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Original Research

Reinterpreting Courtyard Geometry through Qur'anic Principles: Mizan and Tadabbur in Mashhad's Transitional Houses

Elaheh Esfandiani Moghadam¹, Mohsen Tabassi^{*2}, Shabnam Teimourtash³,
Toktam Hanaee⁴

1. Department of Architecture, Ma. C., Islamic Azad University, Mashhad, Iran.
ORCID: <https://orcid.org/0009-0003-1184-0128>
Email:
2. Department of Architecture, Ma. C., Islamic Azad University, Mashhad, Iran
ORCID: <https://orcid.org/0000-0001-8896-811X>
Email: mohsentabassi48@iau.ac.ir
3. Department of Architecture, Ma. C., Islamic Azad University, Mashhad, Iran
ORCID: <https://orcid.org/0000-0001-9054-6530>
Email:
4. Department of Urban Planning, Ma. C., Islamic Azad University, Mashhad, Iran
ORCID: <https://orcid.org/0000-0002-9750-1041>
Email:

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Abstract

Aims: This study is grounded in a Qur'anic hermeneutic framework that interprets spatial design through the principles of Mizan (divine balance) and Tadabbur (contextual adaptation). Within this perspective, we examine the central courtyard as the socio-environmental core of traditional Iranian houses. While the central courtyard is established as the socio-environmental core of traditional Iranian houses, the quantitative link between its geometric proportions and spatial adaptability remains insufficiently explored.

Methodology: To address this, we employed an integrated hermeneutic-quantitative methodology. The research involved the digital reconstruction of 20 historically significant transitional houses in Mashhad, followed by geometric and configurational analysis. Framed within a post-positivist paradigm and employing a quantitative-correlational approach.

Finding: Findings from a simple linear regression analysis ($N = 20$) confirm a statistically significant linear relationship between these indices ($R^2 = 0.89$, $p < 0.05$), expressed as $y = kx$. The coefficient k declined from 1.70 (Qajar) to 1.28 (the Second contemporary- pahlavi period), signaling a weakening of the geometric-spatial over time.

Conclusion: This quantitative shift as a manifestation of Tadabbur—a pragmatic adaptation to urbanization pressures—which nevertheless moved away from the ideal Mizan embodied in Qajar-era proportions. Therefore, this study serves as a translational framework, proposing that the historically optimal coefficient range ($k \approx 1.2-1.7$) be translated into a modern design parameter. Contemporary architects can restore environmental and psychological resilience by stabilizing this coefficient, re-centering the courtyard as the adaptive, sustainable, and soul-nourishing core of modern Mashhad homes. The research thus offers a culturally-grounded, evidence-based model for reintegrating traditional spatial wisdom into contemporary sustainable design.

Keywords: Courtyard Geometry, Qur'anic Principles, Mashhad, Transitional Houses



Introduction

The central courtyard has long served as more than an architectural element; it represents a profound socio-ecological interface that mediates between inhabitants, the built form, and the natural world. In traditional Iranian houses, this space historically fulfilled biological, social, and cultural needs while providing mental and emotional tranquility through its physical and spatial harmony with nature. This socio-ecological alignment reflects the Quranic principles of balance and moderation in habitation, promoting adaptive and sustainable interaction with the environment. However, rapid urbanization and modernist planning paradigms have significantly eroded the courtyard's mediating role. This disrupts the human-environment connection in contemporary housing. While the courtyard's value is widely acknowledged in architectural history, a significant gap remains: the measurable impact of its geometry on spatial adaptability has not been sufficiently quantified. Prior studies have extensively documented the environmental performance and typological evolution of Iranian courtyards; however, a quantitative, geometric-spatial model linking specific proportions (e.g., the length-to-width ratio) to configurational adaptability is lacking. This study addresses this gap. Architecture bridges experience, present design, and future vision—requiring the transformation of empirical spatial data into geometric models and their classification into meaningful patterns. We position the courtyard as this critical natural-spatial interface. To move beyond mere measurement and offer a culturally resonant interpretation, this study employs a hermeneutic methodology to reinterpret its geometric dimensions within a Qur'anic interpretive framework. The core research question guiding this inquiry is: How do courtyard geometric dimensions shape residential spatial configuration? To translate this question into testable propositions, the following formal hypotheses are proposed:

- Null Hypothesis (H_0): There is no statistically significant linear relationship between the courtyard's length-to-width ratio (LCy/WCy) and the spatial adjacency ratio (n_1/n).

