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Analyzing the Role of Intermediate Spaces in the Spatial Legibility of Traditional Iranian Houses with an Emphasis on Vitality Using Space Syntax Method Case Study: Borujerdi House, Kashan

Mohammad Mohajer[1], Sindokht Rezaei Lipae[2,*] iD

[1] Islamic Azad University, Rasht Branch, Rasht, Gilan, Iran; moh.moh.arch@gmail.com.

[2] Jihad Daneshgahi Institute of Higher Education, Rasht, Gilan, Iran; sindokht-rl@yahoo.com.

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Abstract

With the decline of these spaces in contemporary housing, structural legibility and related environmental qualities have diminished. This paper aims to quantitatively explain the role of intermediate spaces in shaping spatial legibility and their impact on the potential for vibrancy in traditional Iranian architecture. The main research question is how the elimination of intermediate spaces weakens legibility and vibrancy by affecting spatial configuration. To address this question, the Space Syntax method and Depthmap software were employed to analyze the Borujerdi House in Kashan under two conditions: with and without intermediate spaces. Findings revealed a significant decline in key indicators following the removal of these spaces: the mean Integration dropped from 7.19 to 2.42, while the Mean Depth increased from 0.237 to 0.435. More importantly, the correlation coefficient between Connectivity and Integration (R^2), representing spatial legibility, decreased from 0.906 (highly legible) to 0.582 (moderately legible). The results confirm that intermediate spaces, by significantly enhancing structural legibility, contribute to spatial intelligibility and strengthen key components of vibrancy through improved accessibility and visual control. These findings highlight the need to revitalize the organizational logic of such spaces in contemporary architecture.

Keywords: Intermediate space, Space syntax, Spatial legibility, Vibrancy, Traditional Iranian architecture.

1|Introduction

The quality of the built environment has always been a primary concern for architects and urban planners. Among the various aspects of spatial experience, spatial legibility—that is, the ability of a space to be understood and to form a coherent mental map—plays a fundamental role [1]. Legible environments facilitate

Analyzing the role of intermediate spaces in the spatial legibility of traditional...

312

orientation and encourage movement, thus creating favorable conditions for increased social interactions and, ultimately, vibrancy.

Robert Cowan [2], in The Dictionary of Urbanism, defines vibrancy as a place's suitability for living and its ability to provide a desirable quality of life. John Ross, the head of the UK Commission for Architecture and the Built Environment, argues that instead of the term livability, the expression quality of life should be used when referring to vibrancy. He defines vibrancy as the quality of life as perceived and experienced by people within urban spaces. In other words, beyond being an ultimate goal, vibrancy has become a strategic tool for cities competing globally to attract more investment, talent, and international attention—enhancing their competitiveness and helping them realize their desired visions.

In traditional Iranian architecture, spatial legibility was not achieved through simplicity but through a complex, hierarchical spatial organization. Intermediate spaces—such as entrances, vestibules (hashti), corridors, and verandas (iwan)—functioned as intelligent thresholds that not only defined boundaries but also enhanced legibility and comprehension of the spatial whole by controlling movement and visibility. Consequently, they contributed to the cultural identity of space.

In the historical fabric of Iranian cities, connecting or transitional spaces with diverse forms, functions, and meanings served as crucial links that unified architectural and urban elements under a single identity. Such spaces, due to their generative purpose, possessed a dual nature—both as a process and as a product. The intermediate space simultaneously structured spatial form and guided the differentiation and orientation of meanings, ultimately leading to a unified spatial whole [3].

From birth to death, the house is the first and most enduring spatial environment that surrounds the human being. The architectural space of a house serves as a container for human activities and maintains an inseparable relationship with human life. The traditional Iranian house, much like the traditional human, possesses both an outer appearance and an inner essence, symbolically expressed. Its visible form consists of functional spaces and geometric order, while its inner essence reflects a higher truth rooted in human nature. Part of this visible form consists of intermediate spaces endowed with profound symbolic and semantic value [4].

This study aims to analyze the spatial organization of traditional Iranian houses using the Space Syntax method and the Depthmap software to assess their legibility and, consequently, their spatial vibrancy. The study tests the hypothesis that intermediate spaces, through their influence on spatial configuration, affect both the legibility and vibrancy of traditional Iranian houses.

1.1 | Problem Statement

A house is the place where one resides to achieve tranquility. This definition, emphasizing moral and human dimensions, makes the act of designing a house profoundly complex—since it regards the house as a means for human growth, transcendence, and peace. The difference between a house and a mere shelter or dormitory lies in the presence of such humanistic and spiritual qualities. Traditional Iranian houses, as part of the nation's architectural heritage, were designed to meet both material and spiritual needs [4].

Like the traditional human being, the traditional house has both an external form and an internal essence, expressed symbolically. The external form is represented in functional spaces and geometry, while the inner essence is rooted in an innate higher truth. Intermediate spaces—such as entrances, vestibules, corridors, courtyards, verandas, and arcades—constitute part of this external form and carry deep symbolic and semantic meanings [4].

