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Syntactic analysis of traditional houses in urban kampung

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Abstract

This research investigates a syntactical study and comparative analysis of the statistical and spatial characteristics of traditional houses in an urban kampung settlement, focusing on a selected case study built by a participatory Arabic community in Palembang, South Sumatra, Indonesia. This research aims to determine a formal rule basis for spatial configurations to reveal identical sociospatial structures based on syntactical analysis. This experiment measures spatial layout variation through space syntax analysis to provide a better understand of how the correlation between spatial configuration and sociospatial structures in traditional houses can be deconstructed. This syntactical analysis applies four distinctive procedures: a selected case study, data collection, statistical and graphical analysis, and graph analysis. The results indicate that the spatiality of all traditional houses in this kampung settlement highlights the spatial hierarchy order as a formal rule-based system, and approximately an average of 10% of this community is concerned with designing intelligible layouts. *Rumah Batu* and other dwellings have a similarity and closeness. The main dwelling's function involves more steps to separate public and private functional rooms, but a functional transformation from a dwelling into a public facility creates a short distance for easy access by users. Additionally, this separation affects occupants, especially in terms of spatial distribution activities, movement flows, and other social phenomena. This approach provides practical and tangible benefits for preservation values related to buildings; this strategy may also change how buildings are perceived in other built environments.

Keywords Syntactical analysis, Traditional housing, Urban kampung, Space syntax

1 Introduction

Kampungs, which are sometimes referred to as kampongs, are a unique feature of urban settlements in Indonesia that have a valuable history and cultural significance. They are urban villages that are characterised by a close-knit community, a noticeable architectural style, and a unique sociocultural identity. These characteristics constitute what is known as an autonomous community model (Funo et al. 2002). In terms of architectural style, kampungs have traditional houses that have been constructed through the expression of community characteristics. Traditional houses depict the architectural language of people and the social and cultural impact of a specific place (Brown and Maudlin 2012), which leads to a sense of belonging. This language reveals a distinctive milieu feature with significant cultural and historical value that reflects vernacular settlement patterns. However, the proliferation of modernisation and urbanisation has created considerable challenges for traditional housing in the existence of kampungs.

Although traditional buildings display distinctive spatial characteristics, all of the elements, such as the spatial

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layout and the orientation of the houses, were designed and built into communities. This reflects how communities identify this morphological strategic arrangement based on the local cultural context. Due to modernisation and the declining quantity and quality of traditional genuine residents, these traditional houses in Indonesia are in danger of losing their value, and their built form and layout may degenerate due to aesthetic changes in their original typologies. On the one hand, traditional houses show historical inheritance and robust cultural identity that are tightly linked to the heritage of the area surrounding them. On the other hand, traditional houses are also mostly considered low-status and represent a low-living standard of housing at present (Oliver 2006).

Previous research has examined decoding spatial organisation. Using case studies, researchers have investigated the structural characteristics of rural home spaces by spatial connectivity, relative asymmetry value in southern France from the aspects of social culture, the behavioural patterns and family daily activities of a certain social culture (Hillier et al. 1987), the decoding of houses and homes (Hanson 1998), spatial architectural style in considering Glenn Murcutt's design (Lee et al. 2013), the generation of settlement grammar patterns (Andino and Chien 2013), a syntactical and grammatical approach to architectural configuration (Lee et al. 2015), a typology of spatial configuration in Korean housing (Byun and Choi 2016), transforming housing typologies (Eloy 2016), the spatial configuration of house layouts and transformation in Biskra city (Barkat et al. 2020), behavioural patterns in spatial configuration of traditional houses in China (Ding and Ma 2020), spatial configuration of users' social interaction in mass houses in Algeria (Zerouati and Bellal 2020), and decoding sociospatial in syntactical analysis of a rural settlement in Algeria (Djezzar and Bada 2023). The syntax of architectural space has been applied in a set of analytical, quantitative, and descriptive tools to analyse spatial organisations in different forms and at different scales (Hillier and Hanson 1984; Hillier 1996). The established research has focused on layout transformation and houses designed by designers. However, little is known about traditional housing in the urban kampung context, especially in Indonesia. Therefore, this research deconstructs the original spatial layouts built by Arabic communities and provides a formal basis for traditional housing with quantitative aspects.

In the context of Indonesia, traditional houses in a kampung cannot survive due to modernisation. In terms of the proliferation of technology and modernisation, the architecture style of this traditional building in Palembang tends to be abandoned or replaced by modern housing that is suitable for dwellers' needs. This has caused the inhabitants of these traditional houses to be alert towards this loss, which might highlight the need to conduct preservation and conservation, especially in this kampung. This leads to further transformation and new design of relevant rules. Syntactical analysis provides an opportunity to learn how to deconstruct the correlation between spatial relations and configurations in terms of formal-based rules of traditional houses intangibly in this Arabic kampung, especially the connection between each space that expresses a certain culture and rules in the spatial form of traditional houses.

This study identifies the correlation spatial configuration among different traditional houses, particularly in defining spatial organisation, studying social structures and identifying the similarities of spatial layouts. This research aims to determine the basic rules of spatial-morphological configurations to reveal identical sociospatial structuring based on a syntactical approach through space syntax, especially for kampung settlements. This approach might be considered a guiding feature of people's movement flows (Hillier 2019; Mahfoud et al. 2022) and affect spatial distribution activities and other social phenomena (Hacini et al. 2022). Afterwards, experimenting with this extraction of spatial characteristics is beneficial for understanding how to learn about and preserve vernacular houses in the built environment.

2 Spatial characteristics extraction through syntactical analysis

Space syntax refers to a collection of theories, methodologies, and techniques that were developed in the 1980s by Bill Hillier and Julienne Hanson to examine the relationships between spatial configuration and its social effects (Hillier and Hanson 1988). Through a mathematical and graphical examination of spatial organisation layout plans in topological graphs, spatial and social characteristics can also be interpreted (Ostwald 2011). Another finding was that understanding the spatial configuration of the vernacular houses revealed the fundamental genotype and facilitated the examination of cultural characteristics (Vrusho and Yunitsyna 2016). According to previous research, investigating the syntactical analysis of traditional settlements through space syntax might result in a pattern language of architecture and generate an orderly and logical decomposition of the spatial layout and formal rule basis of traditional houses in urban kampungs with quantitative aspects.

This study primarily aims to conduct a functional space analysis of spatial configuration through syntactical analysis. The syntactical analysis can be performed visually to define a series of qualitative spatial configuration properties, such as depth, spatial hierarchy or permeability, and asymmetry or symmetry (Ostwald 2011). Conducting a syntactical analysis of

traditional housing consists of describing the convex plan map and investigating the relationship between sociocultural features and spatial organisation. Understanding syntax or grammar refers to the connections between architecture and language as a corpus of design ideas. This kind is used as a symbol of form to investigate the relevant characteristics, cultural values, and connotations as expressions to integrate spatial form and function (Zhang and Li 2021). Additionally, pattern language (Alexander et al. 1977) refers to expressing forms that comprehensively reflect spatial structure and logical relationships, especially the inherent beauty of traditional buildings (Alexander 1964) and urban spaces (Dawes and Ostwald 2017). However, pattern language is useful for conceptual design and is lacking in practice due to its semantic and abstract nature (Yu and Min 2022). The spatial configuration of existing traditional houses and their extension buildings can be evaluated by identifying the adaptation and evolution patterns of a community (Yoas and Muslimin 2023), while understanding typologies can reveal possibilities in body-space relationships, shared and distributed spaces, and an understanding of the uses of different spaces individually, collectively, publicly, or privately (De Jorge-Huertas and De Jorge-Moreno 2024). This study investigates the similarity of spatial structure among sampled houses in terms of cultural, social, and environmental aspects of design (Ayyıldız and Durak 2024). Therefore, this method is proposed and developed for identifying spatial layouts in this research through syntactical analysis to discover the underlying configurations of architectural space (Boutabba et al. 2020) via Gamma analysis (Hillier and Hanson 1984; Hillier 1984).