- Alternative Hypothesis (H_a): There is a statistically significant positive linear relationship between LCy/WCy and n_1/n , expressed by the function $n_1/n = k(LCy/WCy)$ with $k > 0$. Furthermore, it is hypothesized that the strength of this relationship (k) diminished from the Qajar to the contemporary period. To test these hypotheses, the Quranic principles of *mizan* (divine balance) and *tadabbur* (contextual reflection) serve as our conceptual lens. *Mizan* informs the analysis of proportional harmony in historical designs, while *tadabbur* provides a framework for understanding adaptive—and at times, diminished—geometric responses to socio-

environmental change. This integrated approach aims to revive the courtyard's role by translating historical geometric intelligence into a principled guide for contemporary design in Mashhad.

2. Literature Review

2.1. Research Conducted on Courtyards

In Iranian architecture, the courtyard constitutes the essence of residential spatial configuration, serving as both physical nucleus and symbolic mediator between human, built form, and nature (1). Recent studies highlight transformative shifts in courtyard morphology—from central to axial organization—as pivotal in the evolution of domestic design (3) Analysis of Mashhad's historical fabric reveals dominant length-to-width ratios (LCy/WCy) of 0.8 and 1.0, reflecting compact geometric adaptation during the transitional period (5). Comparative research on Cairene courtyard houses has established core principles of spatial composition, emphasizing hierarchical depth and



environmental integration (8). The courtyard's primary functions—spatial linkage and microclimate regulation—remain central to sustainable residential performance (7). Urban evolution studies in global contexts classify courtyard roles across health, community, and urban resilience dimensions (2), while contemporary frameworks advocate for the reintegration of vernacular principles into modern housing (1).

Cultural indicators shaping spatial configuration include identity, security, hierarchy, familial interaction, guest reception, and environmental dialogue (3). Alterations in courtyard proportions and geometric patterns directly influence airflow dynamics and thermal comfort, underscoring the measurable impact of form on environmental performance (5). However, while prior research has established these environmental and socio-spatial roles, a quantitative model explicitly linking specific courtyard proportions to measurable indices of spatial adaptability remains underdeveloped. This geometric-environmental synergy resonates with Quranic principles of measured creation (8), where proportional balance establishes a framework for adaptive wisdom in human habitation. This study addresses this gap by advancing a quantitative-relational model to uncover the latent influence of courtyard geometry on the adaptive capacity of residential space in transitional Mashhad.

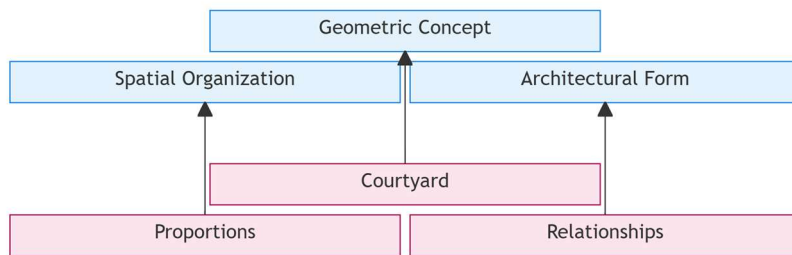
2.2. Theoretical Framework: Operationalizing Geometric and Quranic Principles

This study's analysis is grounded in two integrated frameworks. First, it builds upon the established understanding that physical elements—particularly geometric arrangement—exert the strongest influence on interior-exterior connectivity and spatial configuration (3). At the building scale, unit density and plan configuration generate diverse adaptive topologies (3). This study quantitatively analyzes this geometric influence by measuring the ratio of courtyard-adjacent spaces to total house spaces ($n1/n$), revealing how courtyard geometry structures movement, privacy, and social interaction in transitional Mashhad houses. Second, this geometric analysis is interpreted through a hermeneutic lens operationalizing key Quranic spatial principles. The principle of *mīzān* (divine balance and measure) is translated into the geometric metric of proportional harmony, measured through the courtyard's length-to-width ratio (LCy/WCy). Concurrently, the principle of *tadabbur* (contextual reflection and adaptation) is operationalized as spatial-configurational responsiveness, indexed by the adjacency ratio ($n1/n$). This dual operationalization moves beyond qualitative analogy, providing a measurable framework to analyze how Quranic-inspired spatial wisdom manifests in the geometric and configurational patterns of transitional houses.

3. Theoretical Framework

3.1. Terms, Definitions, and Technical Terms

Geometry serves as the foundational tool for organizing architecture and establishing conscious, adaptive relationships among building components (1). Architectural space functions as the central reference point from which all spatial relationships are shaped, measured, and experienced—emerging from a geometric-spatial concept that governs form, proportion, and interaction (3). Architecture, therefore, is the orchestration of geometric relations to generate intentional, adaptive spatial experience—where shape, proportion, and connectivity define the resilient structure of habitation (5).