In Theories of Architecture, Capon introduces form, function, and meaning as the three essential characteristics of architectural space. Accordingly, transitional spaces, while possessing spatial form and meaning, also gain value from other dimensions.

313

Mohajer and Rezaei Lipae | Arch. Dim. Bey. 2(4) (2025) 311-327

The integration of these three aspects leads to the definition of the third space—the intermediate space—which:

    I.   is enclosed based on physical boundaries that define limits (morphological dimension).

    II.   becomes a focal point for meaning (semantic dimension).

    III.   serves as a site for interaction (functional-communicative dimension).

In other words, the characteristics of intermediate spaces in spatial organization can be summarized as follows:

    I.   Contrast (morphological/physical aspect): represented in Space Syntax analysis by the creation of depth and spatial separation.

    II.   Interaction (functional/communicative aspect): measured through the Integration index, indicating potential for encounters and interaction.

    III.   Understanding (semantic aspect): a qualitative attribute resulting from the balance of separation and integration, making a space legible and intelligible.

Altogether, these characteristics demonstrate the essential role of intermediate spaces in shaping architectural identity by directly influencing spatial organization. In the theoretical model of this study, the concentration of meaning, functional interaction, and formal distinction, enclosed by a threshold that connects the interior and exterior, defines this role.

Intermediate spaces, with their dual nature of connection and separation, function both as process and product. They help form surrounding spaces and simultaneously structure the concepts of contrast, interaction, and understanding. Beyond defining and controlling boundaries and ownership, these spaces also mediate the reception, interpretation, and transmission of spatial information—acting as transitional agents that determine the structural order through organizing principles such as spatial hierarchy.

Therefore, any reduction or elimination of the intermediate space inevitably disrupts spatial organization, leading to identity crises within architectural ensembles.

With the gradual disappearance of intermediate spaces in contemporary residential architecture, spatial quality and vibrancy have declined. One main reason for this deterioration appears to be the loss of structural legibility that these spaces once provided. This study proposes that the value of intermediate spaces extends beyond symbolic or sensory dimensions—it lies in a measurable and powerful configurational logic. Hence, the main problem of this research is to quantitatively and qualitatively explain this process through the following questions:

    I.   What specific impact does the removal of intermediate spaces have on key spatial configuration indicators (Integration, Depth, and Connectivity) in the Borujerdi House?

    II.   How does this affect the level of spatial legibility (measured by the R^2 correlation coefficient)?

    III.   What is the relationship between the decline in legibility and the reduction in vibrancy potential (measured by accessibility and visual connectivity indicators)?

1.2 | Significance and Necessity of the Study

Vibrancy is one of the key spatial qualities discussed by theorists such as Kevin Lynch in The Theory of Good City Form and Ian Bentley et al. in Responsive Environments. One of the main challenges of the third millennium in achieving sustainable urban living is creating truly livable cities.

Although vibrancy is not a new concept—it has existed since the emergence of cities and local communities—the negative consequences of neglecting qualitative aspects in urban planning have made its importance increasingly evident. In urban design literature, vibrancy is regarded as one of the desirable qualities of life that significantly contributes to the social cohesion of citizens.

In everyday life, the rapid pace of urbanization has created numerous tensions for today's citizens, resulting in a decline in urban vibrancy. Consequently, promoting vibrancy has become a central goal in many urban development plans and vision documents. Today, for various reasons, achieving urban liveliness and vitality is a primary concern for urban management systems, particularly in developing countries.

Enhancing vibrancy and encouraging greater public presence in urban spaces not only improves the city's quality but also positively affects its citizens' social well-being. Strengthening vibrancy fosters a stronger sense of place among residents, encouraging their active participation in urban life—an essential condition for achieving long-term urban goals. Therefore, promoting vibrancy at both the urban and neighborhood levels has emerged as a key paradigm in contemporary urban planning [5].

1.3 | Research Objectives

To develop a structured and applicable body of knowledge addressing new housing needs through the rich architectural concepts embedded in the intermediate spaces of traditional Iranian houses, the following objectives are pursued in this research:

General objective

To uncover the latent semantic and symbolic values of intermediate spaces in traditional Iranian houses and to apply these principles in contemporary housing design, thereby reviving their lost identity.

Specific objectives

I. To identify the role of intermediate spaces in the spatial organization and identity formation of traditional houses.

II. To examine the impact of intermediate spaces on variables influencing spatial vibrancy.

III. To develop methods for transferring and adapting the fundamental concepts of intermediate spaces from traditional houses to contemporary housing models to help revive architectural identity.

1.4 | Research Methodology

This research is applied in its purpose and descriptive–analytical in nature, adopting a quantitative approach. The study employs the Space Syntax method for spatial structure analysis.