Syntactical analysis is important because it offers an application of graph theory for understanding a set of rules in spatial design and structure (Hillier 2019). In graph theory, a graph is created to represent the topological relationships between rooms in a building, and this demonstration is used for design development and evaluation (Dawes and Ostwald 2013). Graph theory in architectural analysis is a mathematical model of spatial configuration and architectural forms used to intuitively study the design of spatial arrangements and evolution for architects or designers (Lakshmi et al. 2019). The underlying spatial configuration can be topologically reconceptualised as a graph of rooms (nodes) and doors between them (edges) (Dawes and Ostwald 2013). Each node in the graph represents the functional space, and the edge links the nodes that refer to the connections between them.

3 Methodology

To achieve the research objectives, a combination of fieldwork and qualitative and quantitative analysis is applied syntactically. Qualitative analysis refers to total justified graphs through space syntax analysis using DepthmapX software version 0.7.0 developed by Alasdair Turner, while quantitative analysis refers to the extraction of syntactical layout-based topological types through Agraph tools. Utilising space syntax can be beneficial for both quantitative and qualitative analysis (Ding and Ma 2020), especially in studying spatial configurations of housing layouts and social and cultural logic. This syntactical analysis applies four distinctive procedures (Fig. 1): selected case study, data collection, statistical and graphical analysis, and graph analysis through space syntax. These extractions are compared and interpreted to identify the characteristics of the spatial organisation of each traditional house and spatial structure, which leads to an understanding of sociocultural behaviour through the provided syntactical data.

3.1 Selected case study

Selecting a case for this study involved the consideration of several criteria, including geographical location, architectural style, participatory community, historical value, and age of buildings of kampung settlements. According to these criteria, this study focuses on traditional houses in Kampung Al Munawar 13 Ulu, which is located on the Musi River's riverfront in Palembang, South Sumatra, Indonesia. This kampung is a captivating and unique traditional settlement that was built by Arabic communities (nonnative folks) in the 18th century without the help of architects or designers. This uniqueness represents the intellectual knowledge of the local community (Var and Kobayashi 2017). Arab communities, *al Habsyi, al Hadad, and al Munawwar* (Yusalia 2017) in Palembang played a significant role in spreading the Muslim religion during the Sultanate and Dutch eras. This area is located in the southern part of the Musi River and is called the 'Ulu area' by nonindigenous people or visitors only. During the Sultanate period, Arab communities were not only traders but also visitors who were only allowed to live and stay in the 'Ulu area' because the 'Ilir area' was only for the Sultanate Palace and indigenous residents of Palembang. This regulation impacted the differences in housing typologies between native and nonnative people.

At Kampung Al Munawar, numerous indigenous architectural styles characterise the region's environment. Arabic communities constructed their dwellings in a way that closely resembles architectural styles. The 'colonial style' and 'indie style' are discernible. The colonial style

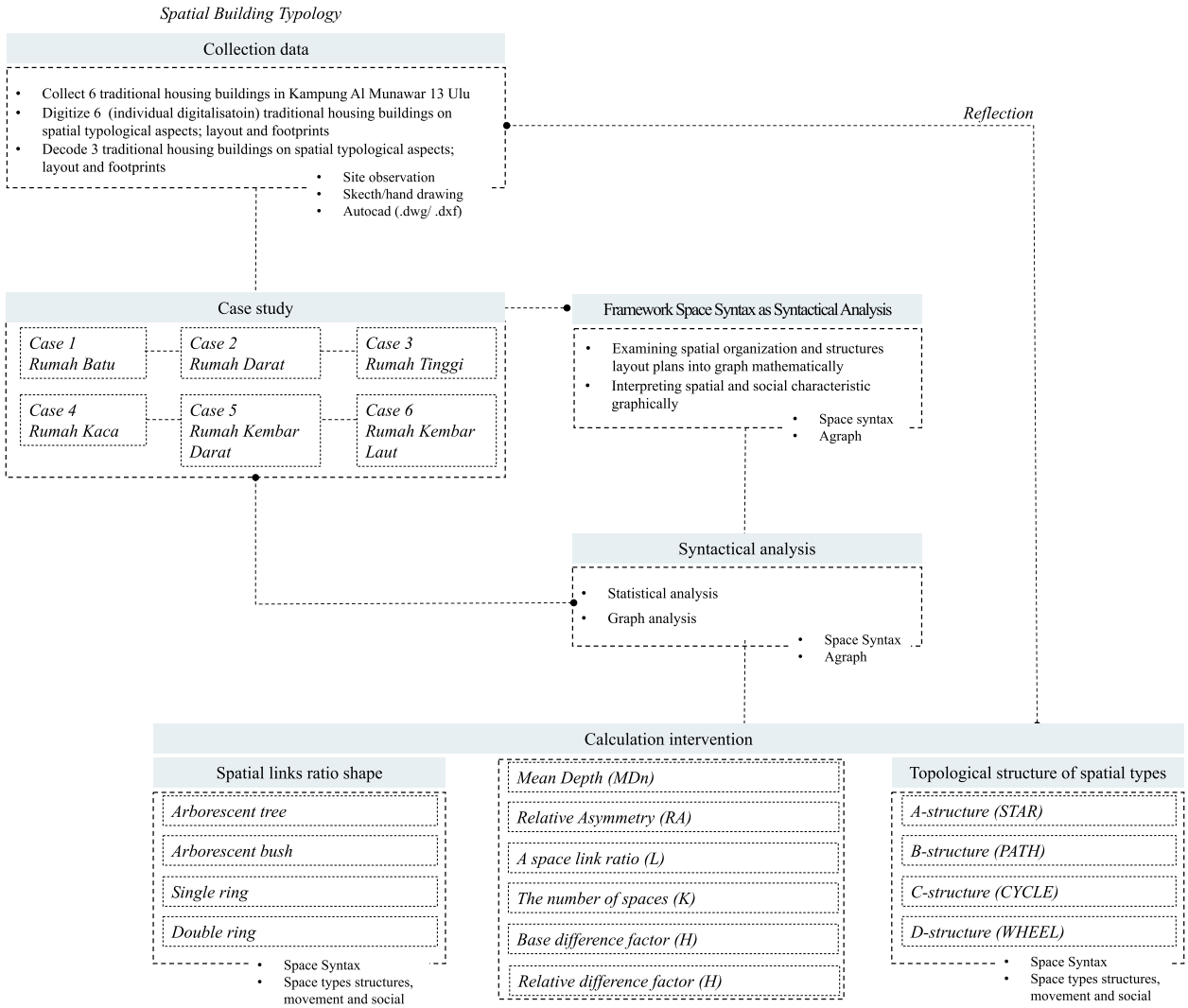


Fig. 1 The corpus of methodology framework (Source: the authors)

reflects the architectural influences of the Dutch colonial era and is exemplified by *Rumah Kembar Darat*, which has symmetrical facades, pitched roofs, and large windows. Conversely, the indie style assimilates the indigenous architectural elements *'Rumah Limas* or *Limasan'* and *'kijing'* from the East Indies, Java, and other parts of Indonesia. This style represents the intricate carvings, decorative motifs, and vernacular techniques – *Rumah Batu* – that reflect the richness of cultural heritage (Santun 2011).

These case study criteria are met by six distinct houses in this kampung. These houses exhibit a significant representation of the historical and sociocultural characteristics of the Arabic community in this kampung, such as hierarchy, the separation of female and male space, community life, mobility, and spatial use. These represent the main buildings in this kampung, namely, *(a) Rumah Batu, (b), Rumah Darat, (c) Rumah Tinggi, (d) Rumah Kaca, (e) Rumah Kembar Darat,* and *(f) Rumah Kembar Laut,* compared to other buildings in this kampung. All these traditional houses have a housing typology, while only *Rumah Kaca* has a school typology, although it was previously a home. The owner dedicated waqf this house to the foundation and transformed it into a school. Subsequently, a few modifications were made to this building to accommodate additional functions, including installing room partitions, enhancing accessibility features to meet educational standards, and installing other educational facilities. This transformation from a dwelling to a community school reflects adaptive reuse to adjust to social needs. Currently, these houses are still in good condition, and others have been refined. The dwelling typology, rooms and activities for male and female inhabitants or guests in these traditional buildings are separated and limited by physical barriers such as walls and doors. These kinds of boundaries are always maintained by the Muslim religion to limit the visual privacy

of residents when interacting with 'nonmahram' guests. Given the valuable culture and history of this indigenous Arabian inheritance, this settlement became one of the tourist destinations in Palembang.

