row houses in the hypo-courted housing type of Hausa traditional architecture in Kano, Nigeria. The decision tree categorizes row houses based on the number of rooms (3, 4, or 5), influencing the placement of the Zaure (entrance hall), which can be recessed, postulated, centered, right-cornered, or left-cornered. The courtyard division varies, with houses having either no division, an inner court, or a forecourt, reflecting privacy zoning. The staircase placement (middle, corner, or absent) impacts circulation, while the ground room space (GRS) and floor room space (FRS) define vertical and horizontal spatial adaptability.

These architectural elements reflect the modular and compact nature of Hausa row houses, optimizing land use, ventilation, and social interaction within closely-knit urban settings. The courtyards act as passive cooling systems, and the Zaure provides transitional space for privacy and security. The study's implications highlight the efficiency of row houses in high-density urban environments while demonstrating how traditional Hausa architecture balances cultural values, climate responsiveness, and spatial functionality for sustainable housing development in Kano.

Figure 6.0: Classification tree for the Story-Building Plan of Hausa Traditional Architectures
Source: Author's analytical work (2023)

The figure presents the spatial organization of story buildings in the hypo-courted Hausa architectural style in Kano, Nigeria. The diagram classifies buildings based on the number of rooms (3, 4, or 5), Zaure (entrance hall) placement, court division, staircase positioning, and spatial allocation. The Zaure may be recessed, postulated, centered, right-cornered, or left-cornered, influencing accessibility and privacy. Courtyards, a vital cooling and social feature, may either be undivided, an inner court, or a forecourt. Staircases, crucial in vertical circulation, are located at the middle or corner, or absent, which impacts movement within the house. The Ground Room Space (GRS) and Floor Room Space (FRS) further define the spatial hierarchy of the residence.

This architectural typology reflects social hierarchy, climate adaptability, and land optimization. Hausa story buildings accommodate extended families, utilizing vertical expansion in urban settings to preserve land, ensure privacy, and enhance airflow. The implications of this study emphasize the sustainability and efficiency of traditional Hausa architecture, offering insights into modern housing solutions that integrate vernacular design principles with contemporary urban planning in Kano.

Summary of the Study

This study examines the Analytical Mapping of Spatial Organization in Kano Metropolis using a Shape Grammar Approach to analyze the traditional Hausa houses in Northern Nigeria. The study focuses on five hypo-courted housing types: square rooms single, rectangular rooms single, apartments, row-houses, and story buildings, identifying their spatial organization, court placement, room arrangements, and circulation patterns. The decision trees illustrate key architectural elements, including the number of rooms (ranging from 3 to 8), Zaure (entrance hall) placement, court division (fore and inner courts), and the role of staircases. The Zaure placement varies (recessed, postulated, centered, right-cornered, or left-cornered), influencing accessibility and hierarchy within the house. Houses are further classified based on court division, stair positioning (middle or corner), and room allocation between the ground and upper floors, demonstrating how Hausa architecture optimizes space, privacy, and climate adaptation through courtyards and structured layouts.

The findings highlight that Hausa traditional houses follow an adaptive, rule-based spatial structure, balancing cultural needs, climatic responsiveness, and urban density constraints. The inner courtyard remains a thermal regulator, ensuring passive cooling and enhancing social interactions within extended families. The gradual transformation from single-story courtyard houses to row-houses and multi-story buildings addresses the growing urban population in Kano Metropolis while retaining traditional spatial logic. The shape grammar approach reveals patterns in spatial configuration, supporting the integration of Hausa vernacular principles into modern urban planning. These insights emphasize the need for culturally sensitive, sustainable housing policies that

preserve heritage, optimize land use, and enhance environmental resilience in contemporary Nigerian architecture.