The statistical population consists of exemplary traditional Iranian houses located in hot and arid climates. The Borujerdi House in Kashan was selected as the case study due to its spatial richness and abundance of intermediate spaces.

The analysis process was carried out in three main stages:

Modeling

The plan of the Borujerdi House was first converted into a Justified Graph representation under two scenarios:

I. The original state, including all intermediate spaces (entrance, vestibule, corridor, verandas, etc.).

II. A hypothetical state where intermediate spaces were removed and direct connections between spaces were created.

Computation

Using DepthmapX software, key spatial configuration indices were calculated for both scenarios, including:

I. Integration (HH): Measures how easily a space can be reached from all other spaces in the system; higher values indicate greater centrality and accessibility.

II. Depth: Represents the average number of steps required to reach all other spaces from a given one; it has an inverse relationship with Integration.

315

Mohajer and Rezaei Lipae | Arch. Dim. Bey. 2(4) (2025) 311-327

III. Connectivity: The number of spaces directly connected to a given space (a local indicator).

IV. Legibility (R^2): Determined by calculating the correlation coefficient (R^2) between Connectivity and Integration across all spaces; a value close to 1 indicates a highly legible system where local perception aligns with global structure.

Comparative Analysis

Finally, the numerical and graphical results of both scenarios were compared to objectively evaluate the effect of removing intermediate spaces on the above indices, particularly spatial legibility.

1.5 | Literature Review

The concept of the house has long been one of the most critical subjects of architectural studies worldwide. Numerous studies, books, and articles have explored the notions of dwelling and traditional housing design. While some of these sources briefly refer to intermediate spaces, few have provided a detailed and comprehensive analysis of the subject.

The following table (not included here) summarizes several of the most significant studies and research projects related to traditional houses and limited investigations concerning intermediate spaces, arranged chronologically by publication date.

Table 1. Published research papers and projects in the field of traditional houses and intermediate spaces.

Author(s)	Title of Research Work	Key Findings/Results
Masaeli [6]	The hidden map as a manifestation of religious beliefs in traditional desert housing of Iran	The inner essence of traditional housing cannot be compared with physical or quantitative architectural parameters; its evaluation is based on spiritual principles rooted in religion and human perfection. Religious beliefs shape traditional housing and comprise two maps: a visible one based on functional needs and a hidden one arising from innate religious desires and the architect's subconscious awareness.
Motadayen [7]	Between inside and outside: the role of connecting elements in iranian urban gardens	Continuity, interpenetration, and the blending of Iranian garden spaces with the city emerge through visual and sensory relationships as well as physical characteristics. The boundary spaces between garden and city act as zones of social interaction and as points of connection between government and community.
Akhavat et al. [8]	Rediscovering spiritual concepts of dwelling in traditional desert housing	Traditional housing responds to both the physical and spiritual needs of humans. Islamic concepts are embedded within its structure. Because it satisfies the innate human desire for perfection, traditional housing forms an intimate relationship with its inhabitants. The spiritual dimensions of housing are more significant than its physical aspects.
Belilan et al. [9]	The role of intermediate space in identity formation of historical urban fabrics in iran	Intermediate spaces organize architectural and urban elements through spatial continuity, hierarchy, and definition of public–private realms. They possess a dual nature—both process and product—and play a critical yet often hidden role in preventing identity crises in architecture and urban design.

Table 1. Continued.

Valizadeh Oghani and Valizadeh Oghani [10]	Hospitality and its manifestation in the spatial structure of traditional iranian houses	The principle of hospitality is clearly expressed in traditional Iranian houses through spatial features such as entrances, vestibules, courtyards, and reception rooms.
Moeini [11]	Reinterpreting qualitative principles of housing in relation to nature from the perspective of the islamic worldview	In the Iranian–Islamic worldview, housing is shaped by spiritual and philosophical principles. Four foundational values—originality, unity, meaning, and humanity—create harmony between nature, residential space, and human needs.
Taheri [12]	Rethinking the concept of dwelling in architecture	Since dwelling originates within the human psyche, only environments of a similar nature can provide true habitation. Dwelling exists between the spiritual and earthly states, representing a continuous transition from the sensory to the imaginative realms through symbolic dualities, as discussed by Jung and various religions.
Asafi and Imani [13]	Recognizing Islamic architectural and urban values in housing and their application to contemporary design	Housing reflects cultural and social traditions and should ensure physical, psychological, and social satisfaction. The physical form must also address meaning, as the concept of "home" extends far beyond its physical structure.
Rastjou et al. [14]	Manifestation of Islamic Thought in Iranian Architecture (Study of Justice in Iranian Houses)	By examining how justice and its derived principles are manifested in Iranian architecture, this study shows that Iranian houses—like religious buildings—are designed and organized according to Iranian–Islamic values and principles.
Daneshmand and Noghrehkar [15]	Entrance design based on threshold architecture principles	Contrary to common belief, thresholds encompass all spaces involved in the transition between areas. Four types of thresholds were identified: entry/exit, gathering, transitional, and external communication. The study classifies entrance characteristics into three threshold layers (familiarity, functional-contact, visual accessibility) and four Aristotelian causes (material, formal, efficient, final).