In addition, every traditional building has a different form and layout, including symmetrical and asymmetrical layouts. These buildings retain this original characteristic. Thus, the abovementioned method is applied to investigate and reveal the syntactical and morphological characteristics of six traditional houses built by the participatory Arabic community. This method supports conceptual thinking, especially learning about the architectural design process from communities at the early stage and preserving the spatial characteristics of traditional houses intangibly in this kampung.

Figure 2 shows that *Rumah Batu* (Fig. 2a) was built by Al-Habib Abdurrahman Al-Munawwar, a leader of Arabic communities in this kampung (Purwanti 2017). This housing was for his third child, Al Habib Ali Al-Munawwar, and was intended for gathering and sheltering when the battle between the Dutch and the Palembang Sultanate periods occurred. It was adopted from *Rumah Limas*, such as '*kijing*'. *Rumah Darat* (Fig. 2b) is the house of Al Habib Muhammad Al-Munawwar, the first child of Al-Habib Abdurrahman Al-Munawwar. This house also adopted *Rumah Limas* but has only one stair in front of the house, which also has predominantly wood material with a terraced floor *(kijing)*.

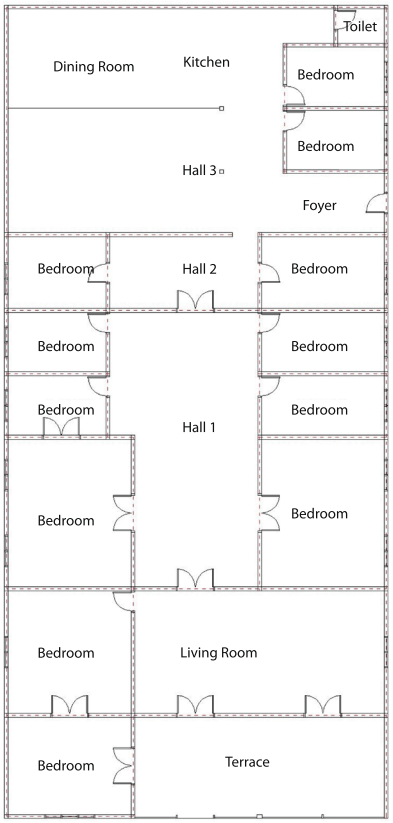
Rumah Tinggi (Fig. 2c) was built by Habib Abdurahman in the 18th century. This building was also adapted from *Rumah Limasan* and has only one story. *Rumah Kaca* (Fig. 2d) is the house of Hababa Roguan Al-Munawwar, the fourth daughter of Al-Habib Abdurrahman Al-Munawwar. This house was constructed in 1914 and is a two-story building with a spacious layout and glass materials for architectural elements, such as windows and doors. Now, all the rooms in this house function as an elementary school, *Yayasan Perguruan Islam Al-Kautsar*. *Rumah Kembar Darat* (Fig. 2e) is the house of Al Habib Hasan Al Munawar, the fourth son of Habib Abdurrahman Al Munawar. This house contains two identical buildings, one in the north and another in the south. These buildings are twin houses that reflect each other. This is why these two homes are oriented towards the open area rather than the Musi River. *Rumah Kembar Laut* (Fig. 2f) has both residences side by side facing the Musi River. This building functions as a meeting place for council events that are linked to family rooms and separated into areas for females and males.

3.2 Data collection

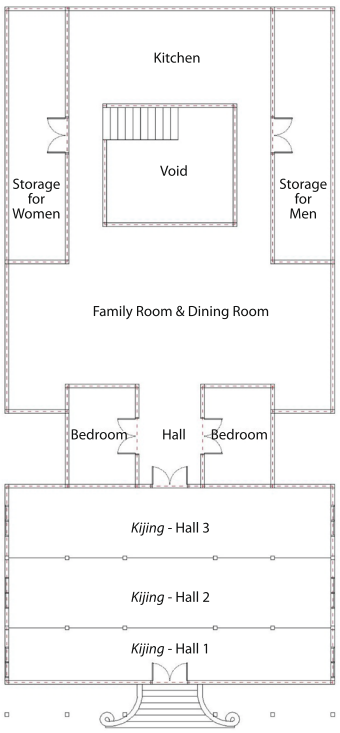
The data were collected during case selection through observations and visits to understand the rule-based layout system in traditional houses in the urban kampung of Palembang. This system shows a distinctive space and style that reflects the local and historical context of Arabic inheritance. In this section, the relevant data that were collected through visiting fieldwork, interviews with the residents, and hand-drawn sketches of the spatial layout footprints of traditional houses are discussed. Then, the sketches are digitised to convert into a convex map as a basis map for the syntactical analysis model. In addition, the room names are codified so that simulations can be easily generated.

There are six traditional houses used for case selection in this investigation (Figs. 3, 4, and 5) with different

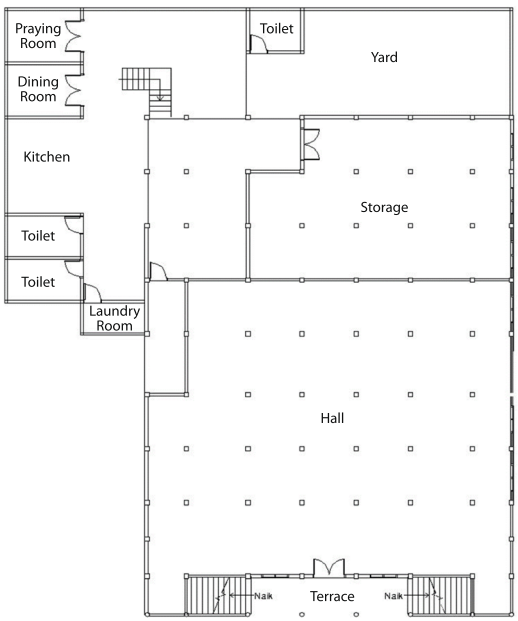
Fig. 2 The observed traditional houses in the Arabic Kampung Al Munawar 13 Ulu, South Sumatera, Indonesia, 2023 (Source: Google Maps and the authors)



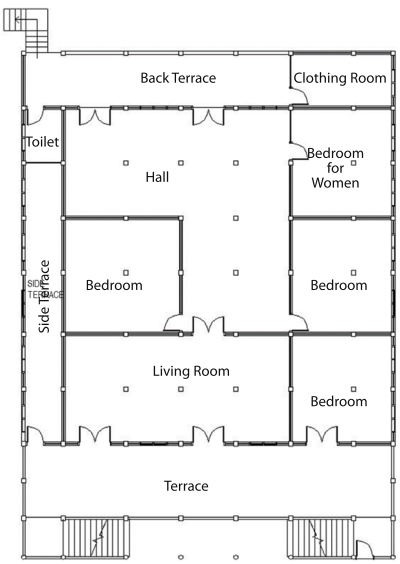
a. Rumah Batu



b. Rumah Darat

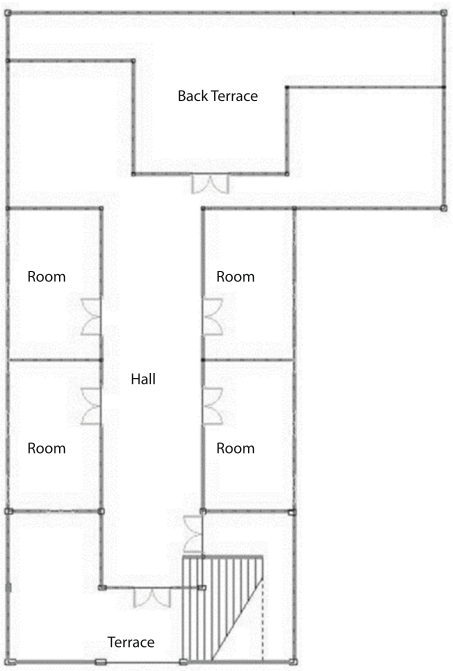


c. Rumah Tinggi (GF)