RESULTS AND DISCUSSION

This section presents the key outcomes stemming from the plans lay-out study and the subsequent shape grammar analysis of collected data. These findings are thoroughly discussed in line with the objectives outlined in the introductory section. The analysis results serve as the basis for the discussions that follow, ultimately enabling us to draw conclusions and formulate recommendations.
This study is carried out with the objective of identifying the unique elements and stylistic range of the specific spatial organization of Hausa Architecture of Northern Nigeria. The table provided above Table 1.0 offers a comprehensive insight into the Hausa architectural attributes of twenty-eight distinguished Houses: Otoro area to the Rigiha lemu in Kano (G.K. Umar 2008).
Figure 1.0, 2.0, 3.0, 4.0, 5.0 and figure 6.0 above provides details about Element of Hausa Traditional Architectures based on the existing data and information, including its the relationship between the court (fore court (**FY**) and inner court (**IY**)), the Room Space (**RS**), the Zaure (**Z**) and a courtyard (**CY**) serves as circulation space in and out of the Room Space (**RS**), the toilet and internal staircase (**SC**) is included at the court-yard (**CY**) for storey type of Hausa traditional architecture.
Figure 1.0, depicts the Classification tree for the plan type of Hausa Traditional Architectures with respect to the spatial organization, number of room, Zaure placement, court division and stair case placement in the Hypo-courted type of the Hausa traditional houses.
In conclusion, the shape grammar analysis of these unique traditional architectures reveals a meticulous of the specific spatial organization of the typical plan layouts of the Hausa traditional architecture found in Northern Nigeria with a view to provide a way of exploring feasible designs. These Hausa shape grammar analysis not only serve functional purposes but also create spaces that inspire cultural appreciation. Hausa traditional architecture found in Northern Nigeria stand as architectural and artistic marvels, representing a computational composition of this unique architectural style in Nigeria's Islamic heritage
Figure 2.0, 3.0, 4.0, 5.0 and figure 6.0, depicts that in all the thirty (30) Hausa houses studied, the Classification tree for the plan type of Hausa Traditional Architectures with respect to the spatial organization, number of room, Zaure placement, court division and stair case placement in the Hypo-courted type of the Hausa traditional houses, it was noticed that all the eight (8) studied square rooms of the Naibawa buildings, Kano, twenty three (23) studied rectangle rooms of the DALA, MASUKWANI WARD, FEGGE and Mai Ya'u, Kano, Three (3) studied apartments Parametric shape of the Unguwa-uku wards, Kano, thirteen (13) studied story buildings of the Unguwa-uku wards, Kano and seven (7) studied row houses of the Unguwa-uku wards, Kano had a common analytic character. Thus, the ratio of permutation of Zaure vocabulary elements on the plan lay-out: inner- yard: inter-connected yard =2:2:7. With regards to Plan Types of

Spatial Organization for Hausa Traditional Architecture: all the twenty six(26) studied plan lay-ouy of the Classification tree for the plan type of Hausa Traditional Architectures with respect to the spatial organization, number of room, Zaure placement, court division and stair case placement in the Hypo-courted type of the Hausa traditional houses are grouped based on the arrangement of the court, the number and location of their room space within the plan. Figure 1.0 is a classification tree for the plans, organized within the works of G.K. Umar (2008). Below are the classified plan types into two major groups based on the court-yard (CY) form:

- Hypo-courted type Hausa Traditional Architecture,
- Interconnect courted type Hausa Traditional Architecture.
1. These may further be divided into five groups in terms of spatial organization and area:
    a. 3-6 Rooms Single type (100 sqm).
    b. 5-8 Rooms Single type (225 sqm).
    c. 2-3 Rooms of 3 Apartments type (486 sqm).
    d. 2-3 Rooms of 3 Row Houses type (900 sqm).
    e. Story Building type.

Conclusion and Recommendation

This study concludes that the Analytical Mapping of Spatial Organization in Kano Metropolis using a Shape Grammar Approach provides a systematic understanding of the traditional Hausa architectural typologies, their spatial configurations, and their adaptation to environmental, cultural, and social needs. The research highlights that Hausa houses follow a structured spatial hierarchy driven by court placement, Zaure orientation, and the strategic positioning of rooms and staircases. The five identified hypo-courted housing types—square rooms single, rectangular rooms single, apartments, row-houses, and story buildings—demonstrate a gradual evolution in response to urban expansion and population growth while maintaining the core principles of Hausa architectural identity. The decision trees and analytical mapping techniques used in the study reveal that Hausa houses rely on courtyards for ventilation, passive cooling strategies, and socially defined spatial divisions, which help optimize privacy and communal interactions.