2|Introduction to the Social Logic of Space in Traditional Iranian Architecture

Traditional Iranian architecture is more than a collection of forms and ornaments—it is the manifestation of a social and cultural system embodied within spatial structure. In this architecture, space is not merely a neutral container but an active medium for social interaction, boundary definition, and the formation of both individual and collective identities.

One of the most crucial spatial–conceptual elements that enables this social logic is the "intermediate space." These spaces—situated between inside and outside, public and private realms, and among various functions—play a vital role in defining the legibility of spatial structure and, consequently, enhancing vibrancy.

This study employs the Space Syntax Theory to quantitatively and objectively analyze this role. The key concepts of this theoretical framework are explained below.

Space is a broad and perceptible concept. As Yazouski [16] states, "Space fills the entire universe and surrounds us throughout our lives; creating visual focus through contrast and differentiation frees the environment from monotony".

Spaces are generally categorized into three types: architectural, urban, and natural. Natural spaces include elements such as trees, shrubs, and the natural surface of the earth, and on a larger scale, the horizon, mountains, sky, and clouds. Hence, natural space can be considered a component of architectural space [17].

317

Mohajer and Rezaei Lipae | Arch. Dim. Bey. 2(4) (2025) 311-327

Table 2. Classification of architectural space [16].

Private Space: Spaces that are accessible only to specific individuals, such as residential houses within a city.

Public Space: Spaces that are open to everyone without any restrictions on entry or exit, such as streets and neighborhood pathways.

Semi-Private / Semi-Public Space: These spaces are primarily associated with apartment buildings and have both private and public aspects in terms of ownership. Due to their functional nature, they are not accessible to all neighborhood residents, for example, the courtyard within an apartment complex.

Open Space: Spaces that lack a roof and whose walls, if present, do not fully enclose the area. Open spaces are generally considered public or semi-public, though private balconies and courtyards are examples that remain private.

Enclosed Space: Refers to volumes or buildings that constitute the primary architectural elements.

Place: Refers to the ability of a space to evoke desirable mental images, shape collective memories, foster a sense of belonging, support continuity of habitation, and preserve these experiences over extended periods of time [18].

2.1|Intermediate Space: The Identity-Forming Joint of Traditional Architecture

2.1.1|Intermediate space

In the Dehkhoda Dictionary, the word "beyn" (between) is listed among antonyms and is defined as separation and connection, distinction and division between two things, and disjunction. The term can mean middle and can function as a noun or as a temporal or spatial adverb. Depending on the context, beyn can be synonymous with words such as connection, continuity, boundary, edge, wall, threshold, and consequently, relation.

It can be argued that, aside from some general definitions by a few sources or specialists, there is no precise definition of intermediate space. The lack of reliable research resources in this field has led to varying and sometimes contradictory definitions. In other words, the belief in the existence of a "third space" and its qualities is defined and interpreted according to perspective. However, what gives coherence and strength to the concept is the examination of the intermediate nature of space in its scope and extent. As Belilan (2011)[9] notes: "Space has always been considered an interdisciplinary concept, and architectural space is recognized as a dimension of space with holistic relationships to its other dimensions."

In the specialized architectural dictionary, intermediate is defined as: "A space that is constantly in motion; a place within itself; a limitation formed at the edge; the territory between two competing agents; ambiguous, wandering, striated, and indeterminate. Intermediate is not necessarily a space or a residual space. In a geometry with complex intermediate relationships, it becomes a stable place, a place whose geometry breathes in and out, a location of simultaneous ambiguities. Thus, the intermediate does not separate but always connects".

Bullenoff, regarding the separation of inside and outside, states: "This duality between inside and outside forms the basis of any spatial perception and can be traced throughout life. The tension between these two poles, their mutual relationship, and balance are necessary. Human inner well-being requires work to be conducted outside and rest within the home spaces".

Hillier and Hanson view relationships between interior and exterior spaces as based on social functions: "The most important result of the primary cell lies in the distinction between inside and outside, i.e., in the differentiation between the internal spaces of a building and collective external spaces. The distinction between inside and outside arises from differences in the way societies create and control individual and social interactions" [19].

In the Dehkhoda Dictionary, beyn is defined as "distance and separation" as well as "middle and intermediary," which clearly reflects the dual nature of this space: both separating and connecting. Despite the explanations above, there is no precise definition of this concept in architectural literature. However, it can be understood as a "threshold" or "transitional realm" that neither fully belongs to the first space nor entirely to the second—a space where the duality of inside and outside is challenged.