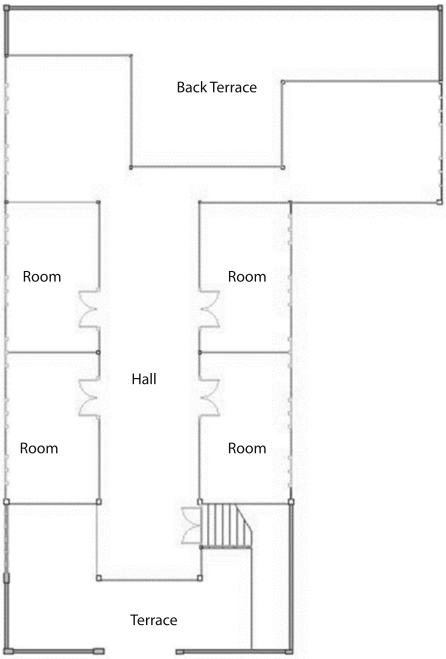


Rumah Tinggi (1F)

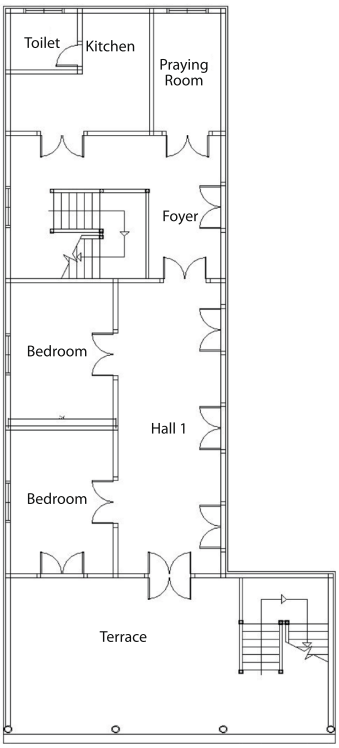
Fig. 3 The layout plans of selected cases of traditional houses (a, b, and c) in Arabic Kampung Al Munawar 13 Ulu, South Sumatera, Indonesia (Source: the authors)



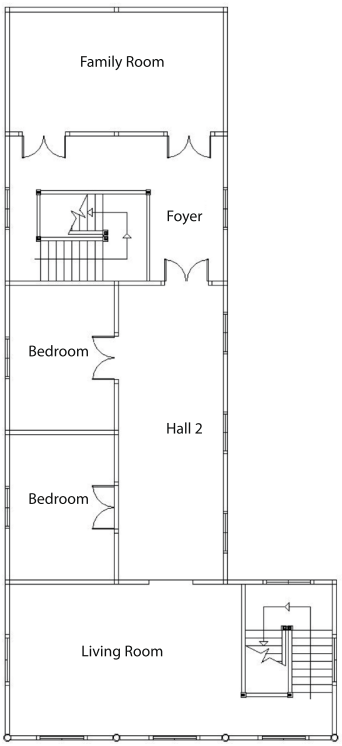
d. Rumah Kaca (GF)



Rumah Kaca (1F)

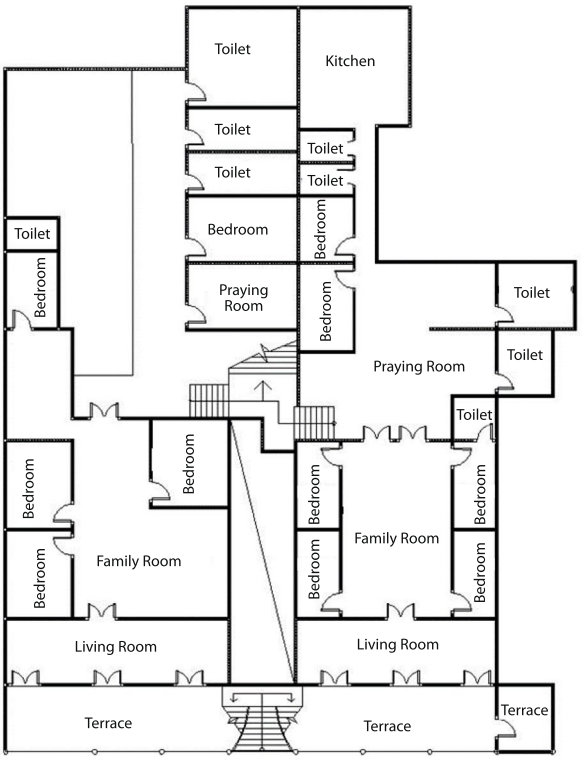


e. Rumah Kembar Darat (GF)

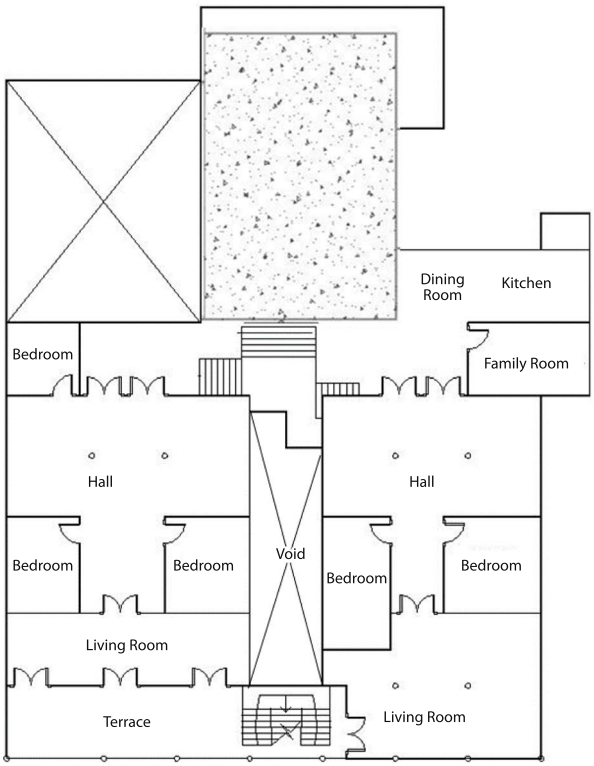


Rumah Kembar Darat (1F)

Fig. 4 The layout plans of selected cases of traditional houses (d and e) in Arabic Kampung Al Munawar 13 Ulu, South Sumatera, Indonesia (Source: the authors)



f. Rumah Kembar Laut (GF)



Rumah Kembar Laut (1F)

Fig. 5 The layout plans of selected case of traditional houses (f) in Arabic Kampung Al Munawar 13 Ulu, South Sumatera, Indonesia (Source: the authors)

characteristics and layout plans, namely, *(a) Rumah Batu, (b) Rumah Darat, (c) Rumah Tinggi, (d) Rumah Kaca, (e) Rumah Kembar Darat, and (f) Rumah Kembar Laut.*

3.3 Syntactical analysis as a statistical and graphical approach

The architectural graph in the mathematical analysis could begin with the derivation of the measurement, including the number of nodes, edges, or types of social space to be classified as 'public' or 'private'. These measurements can be compared with those of other variables (Table 1), such as the mean depth (MD), base difference factor (H), relative difference factor (H*), space link ratio (SLR) and spatial degree. The MD is applied to identify how spaces can be integrated with or separated from other spaces. It also defines how many steps it takes to access a distinguished space from the root space (the original first point of space) (Hillier and Hanson 1984).

$$MD = \frac{TD}{(K-1)} \tag{1}$$

The base difference factor (H) is used to evaluate the entropy of the integrated results in a graph. Entropy measures the distribution of spatial locations in terms of depth from a space (Hillier et al. 1987) and is used to analyse the spatial structure or permeability of buildings. The higher the index of the entropy value is, the more difficult it is to reach other spaces in the spatial layout, but the greater the depth distribution is, and vice versa (Asriana and Indraprastha 2016). When the number index of the base difference factor (H) is closer to the 0 difference factor, the spaces are more structured and differentiated. The closer to 1 the difference factor is, the more homogenised the spaces are to the point where all spaces have equal integration values (Hanson 1998). Moreover, the relative difference factor (H^*) calculates the ranging index in a set of elements of differentiation and flexibility in spatial organisations (Tafti and Lee 2022). Moreover, this factor also measures how different the values are in a set of elements, ranging from 0 (the maximum difference and minimum entropy) to 2 (the minimum difference and maximum entropy) (Hillier et al. 1987).