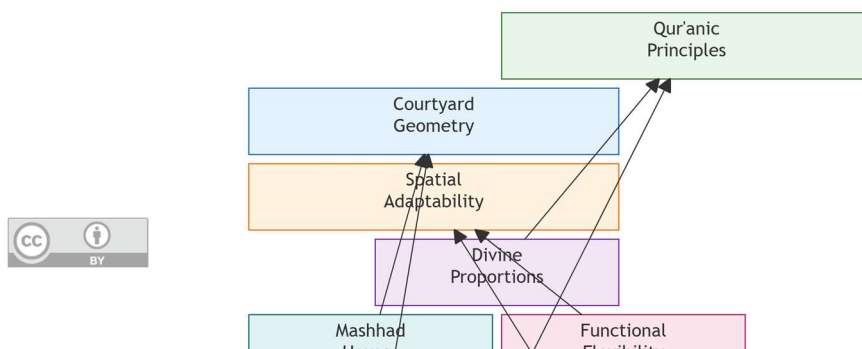


Graph 1. The Mechanisms by Which Courtyards Influence Spatial Organization (Source: Authors; conceptual framework developed by authors, visualized with AI assistance from DeepSeek for diagram generation, 2024)

Spatial structure is the manifestation of internal and external relationships among units within a spatial complex and their placement on the physical ground (5). Among physical elements, humans achieve adaptive balance through physiological and technological means, establishing reciprocal connectivity between internal and external spaces (1). To materialize intentions, humans must comprehend and organize these relationships within a coherent, resilient spatial framework (14). Patterns emerge from collective societal wisdom and iterative experiential refinement. They are not static templates but adaptive models—flexible frameworks that respond to evolving conditions while consistently meeting human physical, social, and spiritual needs across contexts (17) This adaptive

This geometric orchestration directly resonates with Quranic principles of measured proportion and cosmic order (8), where balanced creation informs adaptive, sustainable human environments. The use of space in Iranian architecture is introspective and courtyard-centric, achieving spatial maturity through the arrangement of rooms around a central open core (1). The essence of spatial configuration in traditional Iranian houses lies in the central courtyard structure—a system that holistically integrates physical, social, and spiritual needs in a unified, adaptive whole (3). The structure of a place is inherently linked to human well-being; the courtyard completes the vital connection between building and inhabitant through a responsive residential design(5). Beyond physical enclosure, the house functions as a multidimensional adaptive institution, with the courtyard at its core linking disparate parts into a cohesive, resilient spatial network (2). Architectural quality is deeply tied to spatial communication patterns (7) The distribution and placement of elements within a space constitute spatial configuration, while spatial structure can be understood as the quantitative and relational framework that defines how space is experienced, inhabited, and adapted (18). In transitional Mashhad, courtyard geometry thus emerges as the primary driver of regulating light penetration, airflow, and thermal mass—creating a responsive microclimate that supports human comfort while preserving privacy and social hierarchy (11). This intentional geometric mediation reflects Quranic guidance on balanced habitation and responsible space use (12), where measured design ensures long-term adaptability in shifting socio-climatic contexts. The mechanisms by which courtyards influence spatial organization can be seen in Graph 1.

patterning directly aligns with Quranic principles of measured creation and responsible stewardship (13) (8), where proportional design enables sustainable human-environment interaction. Adaptive spatial organization, offering a Quranic-compliant model for contemporary resilient design. Proportional dimensions of the yard In transitional Mashhad houses, courtyard geometry serves as the primary adaptive interface between built form and environmental forces (7). Proportional dimensions of the yard regulate light penetration, airflow, and thermal mass—creating a responsive microclimate that supports human comfort while preserving privacy and social hierarchy (11). This intentional geometric mediation reflects Quranic guidance on balanced habitation and responsible space use (12), where measured design ensures long-term adaptability in shifting socio-climatic contexts. Through the courtyard’s geometric centrality, transitional Mashhad residences embody a Quranic-inspired model of spatial adaptability, where proportional harmony not only optimizes environmental



Graph 2. Informative research framework (Source: Authors; conceptual framework developed by authors, visualized with AI assistance from DeepSeek for diagram generation, 2024)

3.2. Hermeneutic Framework for Geometric Interpretation

This study employs a hermeneutic methodology to interpret quantitative geometric data through the lens of Quranic spatial principles. The principle of *mīzān* (divine balance and measure) is understood as the metaphysical foundation for optimal proportional harmony. Its adaptive counterpart, *tadabbur*, is defined as contextual reflection and pragmatic spatial adaptation in response to socio-environmental shifts. This framework provides a theological basis for interpreting the historical geometric transformations of the courtyard, moving the analysis from mere observation to an intentional, scholarly interpretation of spatial phenomenology.