In traditional Iranian architecture (e.g., hashti, iwan, corridor, and courtyard), these spaces are not merely physical boundaries. Based on content analysis, three main characteristics can be attributed to them [9]:

 I. Contrast (Physical–Formal): Creating physical boundaries and defining distinct spatial realms.

 II. Understanding (Semantic–Perceptual): Preparing the user mentally to enter a new space and conveying cultural concepts such as invitation, privacy, and ritual.

 III. Interaction (Functional–Communicative): Providing a physical framework for social and communicative actions that are neither possible in fully public nor fully private spaces. Hillier (1996)[20] asserts that this type of spatial connection shapes space and gives it social meaning.

Through the intelligent management of transitions between realms, these spaces make the house's overall structure understandable and legible to both residents and guests.

In this model, semantic focus, functional interaction, and formal distinction indicate the containment of interior space by a threshold that allows communication and connection with the outside. Intermediate spaces, by aiming to connect and communicate and by embodying multiple concepts and meanings, acquire a dual nature: both a process and its product. In this way, they not only help shape surrounding spaces but also simultaneously guide and organize the concepts of contrast, interaction, and understanding.

Thus, a threshold, in addition to defining and controlling territory and ownership, is responsible for receiving, interpreting, transforming, and transmitting information. It functions as a separating, connecting, and linking agent through a transitional domain within spatial organization. This influence is realized through the determination of constituent elements, patterns of relationships, and hierarchical principles of spatial order. Therefore, if the influential role of intermediate space is diminished or weakened under any conditions, it directly leads to disruptions in the spatial organization of the complex, thereby causing an identity crisis within the architecture [21].

Table 3. Classification of intermediate spaces in traditional Iranian architecture based on the characteristics of intermediate space.

Physical–Formal	Semantic–Perceptual	Functional–Communicative
Bazaar	- Cholo-Khan - Hojre (shop units)	- Timcheh (covered bazaar sections) - Corridor - Square - Caravanserai - Charsoo (crossroads) - Rasteh (bazaar alley)
Intermediate and neighborhood spaces	Secondary passages: - Sabat (covered walkway) - Spatial expanses of squares in neighborhood centers - Entrance elements - Openings of entrance vestibules - Iwans in buildings - Dead-end alleys	Openings of entrance vestibules - Iwans in buildings
Residential unit	- Entrance portal - Corridor - Iwan - Hallway	- Hashti (vestibule)

319

Mohajer and Rezaei Lipae | Arch. Dim. Bey. 2(4) (2025) 311-327

2.2 | Space Syntax Theory and Spatial Legibility

Space Syntax theory, developed by Hillier and Hanson [19], is a method for analyzing the relationships between spaces within an architectural or urban configuration. This theory holds that space itself is a social agent, and its configuration directly affects patterns of movement, encounters, and social interactions [20]. Space Syntax analyzes the topological characteristics of space through quantitative indicators, primarily based on connectivity.

2.2.1 | Spatial legibility

The concept of legibility was initially introduced by Lynch [1] as "the ease with which the parts of a city can be recognized and organized into a coherent pattern." Hillier extended this concept from the urban to the architectural scale and defined it in measurable, quantitative terms. From the Space Syntax perspective, legibility refers to the degree of correlation between the local perception of a space and its overall position within the entire structure.

In this study, legibility is statistically measured using the correlation coefficient (R^2) between two primary Space Syntax indicators:

I. Connectivity: A local measure that counts the number of spaces directly connected to a given space [22]. This index represents an individual's initial perception of movement options within a space.

II. Integration: A global measure that assesses the depth of a space relative to all other spaces in a system [20]. This index indicates how accessible a space is within the entire system. Highly integrated spaces are central and easily reachable, with a high potential to attract movement and interaction. Integration is inversely related to Depth, which measures the average number of spatial steps needed to reach all other spaces from a given point.

A configuration is considered legible (R^2 approaching 1) if spaces that appear locally highly connected (high connectivity) are also central and accessible at the global scale (high integration). This alignment between local perception and overall structure allows users to easily navigate and comprehend the building's spatial logic [20], [22].

2.3 | Vibrancy: The Product of Legibility and Accessibility

In the Dehkhoda Dictionary, vibrancy is defined as being lively or animated. Physical desirability, the presence of diverse activities, security, psychological comfort, and the provision of more choices for engagement and cultural or social interactions all contribute to a suitable social life and neighborhood presence [23].

Vibrancy is a concept that extends beyond urban space and can be defined at both micro and macro scales. At the micro scale, it can be divided into physical and non-physical components, while at the macro scale, it encompasses spatial, cultural, economic, and social factors. Concepts such as justice, efficiency, adaptability, flexibility, and environmental quality are essential; according to [24] sustainable urban vibrancy leads to livability.

Vibrancy refers to more than the mere presence of people in a space; it encompasses dynamism, vitality, and continuous social interactions [23], [24]. Although primarily applied at the urban scale, its logic can also be examined at the architectural scale. In the built environment, vibrancy results from the combination of diverse activities, security, psychological comfort, and easy accessibility.