Table 1 The statistical variables (Source: UCL Space Syntax, accessed 2023)

MD	Mean depth is the number of steps to access the spaces from the root space
SLR	A space – link ratio of spaces in a spatial system
L	The number of lines of the link between spaces in graph
K	The number of spaces in the system
H	Base difference factor
H*	Relative difference factor

$$H = -(\frac{a}{t}xln\left(\frac{a}{t}\right) + \frac{b}{t}xln\left(\frac{b}{t}\right) + \frac{c}{t}xln\left(\frac{c}{t}\right)) \tag{2}$$

$$H^* = \frac{H - ln2}{ln3 - ln2} \tag{3}$$

The SLR is applied to assess the spatial distribution and nondistributedness of each space and the house's layout, where the index starts at 0 and is greater than 1. If there is only one nonintersecting route from one space to another in a system, this ratio shows a tree-like structure with less spatial distribution (Bada et al. 2021). However, if there is more than one nonintersecting route, the layout has good spatial distribution and greater flexibility. When the value index is greater than 1, this ratio also indicates a high degree of 'ringness or ringy structure' and is highly distributed (Mustafa and Hassan 2013).

$$SLR = \left(\frac{L+1}{K}\right) \tag{4}$$

These statistical variables will be compared with the values of the spatial structures and morphological relationships of traditional houses, such as the number of lines between spaces in the graph (L), the number of spaces in the system (K), the link ratio of spaces in a spatial system (SLR), the measurement of identifying separated spaces from other spaces (MD), the measurement of the maximum entropy to analyse the spatial structure and permeability (H), and the measurement of the minimum entropy to analyse the spatial structure and permeability (H*).

There are four different topological spaces (Fig. 6): a-type, b-type, c-type, and d-type (Hillier et al. 1987; Hillier 2019). In this way, the concept of space types, which generate spatial structure types of spatial design and describes how every space in a graph relates to the rule system that forms a part, is presented. Every space type has a meaning, especially in the syntactic sense of spatialising concepts and reinforcing expression. Hillier (2019) highlighted that there are four space types: *a-structure (STAR), b-structure (PATH), c-structure (CYCLE) and d-structure (WHEEL).*

Spatial type can be assessed by using the SLR. It is a pivotal metric in this study to express the choice of the path to navigate a spatial order network system directly and indirectly as a person or user moves from one node to another node or from one space to another (Djezzar and Bada 2023). This measures the degree of connectivity and integration between nodes in spatial layouts from outside to inside buildings. There are two types of SLR shapes (Table 2): arborescent and ring-shaped (Elizondo 2022). In the former, an arborescent tree and an

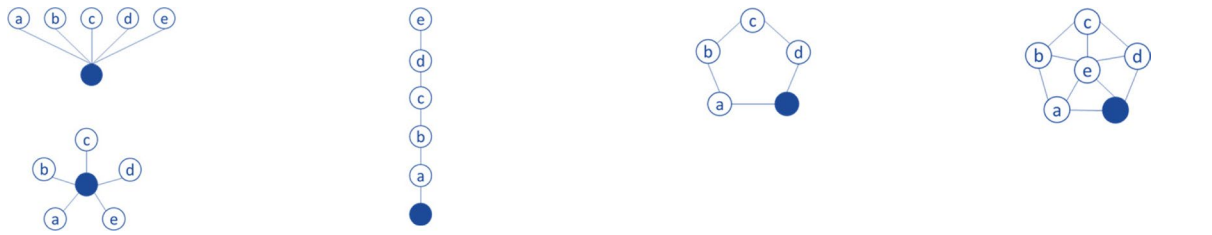
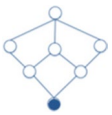


Fig. 6 The emergence of comparing spatial types: structures, movement, and social concepts (Source: Hillier 2019, redrawn by the authors)

Table 2 The emergence of the spatial link ratio shape (Original source: Elizondo 2022 and redrawn by the authors 2023)

Arborescent		Ring	
Tree	Bush	Single	Double
			

arborescent bush are used to describe spatial hierarchy. In contrast, the ring shape consists of a single ring and a double ring to describe configuration permeability. Known as branching or arborescent topological structures often described as 'bush-like' or 'tree-like', these structures balance flexibility and control due to the passing or accessing choice in the plan, while a rhizomorphous topological structure is often described as 'looped' or 'ringed' and provides choice and flexibility in how users move through space (Ostwald and Dawes 2018). In this kampung study, the SLR is essential for measuring the degree of spatial connectivity and integration between different nodes in spatial layouts or from outside to inside buildings.

This phase applies a spatial syntax method as a quantitative analysis to explore the spatial configuration of traditional houses in Kampung Al Munawar 13 Ulu. The six house building plans were converted to identify nodes and links and analysed with a graph plan. The former identifies significant spatial rooms and defines them as nodes through functional rooms to define broader zones within a layout plan, while the link defines the relationship and connectivity between the node sectors. These combinations of sector nodes and links refer to expression and development in graph theory through the space syntax method (Table 3). In other words, links between spaces or nodes represent logical links to define a topological network (Batty 2022).

These parameters and this map conversion into convex layout data could facilitate the identification of the statistical analysis as an abstraction process of the six traditional building layouts by determining the spatial rooms and links, the total depth, the number of step depths and the number of nodes. The total depth of each building differs (Table 4), which affects the reachable or unreachable spaces and the open or closed spaces.

3.4 Graph analysis

The graph analysis tool can be used to generate visibility analysis in DepthmapX software version 0.7.0, which

Table 3 Identifying nodes and links for configurational analysis

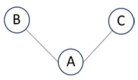
	Node	Link
Description	Defining required spaces (vocabulary)	Defining design layouts (grammar)
Schema	x ➔ node (a)	a, b; a,c ➔ link (a,b); (a,c)
Examples	node (A); node (B); node (C)	link(A,B) + link (B,C)
		

Table 4 The abstraction process of the plans of the six traditional buildings (Source: the authors)

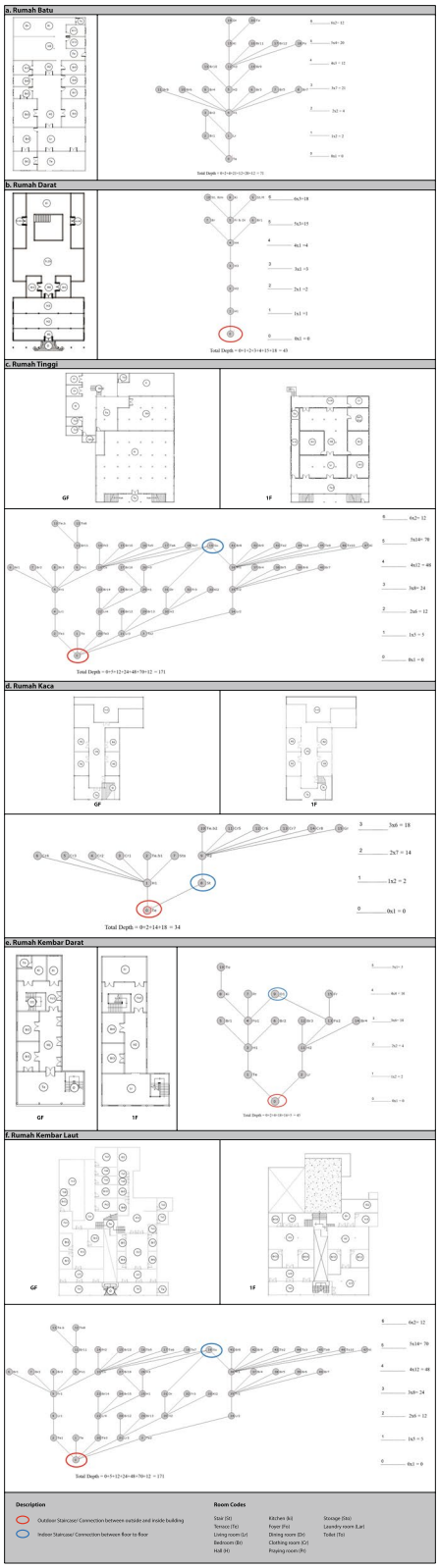


Table 4 (continued)

Outdoor Staircase/ Connection between outside and inside building

Indoor Staircase/ Connection between floor to floor

creates a map of visual fields at points within a building's layout plan. In visual graph analysis, grid points are overlaid on the plan, and each point is connected to every other point (Turner 2004). The related theory was developed by Hillier and Hanson in 1984 to analyse spatial organisation in buildings and settlements. According to this theory, spatial and social forms are closely related to a certain spatial configuration and several social patterns (Hillier 1996). This technique facilitates integrative analysis (Turner et al. 2001) in the built environment through the calculation and measurement of the intervisibility of distributed locations in the entire environment to describe the spatial characteristics of that environment. This kind of statistical analysis can be used to measure the spatial syntax in variance and correlation analysis in two parameters, namely, connectivity and visual integration analysis (Table 5). This analyses the extent to which any points in the spatial network are visible from any others, and subsequently, the points as the calculated nodes are visibility relationships. These features could generate an understanding of navigation, behaviour, and spatial experience (Conroy-Dalton 2003; Wiener and Franz 2005; Alitajer and Molavi Nojoumi 2016).