The findings have significant implications for contemporary urban planning and architectural design in Kano and similar regions. The shift from courtyard houses to row-houses and multi-story buildings reflects the need for higher-density solutions, yet it poses challenges in retaining the environmental and social benefits of traditional configurations. The study emphasizes the importance of integrating Hausa vernacular architecture into modern housing policies, ensuring sustainability, cultural continuity, and spatial efficiency. The shape grammar approach used in this research provides a framework for digital modeling and architectural design, allowing urban planners to redefine housing layouts that respect traditional spatial logic while accommodating contemporary demands. Ultimately, the research underscores the need for preserving Hausa architectural heritage through informed, adaptive, and sustainable urban development strategies that enhance both functionality and cultural identity in Kano's evolving metropolis.

The study critically examines the unique elements and stylistic range of the Hausa Architecture of Northern Nigeria. The above literature shows the little consideration of the analytic computation aspects, despite the advent of new technologies since the twentieth century which has greatly evolved the design landscape.

Conclusively, the decomposition of this stylistic range of Hausa Architecture into a vocabulary of shapes can help simplify the spatial organization or arrangements, as supported by Mitchell (1986). Also the classification of the plan types into two major groups based on the courtyard form, and further sub-division into five groups by the spatial organization and areas. Useful recommendations are also stated, such as the need for exploring a more stylistic range of Hausa Architecture, the formal description of the urban design space based on the Hausa traditional city shape, and the necessary development of a formal generative mechanism to be used as a computational composition.

REFERENCES

Adamu, M. (2005). *Hausa architecture: Space, form, and symbolism*. Ahmadu Bello University Press.

Bianca, S. (2000). *Urban form in the Arab world: Past and present*. Thames & Hudson.

Denyer, S. (1978). *African traditional architecture: An historical and geographical perspective*. Heinemann.

Edwards, B. (2005). *Courtyard housing: Past, present and future*. Taylor & Francis.

Falola, T., & Salami, O. (2020). *The Palgrave handbook of African colonial and postcolonial history*. Palgrave Macmillan.

Gardi, B. (2014). *Indigenous African architecture: Housing forms and culture*. Routledge.

Hillier, B. (1996). *Space is the machine: A configurational theory of architecture*. Cambridge University Press.

Hillier, B., & Hanson, J. (1984). *The social logic of space*. Cambridge University Press.

Mitchell, W. J. (1990). *The logic of architecture: Design, computation, and cognition*. MIT Press.

Nash, J. (2018). *Vernacular architecture and cultural identity: Studies in African spatial design*. University of Chicago Press.

Oliver, P. (1997). *Encyclopedia of vernacular architecture of the world*. Cambridge University Press.

Stiny, G. (2006). *Shape: Talking about seeing and doing*. MIT Press.

Stiny, G., & Mitchell, W. J. (1978). *The Palladian grammar*. Environment and Planning B: Planning and Design, 5(1), 5–18.

Boden, M. A. (2006). *Mind as machine: A history of cognitive science*. Oxford University Press.

Chomsky, N. (1966). *Topics in the theory of generative grammar*. Mouton.

Hillier, B., & Hanson, J. (1984). *The social logic of space*. Cambridge University Press.

Hopcroft, J. E., & Ullman, J. D. (1979). *Introduction to automata theory, languages, and computation*. Addison-Wesley.

Johnson, M. (2004). *A philosophy of second language acquisition*. Yale University Press.

Pullum, G. K., & Scholz, B. C. (2002). Empirical assessment of stimulus poverty arguments. *The Linguistic Review, 19*(1-2), 9-50.

Stiny, G., & Gips, J. (1978). *Algorithmic aesthetics: Computer models for criticism and design in the arts*. University of California Press.

Agarwal, M., & Cagan, J. (1998). A blend of different tastes: The language of coffeemakers. *Environment and Planning B: Planning and Design, 25*(2), 205-226.

Chase, S. C. (2010). Shape grammar implementations: The last ten years. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 24*(2), 203-213.

Duarte, J. P. (2005). A discursive grammar for customizing mass housing: The case of Siza's houses at Malagueira. *Automation in Construction, 14*(2), 265-275.

Herr, C. M., & Kvan, T. (2007). Adapting shape grammars to collaborative and digital design environments. *Automation in Construction, 16*(3), 272-282.

Knight, T. W. (1999). Shape grammars: Six types. *Environment and Planning B: Planning and Design, 26*(1), 15-31.