In this study, vibrancy is considered a direct product of a legible and efficient spatial structure. Based on the Space Syntax literature, two key indicators contribute to the potential vibrancy of a space:

I. Easy Accessibility: Spaces with high integration and low depth naturally attract more people because they are easier to reach. Accessibility is a prerequisite for activity and interaction [25].

II.   Visual Field Potential: The ability to see and be seen within a space, which enhances the sense of security and environmental awareness. This indicator can be measured using Visual Graph Analysis (VGA) and Visual Connectivity. Spaces with wider visual access to adjacent areas facilitate visual interactions and support vibrancy.
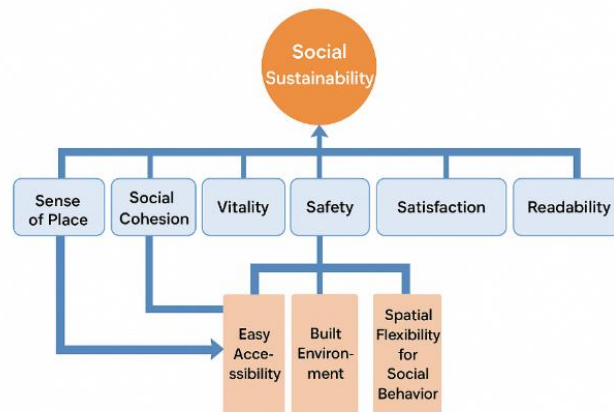

Fig. 1. Conceptual framework of vitality and readability as components of social sustainability.

3 | Operationalization of Concepts: From Configuration to Spatial Quality

This study aims to bridge the gap between quantitative analyses and qualitative concepts by defining the operational variables as follows:

Legibility

Based on Space Syntax theory, the legibility of a spatial system is measured through the correlation (R^2) between Connectivity (a local property counting the number of directly connected spaces) and Integration (a global property that measures the average depth of a space to all other spaces). A high correlation (close to 1) means that a user can infer the overall spatial structure (integration) from local visual information (connectivity), thus making the space "legible" [20].

Vibrancy

In this research, vibrancy is evaluated through two leading space syntax indicators:

Accessibility

This indicator is directly related to high integration and low spatial depth. Spaces with higher integration are generally more accessible and have greater potential to attract movement and activity [25].

Visual Field

This indicator is measured by Visual Connectivity, derived from Visibility Graph Analysis (VGA). High visual connectivity represents a broader field of vision from a single point, enhancing social surveillance and spatial awareness—key components of vibrancy [26].

4 | Research Method

After introducing the concept of intermediate space and defining spatial vibrancy and its components based on expert opinions and literature review, the *Space Syntax* method was employed for spatial analysis.

321

Mohajer and Rezaei Lipae | Arch. Dim. Bey. 2(4) (2025) 311-327

The software DepthmapX was used to analyze the spatial structure of the case study. First, the plan of the Boroujerdi House was divided into a set of Convex Spaces.

Then, two types of analyses were conducted

  I. Convex Space Analysis: To calculate topological indicators, including Integration, Mean Depth, and Connectivity.

  II. Visibility Graph Analysis (VGA) to calculate the Visual Connectivity index.

The analysis was carried out under two scenarios

  I. The first includes all spaces.

  II. The second step is to exclude intermediate spaces (such as vestibules, corridors, and porches) to examine their impact on the overall spatial configuration.

Finally, the findings of both scenarios were compared to extract the desired results.

4.1 | Space Syntax Overview

Space Syntax is a set of theories and methods developed to study the configuration of space at architectural and urban scales, aiming to understand how spatial structures influence social organization and behaviors [19]. Its foundations are rooted in the works of Christopher Alexander and Philip Steadman, while the theoretical framework was first articulated by Hillier and Hanson [19] in The Social Logic of Space. They argued that, in both cities and buildings, the relationship between form and function is mediated by space. Space, therefore, operates socially by accommodating and sustaining movement patterns in accordance with its configuration [19].

4.2 | Spatial Analysis Parameters in Space Syntax

Spatial configuration

Refers to how spaces are arranged and interrelated. It is essential because it reflects the overall structure of spatial connections within a system.

Connectivity

The most basic morphological parameter is the number of direct connections a space has with other spaces.

Depth

Indicates the number of spatial steps required to reach all other spaces from a given one.
Depth is an independent spatial configuration parameter and a crucial variable in the integration calculation. There is an inverse relationship between depth and integration; spaces with high integration have lower depth.

Integration

Represents the average depth of a space to all others in the system — a fundamental concept in Space Syntax. The integration value of each axial line (space) shows how easily one can reach all other spaces, making it a topological (not metric) property.

Intelligibility

The statistical correlation between the connectivity of axial lines and their integration values. This indicator measures how well local spatial information helps users understand the overall spatial system. It reflects the degree of spatial information that can be visually obtained from a single space.