These results will be compared with the aforementioned analysis to identify the differences in the relationships among the spatial structures of the buildings and the various behavioural patterns in these six buildings through colour coding with numerical results. Thus, the spatial function of traditional buildings is a set of spatial relationship decoding processes. This exploration is applied to space syntax for decoding the spatial configuration as reflecting the measurement of the visibility relationships among spaces and identifying the visibility at every angle of this layout. When the colour is close to red, the space is highly visible, and when the colour is close to blue, the space visibility is low, which reveals more private rooms (Asriana et al. 2023).

This method is applied to investigate and reveal the syntactical and morphological characteristics of six traditional houses built by participatory Arabic communities in Kampung Al Munawar 13 Ulu. This method also supports conceptual thinking, especially learning about the architectural design process from communities at the early stage. Connectivity and visual integration represent the measurement of releasing pedestrians or dwellers into the environment and the assessment of visual accessibility from their current spatial location, which informs their choice of

Table 5 The graph analysis measurement, including connectivity, visual integration, and the relationship between those features (R^2) (Source: the authors)

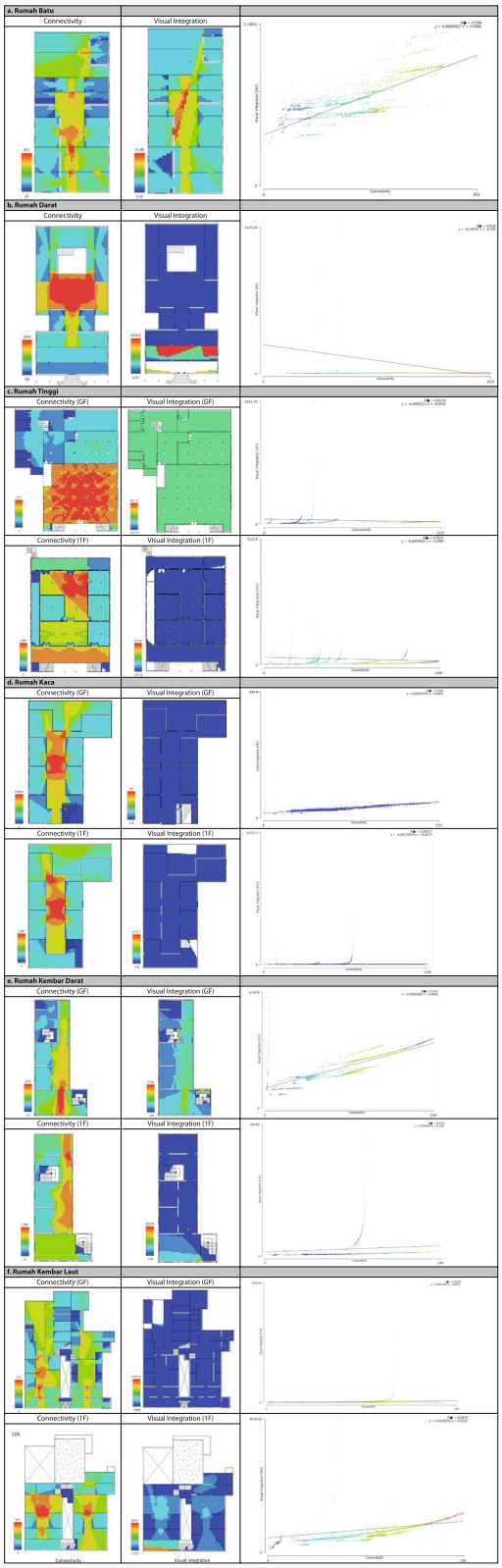


Table 5 (continued)

A colour being close to red indicates that area shows a high index of connectivity, integration, and accessibility

A colour being close to green and yellow indicates that area depicts moderate spatial connectivity, integration, and accessibility

A colour being close to blue indicates that area signifies low connectivity, integration, and accessibility

next destination (Turner et al. 2017) according to their movement pattern and visual perspective.

The graph analysis comprises two aspects: colour graph results (Table 5) and statistical graph results (Table 8). First, the colour graph for connectivity and visual integration (Table 5) is blue, which defines spaces that are more private than those that appear red. Second, the calculation of this graph refers to scatterplot data, which identify the relationships and correlations between two aspects: connectivity and visual integration [HH]. This relationship measures the intelligibility and understandability concept, the R^2 value, of the functional rooms in this building's layout. If the spatial organisation has an R^2 value higher than 0.5, the spaces are understandable and intelligible in the whole system of spatial organisation. In addition, a blue scatterplot indicates poor accessibility and low distribution, indicating unintelligible spaces or environments.

Table 5 compares information about connectivity, visual integration and intelligibility as consequences of the relationship between connectivity and visual integration. Through experimentation, this graph analysis could identify an exploration of sociospatial properties (Behbahani et al. 2017), spatial experience, and spatial distribution and describe spatial configurations regarding accessibility and visibility (Asriana et al. 2023). This graph effectively represents the spatial structure and its effect on social function in architectural spaces. The index level and colour code define which spaces or rooms are more visible or invisible at every angle. On the ground floor (GF), the rooms depict a wide variety of colour codes that reveal the rooms as more connected, accessible and visible to visitors. In contrast, the colour code of the building's first floor (1F) is close to blue, which means that the room has low accessibility in terms of visibility and connectivity. The relationship between connectivity and visibility leads to an intelligibility and understanding of the spatial layout of these traditional dwellings. However, Zerouati and Bellal (2020) have argued that connectivity and integration measurements reveal important indicators of social activities. However, social interaction increases in less connected areas, more closed spaces, and more adjoining spaces (Zerouati and Bellal 2020).

4 Results and discussion

The six traditional houses in the Arabic Kampung Al Munawar 13 Ulu are examples of historical architecture adapted from the traditional houses of Palembang '*Rumah Limas*'. According to the syntactical analysis (Table 6), four traditional buildings in this kampung, *Rumah Batu, Rumah Darat, Rumah Tinggi* and *Rumah Kembar Laut, have the highest step depths (SD) at 6*. However, *Rumah Kaca* had the lowest SD, at 3. Thus, it is determined that *Rumah Kaca* has the shortest distance in flow to a place from the entrance, while *Rumah Batu, Rumah Darat, Rumah Tinggi* and *Rumah Kembar Laut* have the longest distances to pass through the space. In addition, this analysis generates the total depth (TD), the number of links (L) and the number of nodes (K), where these features lead to statistical results (Table 6). *Rumah Darat* has the smallest number of links and nodes at 10, while *Rumah Kembar Laut* has the greatest number of links (L) and nodes (K) of rooms at 52 and 47, respectively.

In this abstraction process (Table 6), the basis data for simulating the calculation of the space syntax ratios, including the SLR, total depth (TD), base difference factor (H) and relative difference factor (H*), are extracted. Among the traditional buildings, *Rumah Kembar Laut* has the highest index of TD at 171, which means that the functional rooms in this house have the most unreachable steps, and the structural types are the most undistributed and unresponsive. In contrast, *Rumah Kaca* has the lowest TD of 34 among the other houses, which means that the functional rooms have the most accessible steps, and the structural types are more open than those of other traditional buildings. *Rumah Kaca* has previously been renovated into a school, which is why event spaces are now accessible via fewer steps. However, the other buildings have more steps. They are accessible because they are still dwellings. This transformation illustrates the adaptive architectural modifications in response to how these buildings are used and who uses them.