McKay, A., Shea, K., & Chau, H. H. (2012). The role of shape grammars in design. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 26*(2), 161-165.

Stiny, G. (1975). Pictorial and formal aspects of shape and shape grammars. *Birkhäuser*.

Stiny, G., & Mitchell, W. J. (1978). The palladian grammar. *Environment and Planning B: Planning and Design, 5*(1), 5-18.

Adamu, M. (2005). *Hausa architecture: A study of form, function, and meaning*. Ahmadu Bello University Press.

Alexander, C. (1977). *A pattern language: Towns, buildings, construction*. Oxford University Press.

Bianca, S. (2000). *Urban form in the Arab world: Past and present*. Thames & Hudson.

Denyer, S. (1978). *African traditional architecture: An historical and geographical perspective*. Heinemann.

Edwards, B. (2005). *Courtyard housing: Past, present, and future*. Taylor & Francis.

Falola, T., & Salami, J. (2020). *The Yoruba in transition: History, values, and modernity*. Carolina Academic Press.

Gardi, B. (2014). *Indigenous African architecture: An analysis of forms and spatial organization*. Routledge.

Hillier, B., & Hanson, J. (1984). *The social logic of space*. Cambridge University Press.

Nash, J. (2018). *Gendered spaces: The social structure of spatial organization*. Palgrave Macmillan.

Oliver, P. (1997). *Encyclopedia of vernacular architecture of the world*. Cambridge University Press.

Omer, S. (2019). *Islamic architecture and urbanism: Principles and practices*. International Institute of Islamic Thought.

Stiny, G., & Mitchell, W. J. (1978). *The Palladian grammar*. Environment and Planning B: Planning and Design, 5(1), 5–18.

B. A. DANJUHA (1988) "HOUSE FORM IN THE NIGERIAN SAVANNA: AN ANALYSIS Of HOUSING AND CITY STRUCTURE IN THE HAUSA TRADITION" unpublished thesis submitted to McGill University Montreal, Canada July 1988

Ejiga, O., O. Paul, and O. Cordelia, Sustainability in traditional African architecture: a springboard for sustainable urban cities. Sustainable Futures: Architecture and Urbanism in the Global South, Kampala, 2012: p. 27–30.

F. W. SCHWERDTFEGER'S (2018) "COMPARATIVE STUDY OF CONVENTIONAL URBAN HOUSES IN THREE REGIONS IN AFRICA" THESIS SUBMITTED FOR A PHD. DEGREE IN ARCHITECTURE SCHOOL OF ENVIRONMENTAL STUDIES UNIVERSITY COLLEGE LONDON Published by ProQuest LLC (2018). (ProQuest 11010417) 17, ProQuest LLC. 789 East Eisenhower Parkway P.O. Box 1346 Ann Arbor, Ml 4 8 1 0 6 – 1346

G. K. Umar (2019) "Transformation in "HAUSA" Northern Nigeria Traditional Residential Architecture" Elixir Sustain. Arc. 126 (2019) 52524-52528 www.elixirpublishers.com (Elixir International Journal)

G.K. Umar, D.A. Yusuf, A. Mustapha, Theory and design for the contemporary residential building: a case study of Kano metropolis, north-western part of Nigeria, International Journal of Innovation Environmental Studies. Res. 7 (1) (2019) ISSN: 2354-2918.

G.K. Umar, D.A. Yusuf, Socio–Cultural rejuvenation: a quest for architectural contribution in Kano cultural centres, Nigeria, Int. J. Adv. Acad. Res. Sci. Technol. Eng. 5 (3) (2019) March 2019. ISSN: 2488-9849.

G.K. Umar, Transformation in Hausa traditional architecture: A case study of some selected parts of Kano Metropolis (1950–2004), 2008. Architecture, ABU Zaria, An unpublished PhD Thesis.

I.I. Danja, X. Li, S. Dalibi, Vernacular architecture of

Northern Nigeria in the light of sustainability, in Proceedings of the IOP Conference Series: Earth and Environmental Science, IOP Publishing, 2017.

J. Lodson and J. E. Ogbeba, U. K. Elinwa (2018) "A Lesson from Vernacular Architecture in Nigeria" Contemporary Urban Affairs 2018, Volume 2, Number 1, pages 84-95

J. Whitehand, Urban Morphology and Historic Urban Landscapes, 27, World Heritage Papers, 2010, pp. 35–44

J.O. Popoola, Responsive housing: the spatial Formation of Housing Environment in Hausa land, Nigeria and the implications for public housing strategy, 1984. Nottingham UK, An unpublished PhD Thesis.