**Fig. 2. Boroujerdi House, Kashan – Qajar-era architecture featuring
iconic windcatchers and the central Kolah Farangi pavilion.**

Case Study

I.   The Boroujerdi House is one of the historical monuments of Kashan, Iran. Located in the Sultan Mir Ahmad neighborhood, it was built in the second half of the 13th century AH during the Qajar period and is registered under No. 1083 on Iran's National Heritage List.

II. The house, with its beautifully symmetrical crescent-shaped windcatchers on the roof of the main hall and the elegant Kolah Farangi (pavilion) above it, showcases one of the finest examples of traditional Iranian architecture.

     According to inscriptions on the four sides of the main hall, the building dates back to 1292 AH.
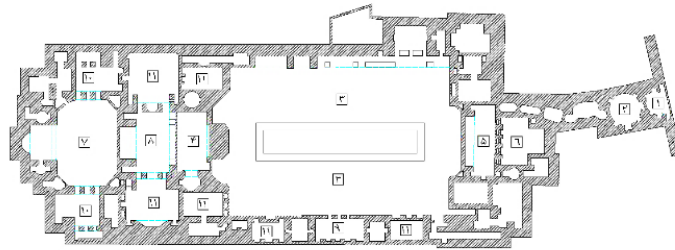

**Fig. 3. The boroujerdi house, ground floor plan (cultural heritage
and tourism organization).**

The valuable paintings and stucco decorations of this house were executed under the supervision of Sani ol-Molk, the great Iranian painter and the uncle of Kamal ol-Molk. UNESCO recognized the historic Boroujerdi House in Kashan as a top tourist attraction in 2015 and 2016.

5 | Research Findings

After analyzing the building's plans using the Depthmap software, the following results were obtained and are presented in *Tables 4* and *5*.

323

Mohajer and Rezaei Lipae | Arch. Dim. Bey. 2(4) (2025) 311-327

Table 4. Diagrams and Correlation Charts of Bonding and Connectivity Components.

Line Equation and Correlation Coefficient	Correlation Diagram of Bonding and Connectivity Components	Visual Connectivity Diagram	Diagram of Connectability	Connectivity Diagram	
R2= 0.906767 Y=30.9168X − 64.7384					First mode (with intermediate space)
R2= 0.582402 Y=40.2067X − 44.3184					Second mode (with elimination of interstitial spaces)

Table 5. Levels of connectivity, bonding, visual connectivity, and spatial depth components for the spaces of boroujerdi house.

Spatial Depth		Visual Connectivity		Covalent Bond		Connectivity		Space Title	Row
Second Mode	First Mode	Second Mode	First Mode	Second Mode	First Mode	Second Mode	First Mode		
0.483	0.537	1888	70	2.07	1.86	19	2	Input	1
**	0.537	**	76	**	1.86	**	2	Eighth	2
0.476	0.126	1953	2288	2.10	7.95	25	141	Yard	3
**	0.074	**	2070	**	13.49	**	364	Porch	4
0.442	0.413	124	1163	2.26	2.42	41	4	Moonlight	5
0.469	0.269	110	622	2.13	3.72	100	4	Hall	6
0.322	0.071	410	835	3.10	13.98	81	318	Shah's residence	7
0.488	0.074	376	1348	2.05	13.49	25	288	Five doors	8
0.621	0.256	147	297	1.61	3.91	7	7	Three doors	9
0.329	0.099	166	230	3.04	10.05	101	301	Ear-ringed room	10
0.288	0.156	289	482	3.47	6.42	7	112	Room	11
0.435	0.237	607	861.91	2.42	7.19	45.33	140.27	Average	

According to the above table, the average values of connectivity, bonding, visual connectivity, and spatial depth for the first condition (i.e., with the presence of intermediate spaces in the spatial organization of the studied sample) are 140.27, 7.19, 861.91, and 0.237, respectively. The correlation between the bonding and connectivity components in this condition is 0.906, indicating very high clarity, or, in other words, high legibility of the spatial organization of the Boroujerdi House.

Table 6. Comparison of spatial configuration indicators before and after removing intermediate spaces.

Indicator	Original Condition (With Intermediate Spaces)	Hypothetical Condition (Without Intermediate Spaces)	Percentage Change
Average bonding (integration)	7.19	2.42	%66.3 -
Mean Depth	0.237	0.435	%83.5+
Legibility coefficient (R^2)	0.906	0.582	%35.7-
Average connectivity	140.27	45.33	%67.7-

As shown in the table, removing intermediate spaces results in a sharp decline in bonding and a significant increase in spatial depth, indicating more difficult access to spaces and disruption of the overall structure. This difference is clearly visible in the integration analysis maps (*Fig. 1*). In the original condition, the central courtyard functions as a highly integrated (Red) core, connecting all spaces. In contrast, in the second condition, this integration is lost and spaces appear as isolated islands (blue and green).