The base difference factor (H) measures the entropy index related to the spatial distribution in terms of spatial depth and analyses the permeability of buildings in spatial structures (Hillier et al. 1987). *Rumah Darat* has the highest index of the base difference factor (H) at 0.58, which reveals that the maximum index of entropy value is the most difficult it is to reach other spaces in the spatial layout, but the rooms are more distributed in terms of depth compared to *Rumah Kembar Laut*, which shows the lowest index of the base difference factor (H) at 0.23. *Rumah Kembar Laut* also has a value closer to 0 for the base difference factor (H) compared to the others. This means that the spatial organisations in this house are more structured with differentiated space. In contrast, *Rumah Darat* has an index closer to 1, which means that the space has equal integration value and is more homogenised.

Rumah Darat also has the largest index of the relative difference factor (H*) at -0.26, and *Rumah Kembar* Laut has the smallest index of the relative factor at -1.12. The minimum index of (H*) might indicate a greater degree of differentiation or rigid hierarchy in *Rumah Kembar Laut*. In contrast, *Rumah Darat* has the maximum index of relative difference factor (H*) that might reflect a homogeneous or decentralised flexible hierarchy.

According to other findings, all these traditional buildings have an SLR index greater than 1, indicating a high degree of ringy structure and greater distribution. Moreover, all these traditional buildings reflect the combination types of spatial link shapes, including combinations of arborescent trees, arborescent bushes, and single rings (Table 7). Compared with other buildings, *Rumah Tinggi* and *Rumah Kembar Laut* exhibit a significant number of combinations of arborescent trees, arborescent bushes and single rings. These traditional buildings depict a combination of spatial hierarchy and configurational permeability. Moreover, only *Rumah Kaca* has an arborescent bush in the spatial link shape type, meaning that its spatial layout is more of a hierarchical space than other buildings.

Table 6 The degree of syntactical analysis in traditional buildings, Kampung Al Munawar 13 Ulu

Name of houses	Room	Room Rank	Number Depth	Total Depth (TD)	L	K	SLR	MD	*i* Min	*i* Mean	*i* Max	(H)	(H*)
Rumah Batu	Hall 1	4	6	71	21	20	1,10	3,17	2,79	4,76	9,04	0,39	-0,72
Rumah Darat	Hall 4	4	6	43	10	10	1,10	2,87	1,36	2,71	5,00	0,58	-0,26
Rumah Tinggi	Foyer	3	6	75	24	22	1,14	3,67	2,85	4,07	5,63	0,38	-0,75
Rumah Kaca	Stair (So)	1	3	34	15	15	1,07	3,08	0,18	0,29	0,33	0,45	-0,59
Rumah Kembar Darat	Foyer 1	4	5	45	16	15	1,13	3,15	2,28	3,43	5,25	0,47	-0,53
Rumah Kembar Laut	Stair (Su)	5	6	171	51	47	1,11	4,29	4,43	7,29	12,71	0,23	-1,12
Min				34	10	10	1,07	2,87	0,18	0,29	0,33	0,23	-1,12
Max				171	51	47	1,14	4,29	4,43	7,29	12,71	0,58	-0,26

Table 7 The types of spatial link shapes and topologies of spatial structures

Name of Houses	Type of Spatial Link Shape	Topology of Spatial Structures
Rumah Batu	Combination of arborescent bush and ring single	Combination of *a-structure, b-structure,* and *c-structure*
Rumah Darat	Combination of arborescent tree and arborescent bush	Combination of *a-structure* and *b-structure*
Rumah Tinggi	Combination of arborescent tree, arborescent bush, and ring single	Combination of *a-structure, b-structure,* and *c-structure*
Rumah Kaca	Arborescent bush	Combination of *a-structure* and *b-structure*
Rumah Kembar Darat	Combination of arborescent tree, and ring single	Combination of *a-structure, b-structure,* and *c-structure*
Rumah Kembar laut	Combination of arborescent tree, arborescent bush, and ring single	Combination of *a-structure, b-structure,* and *c-structure*

As shown in Table 7, all these traditional buildings consist of an *a-structure* and *b-structure* in the context of topological spatial structures, especially *Rumah Darat* and *Rumah Kaca*. The feature of the *a-structure* represents high integration and high local choice. It affects the concept of movement, which is more stasis and generates the concept of socialism in long models. Moreover, the feature of the *b-structure* defines low integration and low local choice, and the movement concept is more axial and generates long models of social concept distances. Other buildings, *Rumah Batu, Rumah Tinggi, Rumah Kembar Darat and Rumah Kembar Laut,* consist of combinations of *a-structures, b-structures, and c-structures*. The feature of the *c-structure* determines low integration and low local choice with the spatial movement in making routes; also, this structure type generates social concepts in short models' access.

In Table 8, *Rumah Batu* shows $R^2 = 0.558$. This value is the highest R^2 value (the correlation between connectivity and visual integration [HH]) compared to that of other buildings. This indicates that *Rumah Batu* is more intelligible and understandable, more visible and more permeable in spatial organisation compared to the other sampled buildings. *Rumah Darat* and *Rumah Kembar Darat* also reveal $R^2 = 0.520$ and $R^2 = 0.541$, respectively. This means that these houses likely have intelligible and understandable layouts. The colour code in *Rumah Batu* (Table 5) has diverse colours, which means that the spaces are highly accessible and well distributed throughout the whole system, among other buildings. Approximately 10% of the community is concerned with designing intelligible layouts. In contrast, *Rumah Kembar Laut* has the lowest index of $R^2 = 0.013$ (the correlation between connectivity and visual integration [HH]). This means that *Rumah Kembar Laut* is highly invisible, more interrupted and segregated, it is easier to get lost in this building, and it is difficult to redirect to other spaces. Additionally, the colour code has diverse colours, but only in a specific area. This shows that the spaces are poorly distributed and poorly accessible in a whole system.

The following is the conclusion of the syntactical study (Table 9) that compares and interrelates the statistical and graph analysis with minimum and maximum results. This study explored syntactical analysis to measure the basic rules of spatial-morphological configurations to reveal the identity of sociospatial structuring in

Table 8 The calculation of graph analysis, including connectivity, visual integration, and relationships

Name of Houses	Connectivity		Visual Integration		R^2 Value	R^2 Value (Conversion)
	min	max	min	max		
Rumah Batu	21	853	2.94	11.60	0.558	25%
Rumah Darat	182	2619	6.36	6579.24	0.520	23%
Rumah Tinggi (GF)	1	1157	1911.73	1911.73	0.014	1%
Rumah Tinggi (1F)	9	1690	477.12	3131.80	0.023	1%
Rumah Kaca (GF)	4	1584.83	4.22	139.00	0.434	19%
Rumah Kaca (1F)	4	3108	3.44	1373.70	0.071	3%
Rumah Kembar Darat (GF)	21	2329	3.09	27.06	0.541	24%
Rumah Kembar Darat (1F)	23	1780	3.98	650.08	0.013	1%
Rumah Kembar Laut (GF)	4	979	0.968	4545.44	0.013	1%
Rumah Kembar Laut (1F)	1	959	1.923	80.81	0.047	2%
Min	1	853	0.968	11.60	0.013	1%
Max	182	3108	1911.73	6579.24	0.558	25%
Average						10%