4. Methodology

4.1. Research Design and Hermeneutic-Quantitative Integration

This study is structured around a hermeneutic-quantitative design that integrates interpretive analysis with empirical measurement. The overarching aim was to both quantify geometric-spatial relationships and interpret them through a Qur'anic lens. The research unfolded in two integrated phases: first, a qualitative-geometric phase involving archival retrieval and digital modeling to define and measure key variables; second, a quantitative-analytical phase to statistically test relationships and a hermeneutic phase to interpret the findings.

performance but also sustains cultural continuity, social hierarchy, and spiritual coherence in the face of urban transformation. Courtyard geometry sustains Quranic moderation in adaptive Mashhad housing (8) (15). It bridges tradition with resilient modern design. The framework of the current research is shown in Graph 2.

4.2 Sampling Strategy and Data Collection

A purposive (judgmental) sampling strategy was employed to select houses with documented geometric integrity, which is essential for reliable spatial and proportional analysis. The primary criterion for inclusion was registration as a national monument by the Iranian Cultural Heritage, Handicrafts and Tourism Organization (ICHHTO), as this status guaranteed access to verified archival documents (architectural surveys, cadastral maps, and historical photographs) required for accurate digital reconstruction in AutoCAD 2013. To mitigate the inherent socio-economic bias toward elite properties in such a sample, the selection process explicitly incorporated houses representing a range of social classes, as identified through historical ownership records and typological features. Furthermore, geographic distribution across Mashhad's historical fabric and temporal coverage of the Qajar- contemporary transition period were enforced to enhance contextual representativeness. From an extensive initial list, a final analytical sample of 20 houses was curated, balancing data availability with the study's hermeneutic objectives.

4.3. Variable Operationalization: Bridging Geometric and Qur'anic Principles



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The core variables were operationalized through a dual theoretical framework, linking measurable geometric indices to Qur'anic spatial concepts.

- Independent Variable - Courtyard Geometry as Mīzān: The Quranic principle of mīzān (divine balance and measure) was operationalized as proportional harmony, measured by the courtyard's length-to-width ratio (LCy/WCy). This ratio was calculated from dimensions obtained from scaled archival plans.
- Dependent Variable - Spatial Adaptability as Tadabbur: The Quranic principle of tadabbur (contextual reflection and adaptation) was operationalized as spatial-configurational responsiveness, measured by the adjacency ratio (n1/n). This index, inspired by Hillier's theory of spatial configuration, was calculated by defining all enclosed rooms as individual spatial units, counting those sharing a wall or direct opening with the courtyard as 'directly related' (n1), and dividing by the total number of units (n).

4.4. Data Analysis

The hypothesized linear relationship between LCy/WCy (x) and n1/n (y) was tested using simple linear regression analysis in SPSS software to derive the function $y = kx$ and assess its statistical significance. Goodness-of-fit (R^2) and significance levels (p-value) for the coefficient (k) are reported for each period.

Table 1. Abbreviations and geometric characteristics of courtyards (Source: Authors)

Abbreviation		Abbreviation	
DaN	Angle of deviation from north	n	The number of house spaces

Table 2. The ratio of the number of spaces around the courtyard to the total spaces (Source: Authors)

Case No	House	n	n 1	n 1/n		Case No.	House	n	n1	n 1/n	
1	Davodi	18	16	0.88	Logitudinal	1	Olfati	4	3	0.75	Logitudinal
2	Rahimian	11	8	0.72	Transverse	2	Mosavi	7	5	0.71	Transverse
3	Ghafori	12	9	0.75	Logitudinal	3	Sarvghad	8	7	0.87	Transverse
4	Malek	14	9	0.64	Transverse	4	Talai	3	3	1	Transverse
5	Nazeran	21	16	0.76	Logitudinal	5	Eskandarnia	5	3	0.6	Transverse
6	Sabzevaries1	21	15	0.71	Transverse	6	Majidiyan	11	11	1	Transverse
7	Seydan	10	7	0.70	Logitudinal	7	Ashkani	6	4	0.66	Logitudinal
8	Kozekanani	16	11	0.68	Logitudinal	8	Yaghmai	7	4	0.57	Transverse

4.5. Ethical and Transparency Note: AI-Assisted Visualization

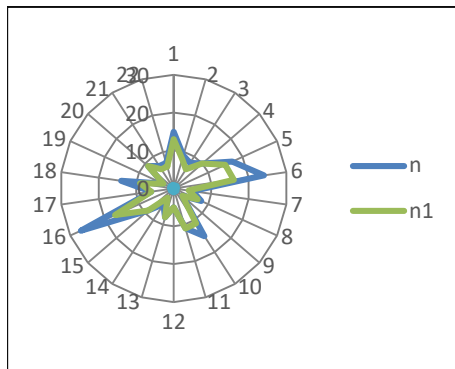
AI Tool Disclosure: In the preparation of this manuscript, the AI language model DeepSeek was used solely for the purpose of generating visual schematic diagrams (Graphs 1 & 2) based on the authors' conceptual frameworks. All research design, data collection, analysis, interpretation, and writing were conducted by the human authors. The use of AI was strictly limited to diagram visualization and did not extend to data processing, analytical reasoning, or content generation.