The most significant finding of this study is the steep drop in the legibility coefficient (R^2) from 0.906 to 0.582. This 35% decrease demonstrates that the coherence between local perception (connectivity) and the overall structure (integration) has been disrupted. In other words, after the removal of transitional spaces, the house's spatial structure becomes more confusing and unpredictable for users.

6 | Discussion and Research Findings

This study aimed to elucidate the role of intermediate spaces in traditional Iranian architecture from a spatial configuration perspective. The results clearly address the research questions:

I. Removing intermediate spaces drastically reduces integration and increases spatial depth, transforming the house's spatial structure from a coherent system into a set of discrete spaces.

II.   This structural change leads to a sharp decline in spatial legibility (R² from 0.906 to 0.582). These findings indicate that intermediate spaces are not merely decorative or functional elements but "intelligent configurational tools" that help make the overall structure understandable.

III. The decline in legibility directly undermines the potential for vibrancy, as a space that is difficult to comprehend limits movement and interaction.

IV.   Comparing the integration parameter —the primary measure of spatial organization —between the first and second conditions shows a decrease in easy access after removing intermediate spaces in the Boroujerdi House.

V.   Connectivity, as another parameter, corroborates the above conclusion: access to spaces is significantly reduced.

VI.   Visual connectivity analysis also indicates that the visual field component decreases when intermediate spaces are removed.

VII. The reduced correlation between connectivity and integration in the second condition compared to the first reflects decreased spatial clarity and thus lower legibility.

VIII. Intermediate spaces directly influence spatial organization, affecting both easy access and visual field components. Any alteration or removal of these spaces changes these components, thereby impacting two key indicators: legibility and spatial vibrancy. In the case study, their removal significantly reduced both legibility and vibrancy.

The results clearly demonstrate that removing intermediate spaces from the Boroujerdi House's physical structure goes far beyond a simple plan change, fundamentally altering the logic of spatial organization. The sharp decrease in average integration (from 7.19 to 2.42, *Table 5*) and the nearly doubled mean depth (from 0.237 to 0.435) confirm that these spaces play a vital role in facilitating "easy access" and shortening circulation paths throughout the house.

Most importantly, the steep drop in the correlation coefficient (R²) between integration and connectivity — from 0.906 to 0.582 —indicates a significant decline in spatial legibility. In the original condition, the house's structure was highly predictable and comprehensible, allowing users to infer the position of a space within the overall system based on local connectivity. The removal of intermediate spaces destroys this transparent logic, turning the house into a collection of confusing, fragmented spaces. This decline is not merely numeric; it reflects reduced access to spaces and, consequently, lower vibrancy.

This finding supports and reinforces Hillier and Hanson's [19] theoretical framework in The Social Logic of Space, demonstrating, through an Iranian case study, that spatial configuration is not purely geometric but reflects and shapes social relationships. Intermediate spaces in the Boroujerdi House serve as "intelligent thresholds," managing transitions from public to private areas and establishing a hierarchy of access, thereby materializing the social logic of the Iranian family (e.g., separation of inner and outer areas, levels of privacy) within the built form. The analysis shows that this social logic has a structural and quantitative basis: high legibility in the original condition corresponds to the transparency of the social and cultural structure.

Furthermore, this research complements previous studies that have primarily focused on the semantic and identity values of intermediate spaces (e.g., Ahmadnejad [27], Gharavi Alkhansari [28]). It demonstrates that concepts such as "identity" and "meaning" in traditional architecture are not abstract or floating but are rooted in a strong, efficient spatial configuration. A readable, understandable space aligned with users' behavioral and cultural patterns evokes a sense of belonging and identity. Therefore, the identity crisis observed in contemporary housing may primarily stem from structural legibility issues arising from the removal of transitional spaces.

The decline in visual connectivity also supports this point: intermediate spaces regulate visual fields, enhancing social surveillance and interaction opportunities, which are key elements of vibrancy at the architectural scale.

These findings have important theoretical and practical implications. Theoretically, they show that the concept of vibrancy, often applied at urban and public scales, can also be defined and measured at the architectural scale using structural indicators such as legibility and access. In practice, the research warns architects and contemporary housing designers that reviving quality and identity is not achieved through mere formal imitation of traditional elements (e.g., adding an arch or a decorative portal), but by recreating the principles and logic of spatial organization. Designing thresholds, pause-inducing entrances, spatial filters, and hierarchical circulation paths that enhance legibility and comprehensibility can significantly improve quality of life and vibrancy, even without traditional forms.

The study has limitations. Focusing on a single case, although illustrative, limits the generalizability of the results. Future research should apply this analytical method to a broader range of traditional houses across different climates and historical periods to develop a comprehensive understanding of intermediate spaces in Iranian architecture. Combining spatial configuration analysis with behavioral and survey studies in contemporary housing could also clarify the relationship between spatial configuration and occupants' perceptions of legibility and vibrancy.

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Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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327

Mohajer and Rezaei Lipae | Arch. Dim. Bey. 2(4) (2025) 311-327

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