Table 9 Comparing the syntactical results of traditional buildings

Name of Houses	Syntactical Study						
	Statistical Analysis						Graph Analysis
	Depth (D)	Space Link Ratio (SLR)	Base different factor (H)	Relative different factor (H*)	Space Link Shape	Spatial Structures	R^2 Value
Rumah Batu	The highest depth reveals the longest distance to pass the space	Index SLR > 1, it presents a high degree of ringy structure and more distributed	--	--	arborescent bush ring single	a, b, c, structures determine low integration and low local choice with the spatial movement in making route, also this structure type generates social concepts in short models' accesses	The highest index of $R^2 = 0.558$ value defines highly more intelligible and understandable, more visible, and more permeable in the spatial organisation
Rumah Darat			The highest index of H; the maximum index of entropy is the most permeable on the spatial structure	The highest index of H*; homogeneity or decent flexibility hierarchy	arborescent tree arborescent bush	a, b structures	--
Rumah Tinggi			--	--	arborescent tree arborescent bush ring single	a, b, c, structures determine low integration and low local choice with the spatial movement in making route, also this structure type generates social concepts in short models' accesses	
Rumah Kaca	The lowest depth presents the shortest distance to pass the space				arborescent bush	a, b structures	
Rumah Kembar Darat					arborescent tree ring single	a, b, c, structures determine low integration and low local choice with the spatial movement in making route, also this structure type generates social concepts in short models' accesses	The lowest index of $R^2 = 0.013$ defines highly more unintelligible, more invisible, more interrupted, easier getting lost, and hardly effort to redirect to other spaces
Rumah Kembar laut	The highest depth reveals the longest distance to pass the space		The lowest index of H; the minimum index of entropy is the most impermeable on spatial structure	The lowest index of (H*) might indicate a higher degree of differentiation or rigid hierarchy	arborescent tree arborescent bush ring single		

this kampung settlement. *First*, the results of the statistical analysis include the abstraction decoding of spatial configuration, space link shape and topological spatial structures, such as total depth (TD), the SLR, the base difference factor (H), the relative difference factor (H*), the space link shape and spatial structures. The comparison results show that there is a similarity in layout and closeness typology in the statistical analysis features among these six traditional dwellers. Thus, all traditional buildings in Kampung Al Munawar 13 Ulu have an SLR degree index higher than 1, representing the spatial link shape. This demonstrates that their spatial organisations are ringy space and more distributed, as well as social concepts and spatial movement forms. *Second,* there is the result of graph analysis of connectivity, visual integration and the relationships between those features, which is called the intelligibility space. These comparison results are represented by R^2 *values,* and only *Rumah Batu* seems to have the highest R^2 *value.* This house has a more intelligible layout plan that is more understandable, visible and permeable than those of the other five houses. *Third*, based on functional buildings, *Rumah Kaca* has transformed into a school as a public facility in this kampung. This reveals that this house has fewer steps to create a short distance for easy access by users compared to other buildings as main dwellings with more steps to separate public and private functional rooms. Functional buildings play a significant role in shaping the sociocultural community and controlling spaces for social gatherings, religious activities and community events. Therefore, examining syntactical studies, functional attributes, community social behaviour, religious beliefs, valuable context, and cultural practices within this built environment can elucidate the cultural significance of traditional houses in shaping the everyday lives of dwellers and community identity.

5 Conclusion

All of the aforementioned methods are considered novel for extracting spatial characteristics based on syntactical analysis through space syntax in the selected traditional houses, which were built by an Arabic community in an urban kampung settlement in Palembang, Indonesia. These six buildings have a fundamental characteristic, especially the concept of privacy, since Muslim refers to segregation between males and females, except as 'mahram'. Thus, for constructing the spatial layouts of traditional buildings in this kampung, the spatial hierarchy was considered and highlighted in a formal rule-based manner, resulting in the pattern language of architecture in these traditional Arabic buildings, Kampung Al Munawar 13 Ulu. Another finding shows that the first constructed house is *Rumah Batu,* which was built for the first leader of Arabic communities in this kampung. The spatial organisation in this house was highly understandable, more visible and more permeable than those of the other five sampled buildings. Experiments using syntactical analysis in these traditional buildings could define public and private rooms. The public rooms are likely located in the first or the second depth in the spatial organisation and positioned on the flexible looped parts of the graph, while private rooms are likely located in the fifth or sixth depth, which means more controlled and hierarchical sections. Noticeably, the Hall or Terrace or '*Kijing*' in Arabic Kampung Al Munawar 13 Ulu serves as an assemblage room to control and distribute users and activities to other rooms. It could also be highlighted as a transitional space between public and private rooms.

This research focused only on the Arabic Kampung Al Munawar 13 Ulu, which is located in the riverfront settlement and southern part of the Ulu area of Palembang city. Addressing this study's limitations, such as data availability constraints and methodological challenges, will be important for refining the approach and advancing the field of heritage conservation and other studies. This analysis enables us to recognise the layout and spatial organisation of traditional houses as a guide and offers valuable lessons for architects or heritage practitioners in the preservation and adaptive reuse of traditional buildings.

Through syntactical analysis, this study has gained valuable insights into the spatial characteristics and organisational rules of traditional houses in the urban kampung settlement. Additionally, this study highlighted the intricate relationships among spatial configurations, social dynamics, tradition, geographic regions and cultural practices within this settlement. Therefore, by assessing traditional house design through the lens of syntactical study and space syntax theory, this study identified patterns and spatial characteristics, including spatial layouts, spatial use, spatial rules and spatial hierarchy, to understand the significant sociocultural shaping of everyday life in the built environment.

Furthermore, there is potential for further research and for understanding other constructive rule-based forms of traditional houses in other urban kampung settlements. For instance, this research could compare other spatial organisations of traditional buildings in the 'Ilir area' in Palembang or other kampungs with a distinctive community in regions worldwide. This study highlights the potential for space syntax as a tool for evaluating traditional house design and heritage conservation efforts by integrating spatial analysis techniques with qualitative assessments. This can be developed by architects or stakeholders to develop strategies for sustainable conservation practices by involving the community to meet their needs. Then,

a comprehensive framework for preserving and assessing traditional architecture can be developed in a culturally sensitive way. Moreover, this study reveals a clear link between tangible and intangible heritage in the interconnectedness of physical structures with cultural practices, traditions and memories. By determining and learning how spatial configurations affect social behaviours and cultural practices within the kampung environment, this research represents how tangible and intangible aspects are linked holistically and naturally. This study provides the following insights for future research to create, adapt, and preserve the value of traditional buildings both intangibly and tangibly through spatial characteristic extraction in other kampungs or other built environments.

This syntactical study of statistical and graphical features reimagines existing space syntax theories and paves the way for deconstructing the correlation between spatial configuration and sociospatial structures through the spatial layout of houses or other buildings. In this sense, this study contributed to determining the broader basic rules of spatial organisation and identified the types of sociospatial structures in buildings and built environments that affect users, particularly regarding spatial distribution activities, movement flows, and other social phenomena. This approach provides practical and tangible advantages for building preservation but also potentially alters the way in which buildings are perceived in other built environments.

Abbreviations

D	Depth
SD	Step depth
MD	Mean Depth
TD	Total depth
H	Base Different Factor
H*	Relative difference factor
SLR	Spatial Link Ratio
L	Number of lines of the link between spaces in graph
K	Number of spaces in the system
RA	Relative asymmetry
RRA	Real Relative Asymmetry
a	Max RA
b	Mean RA
c	Min RA
t	a + b + c (Max RA + Mean RA + Min RA)
i	Integration
i_{min}	Integration minimum
i_{mean}	Integration mean
i_{max}	Integration maximum
ln	Natural logarithm
R^2	Intelligibility (relationship between connectivity and visibility)
HH	Visual Integration [Hillier and Hanson]
GF	Ground Floor
1F	First Floor
O	Outside/Outdoor Staircase
St	Staircase
Te	Terrace
Te. f	Terrace (front)
Te. s	Terrace (side)
Te. b	Terrace (back)
Lr	Living room
Br	Bedroom
H	Hall
Ki	Kitchen
Fo	Foyer
Dr	Dining room
Fr	Family room
Gr	Guest room
Ic	Inner court
Cr	Clothing room
Pr	Praying room
Sto	Storage
St. Wm	Storage for Women
St. M	Storage for Men
Su	Indoor Staircase
Lau.r	Laundry room
To/Toi	Toilet

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Authors' contributions
Nova Asriana: Conceptualisation, Investigation, Methodology, Software, Visualisation, Writing – original draft, Funding acquisition. Rendy Perdana Khidmat: Conceptualisation, Methodology, Writing – review and editing. Meldo Andi Jaya: Methodology, Investigation, Writing – review and editing. Verarisa Anastasia Ujung: Writing – review and editing. Widi Dwi Satria: Writing – review and editing. Riza Andriani: Methodology, Writing – review and editing. All author(s) read and approved the final manuscript.

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