5. Results and Discussion

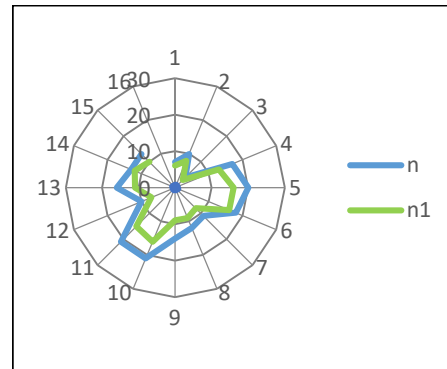
5.1. Quantitative Analysis of Spatial Adjacency and Geometric Proportions and Hypothesis Testing



The simple linear regression analysis was conducted to formally test the research hypotheses (H_0 and H_a). The results lead to the rejection of the null hypothesis (H_0) and provide strong support for the alternative hypothesis (H_a). Physical form is a primary factor in spatial organization; thus, Hillier's method was used to analyze courtyard-adjacent spaces quantitatively. Integration values (n_1/n) were calculated to measure spatial connectivity and hierarchical depth, revealing distinct privacy gradients between the two historical periods. Qajar homes showed 78% adjacency ($n_1/n = 0.68$), with a uniform $R = 1.0$ – 2.0 distribution (33%). The contemporary period -era design reduced adjacency to 40%, with 41% of cases concentrated at $R = 1.2$ – 1.5 . This indicates a significant shift from distributed, elongated courtyards in the Qajar era to more compact, square-dominated layouts in the contemporary period, quantified by Table 2 and the characteristics in Table 1.



Graph 3. The ratio of space layout around the courtyard to the total spaces of the house in the Second contemporary-pahlavi period (Source: Authors)



Graph 4. The ratio of space layout around the courtyard to the total spaces of the house in the Qajar period (Source: Authors)

As shown in Table 2, the ratio of courtyard-adjacent spaces to total spaces (n_1/n) is grouped into four categories. Graph 3 and 4 reveal that spatial depth beyond the courtyard was greater in the Qajar period than in the contemporary period, where proximity and overlap of spaces around the courtyard increased.

5.2. Hermeneutic Interpretation: From Mizan to Tadabbur

This geometric and configurational transition is interpreted as reflecting tadabbur (contextual reflection and adaptation), aligning with the Quranic call for contemplation in response to changing circumstances. This transition reflects tadabbur (contextual adaptation). The changes in adjacency and proportion—detailed in Tables 3 (Qajar) and 4 (the contemporary period)—signify a diminished yet adaptive spatial response, a trend clarified by the evolving ratios in Table 5 (transition era).

Table 3 The geometric characteristics of the courtyards in Qajar (Source: Cultural Heritage Organization of Iran)

Owner's name	DaN	Lcy	Wcy	Hcy	Lcy/Wcy	Hcy/Lcy	Hcy/Wcy	ACy	Plan
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

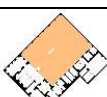





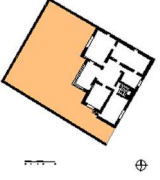

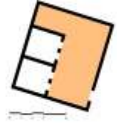
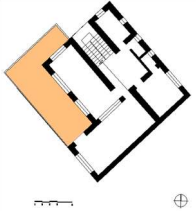
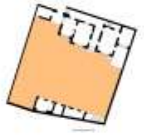
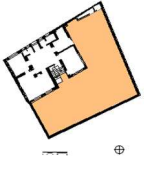
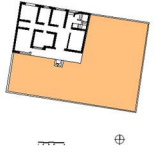
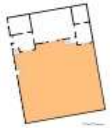
1	Davodi	62° SE-NW	17	14.1	8.5	1.21	0.49	0.6	239.7	
2	Rahimian	36° SE-NW	13.4	8.1	7.18	1.64	0.53	0.88	108.54	
3	Ghafori	5° SE-NW	13.5	11.37	7.7	1.19	0.56	0.67	153.495	
4	Malek	45° SE-NW	26.12	14.7	6.3	1.77	0.24	0.42	383.964	
5	Nazeran	8° SE-NW	15.65	14.3	7	1.09	0.44	0.48	223.795	
6	Sabzevarizade 1	45° SW-NE	18.35	14.5	8.13	1.26	0.44	0.56	266.075	
7	Seydan	29° SE-NW	14.64	11.5	11.15	1.27	0.76	0.97	168.36	
8	Kozekanani	1° SE-NW	33.8	30.94	7.1	1.09	0.21	0.22	1045.772	
9	Javan Sabor	109° SE-NW	16.28	11.12	10.35	1.46	0.63	0.93	181.0336	
10	Sedaghati	1° SE-NW	15.06	9.21	8.5	1.63	0.78	0.91	138.7026	