K.G. Umar, Methodological issues in architectural conservation, preservation and restoration of Hausa traditional residential building: a case study of Kano metropolis, Int. J. Adv. Acad. Res. Sci. Technol. Eng. 5 (2) (2019) ISSN: 2488-9849.

M. Adamu, Interpretation of significance and messages in Hausa traditional architecture. Case of the "Zaure" entrance hall, J. Assoc. Archit. Educ. Niger. 4 (2005) 10–21.

M.B. Shehu (2016) "CULTURAL SYMBOLISM IN TRADITIONAL HAUSA ARCHITECTURE OF NORTHERN NIGERIA" unpublished thesis submitted to the University of Kent 2016

O. P. Agboola and M. S. Zango (2014) "DEVELOPMENT OF TRADITIONAL ARCHITECTURE IN NIGERIA: A CASE STUDY OF HAUSA HOUSE FORM" International Journal of African Society Cultures and Traditions Vol.1, No.1, pp.61-74, June 2014 Published by European Centre for Research Training and Development UK (www.ea-journals.org) 61

O.P. Agboola, M.S. Zango, Development of traditional architecture in Nigeria: a case study of Hausa house form, Int. J. Afr. Soc. Cult. Tradit. 1 (1) (2014) 61–74.

U. H. BAMALLI (2020) "RETHINKING & RESUSCITATING HAUSA-LAND DOMESTIC VERNACULAR ARCHITECTURE - KANO, A CITY STATE (GIDAJEN HAUSA NA KANO)" unpublished MASTER thesis submitted to 03-07-2020 LA SALLE SCHOOL OF ARCHITECTURE RAMON LLULL UNIVERSITY, BARCELONA 2020

Z. Dmochowski, An Introduction to Nigerian Architecture-Northern Nigeria, 1, Ethnographica Ltd., London, 1990, p. 1.2. pp.

Bako, M. (2013). Hausa Architecture and Its Significance in Nigerian Cultural Heritage. Nigerian Journal of Culture.

Bugaje, U. M. (1991). Islam and Society in Hausa Land. African Journal of History.

Denyer, S. (1978). African Traditional Architecture: An Historical and Geographical Perspective. Heinemann Educational Books.

Eziyi, I., Olatunde, A., & John, K. (2017). Traditional Building Materials and Climate Adaptation in Northern Nigeria. Journal of Environmental Studies.

Fagg, W. (1983). Nigerian Art and Culture. British Museum Publications.

Hausa Arts. (2019). Traditional Hausa Symbols and Designs. Cultural Studies Press.

Hiskett, M. (1984). The Development of Islam in West Africa. Longman.

Maishanu, U. (2012). The Architectural Heritage of Northern Nigeria. Nigerian History Journal.

Olotuah, A. O. (2019). Modernization and Preservation in African Traditional Architecture. Nigerian Building and Environment Journal.

Prussin, L. (1986). African Nomadic Architecture: Space, Place, and Gender. Smithsonian Institution Press.

Renner, M. (2017). Spatial Organization in Hausa Architecture. Journal of African Architecture.

Sa'idu, S. (2014). Sustainable Building Practices in Hausa Traditional Architecture. Environmental Sustainability Journal.

Sani, I. et al. (2020). Heritage Conservation of Hausa Architecture in Nigeria. African Architectural Review.

Suleiman, M. (1998). Symbolism in Hausa Traditional Art. Nigerian Art Journal.

Olakanbi, B. A. and Osama A. R. 2016. "Design of Generative Model for the Language of Traditional Suakin using Parametric Shape Grammar". International Journal of Computer- Aided Technologies (IJCAx) Vol.3, No. 2/3, July 2016.

Olakanbi, B. A. and Osama A. R. 2016. "Style Generative Tool for Suakin Architecture". International Journal of Architecture (IJA) Volume 2, Issue 1, January-June 2016, pp. 01–15, Article ID: IJA_02_01_001

Olakanbi. B. A, 2012, "utilization of parametric system in design process of tall building", College of Architecture engineering, Sudan University of Science and Technology.