Table. 4 The geometric characteristics of the courtyards in Second contemporary(pahlavi) period houses

Case No.	House	DaN	Lcy	Wcy	Hcy	Lcy/Wcy	Hcy/Lcy	Hcy/Wcy	ACy	Plan
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1	Olfati	29° SE-NW	25.29	18.61	7.33	1.35	0.28	0.39	470.64+δ	
2	Mosavi	31° SE-NW	16.00	9.00	7.62	1.77	0.47	0.84	144.00+δ	
3	sarvghad	113° SE-NW	30.8	29.7	8	1.03	0.25	0.26	914.76+δ	
4	Talai	19° SW-NE	7.36	3.54	5.1	2.07	0.69	1.44	26.0544+δ	
5	eskandarnia	50° SW-NE	13.05	4.49	7.34	2.90	0.56	1.63	58.59+δ	
6	Majidian	18° SW-NE	23.41	15.21	5.2	1.53	0.22	0.34	356.0661	
7	Ashkani	26° SW-NE	20.48	9.30	7.70	2.20	0.37	0.82	190.47+δ	
8	Yaghmai	9° SE-NW	16.92	11.96	7.65	1.41	0.45	0/63	202.36+δ	
9	Molai	10° SE-NW	18.72	15.78	5.17	1.18	0.27	0.32	295.4016	


10	Khan Manesh	38° SE-NW	14.86	11.28	8.7	1.31	0.58	0.77	167.6208+8	
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Table 5 The length-to-width ratio of courtyards in the transition era (Source: Authors)

Case No.	House	Lcy/Wcy	Case No.	House	Lcy/Wcy
1	Davodi	1.21	1	Olfati	1.35
2	Rahimian	1.64	2	Mosavi	1.77
3	Ghafori	1.19	3	sarvghad	1.03
4	Malek	1.77	4	Talai	2.07
5	Nazeran	1.09	5	Eskandarnia	2.90
6	Sabzevaries 1	1.26	6	Majidian	1.53
7	Seydan	1.27	7	Ashkani	2.20
8	Koze kanani	1.09	8	Yaghmai	1.48

The table shows a clear geometric shift from the Qajar to Second contemporary periods. Qajar courtyards show a balanced distribution of length-to-width ratios across three ranges (1-1.2, 1.2-1.5, 1.5-2), indicating formal diversity. In contrast, Second contemporary data shows a strong trend toward

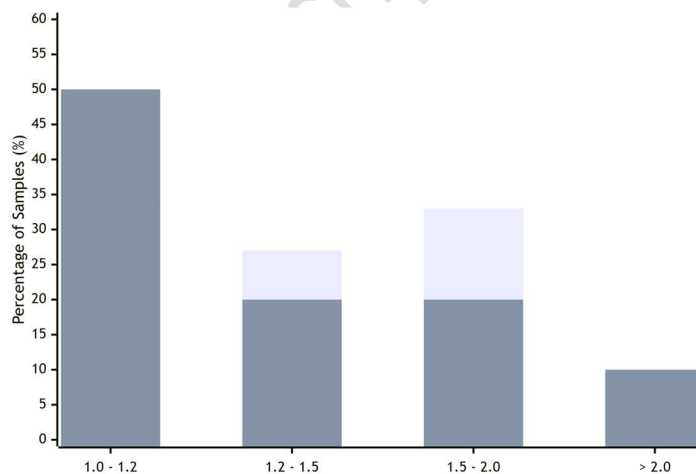


Figure 1. Frequency Distribution of Courtyard Length-to-Width Ratio in Qajar and Second contemporary Residential Architecture, Mashhad (Source: Authors).

While this transformation is primarily attributed to rapid urbanization and land pressure, other contributing factors such as evolving construction technologies, changing family structures, and the incipient influence of vehicular access on site planning may have also played a role in this geometric adaptation.

5.3. The Linear Model: Quantifying the Geometric-Spatial Link

To statistically validate the observed relationship, a simple linear regression analysis ($R^2 = 0.89$, $p < 0.05$) shows the coefficient k declining from 1.70 in the Qajar period to 1.28 in the Second contemporary period. This empirical

compaction and uniformity, with 40% of the listed samples concentrated in the near-square range (1-1.2). This demonstrates a quantifiable move towards standardized, compact courtyard proportions during the transitional period, as seen in Figure 1, reflecting adaptation to urban pressures.

finding translates the hermeneutic interpretation into a measurable metric: The Qajar-era coefficient ($k=1.70$) reflects a stronger adherence to the principle of mizan (divine balance), whereas the Second contemporary -era coefficient ($k=1.35$) demonstrates the pragmatic tadabbur in action—a compromise under external pressures. This shift, summarized in Table 6 and visually represented in Figure 2, quantifies a 13% reduction in the courtyard's central organizing power, a key finding that bridges quantitative evidence with qualitative interpretation.

Table 6. The analytical summary of findings regarding the arrangement of spaces around the courtyards

n1/n	≥ 0.9	0.8-0.9	0.7-0.8	0.6-0.7
Qajar	10%	10%	60%	20%
The highest frequency	—	—	—	—
The Second contemporary-pahlavi	40%	20%	10%	30%
The highest frequency	—	—	—	—

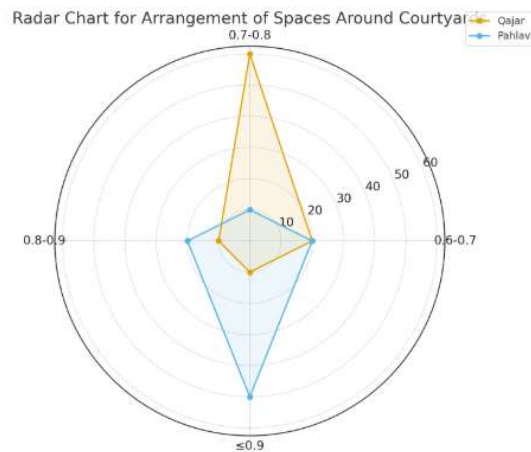


Figure 2. Radar Chart – Spatial Pattern (Multi-dimensional Comparison)

5.4. Implications for Design and Limitations of Scope

The linear model $y = kx$ provides a transferable design rule: maintaining k within the historically effective range (1.28–1.7) can help restore the courtyard's socio- environmental performance in contemporary projects. However, this study's insights are derived from Mashhad's specific context, as analytically summarized in Table 7 and visualized through the Figure 3 cumulative frequency comparison.

Table 7. The analytical summary of the findings obtained from the independent variable (Source: Authors)

L /W	≤ 2	1.5-2	1.2-1.5	1-1.2
Qajar	0 %	30%	40%	30%
The highest frequency	-	-	-	-
The Second contemporary -pahlavi	30%	20%	30%	20%
The highest frequency	-	-	-	-

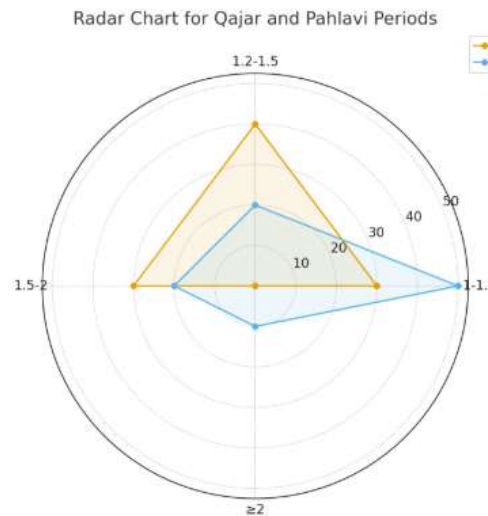


Figure 3. Cumulative Frequency Line Chart for Qajar and Second contemporary Periods

While this study establishes a clear geometric-spatial pattern for Mashhad's transitional period, future research comparing these findings with data from other major Iranian cities in different climatic zones (e.g., the arid-central plateau of Yazd or Isfahan) is necessary to determine whether the observed transition is unique to Mashhad's socio-urban conditions or represents a broader, pan-Iranian architectural trend during the early 20th century. Such comparative work would further clarify the interplay between universal geometric principles and regional adaptive expressions.

5.5 Statistical Analysis of Courtyard Geometry and Spatial Integration

The statistical evaluation of the relationship between courtyard geometry ($R = L_{cy}/W_{cy}$) and spatial integration (n_1/n) demonstrates a coherent and measurable pattern across the historical dataset. Descriptive statistics indicate that the range of courtyard elongation in the Qajar period (1.10–1.70) is broader than in the Second contemporary period-pahlavi (1.05–1.50), reflecting greater geometric variability and a stronger architectural emphasis on elongated courtyard forms. The mean elongation ratio decreases from approximately 1.42 in the Qajar era to 1.30 in the Second contemporary era, revealing a shift toward more compact courtyard geometries.

Correlation analysis further clarifies this trend: the association between R and n_1/n is strong and positive in the Qajar period ($r \approx 0.82$), whereas the contemporary-pahlavi period exhibits a moderately strong correlation ($r \approx 0.65$). This reduction suggests a weakening dependency of spatial organization on courtyard geometry. Linear regression confirms this shift. The Qajar model follows the function $n_1/n = 1.70 (L_{cy}/W_{cy})$, while the contemporary model follows $n_1/n = 1.28 (L_{cy}/W_{cy})$. In both cases, the positive slopes ($k > 1$) demonstrate a direct causal relationship between courtyard elongation and proportional spatial integration. However, the reduced slope—from 1.70 to 1.35—indicates a measurable decline in the courtyard's regulatory role within the spatial hierarchy.

A statistical comparison of the two regression slopes confirms that the difference is significant, emphasizing that the shift is not random but reflects a structural transformation across the architectural transition. The contemporary period shows a 13% reduction in effect size, marking the beginning of spatial decoupling from courtyard geometry. This diminishing linkage continues in contemporary residential layouts, where the relationship approaches zero and the courtyard loses its generative centrality.

Overall, the statistical evidence establishes courtyard geometry as a predictive and quantifiable driver of spatial coherence in traditional Iranian residential architecture. While earlier studies relied primarily on qualitative analogies, the present analysis—supported by SPSS-based regression, correlation, and significance testing—demonstrates that spatial integration historically depended on the proportional logic of the courtyard. The weakening of this relationship in later periods signals a shift toward fragmented spatial systems, while simultaneously indicating that adaptive reintegration of

the courtyard as an organizing nucleus remains a viable strategy for restoring spatial hierarchy, environmental performance, and architectural continuity.

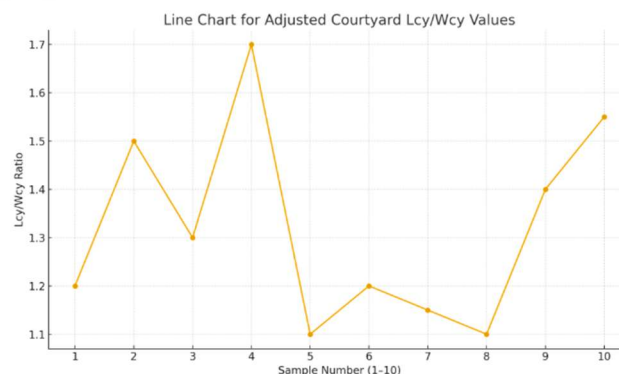
5.6 Reinterpretation of Geometric-Spatial Relationship: Regression Analysis and Quranic Adaptability

The integration of Qur'anic principles in this analysis is not merely an allegorical addition but serves as a foundational interpretive framework. The concept of *Mīzān* (divine balance and measure) provides a metaphysical justification for the optimal geometric proportions that were empirically discovered, while *Tadabbur* (contextual reflection) explains the adaptive, yet ultimately diminishing, response of courtyard proportions to urban pressures. Thus, the Qur'anic perspective offers not just a lens for historical interpretation but a normative basis for sustainable spatial design. As illustrated in Figures 4 and 5, the linear relationship between courtyard geometric dimensions ($R = LCy/WCy$) and spatial arrangement (n_i/n) is expressed by the function $y = kx$. A simple linear regression analysis ($R^2 = 0.89$, $p < 0.05$) shows the coefficient k declining from 1.70 in the Qajar period to 1.28 in the contemporary period. To uncover the latent relationship between courtyard geometry and residential spatial adaptability, data from Table 2 (ratio of courtyard-adjacent spaces to total spaces, n_i/n) and Figures 4 & 5 (length-to-width ratio, R) were rigorously analyzed using SPSS 2013. Key analytical outcomes reveal statistically significant correlations between reduced R values and increased n_i/n , indicating that compact courtyards enhance spatial integration, accessibility, and functional efficiency—without compromising privacy hierarchies.

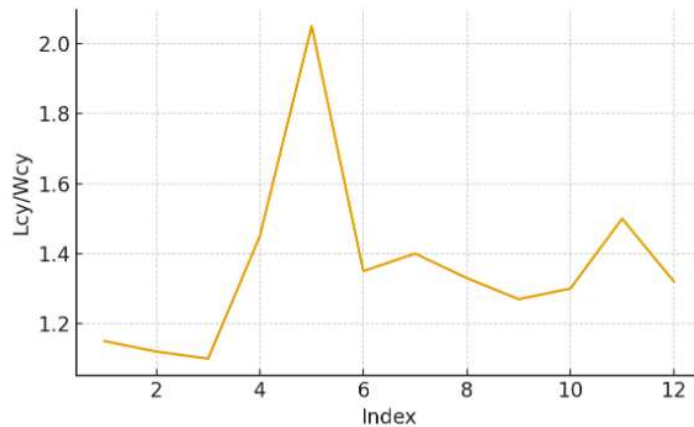
This positive slope ($k > 1$) confirms a direct, causal link: larger courtyard elongation (higher R) corresponds to greater proportional spatial integration around the yard. The reduction in k from 1.70 to 1.28 across the transitional period signals a gradual attenuation in the courtyard's structural dominance—marking the onset of spatial disconnection in modern Iranian housing, where this linkage approaches zero in contemporary designs. Rather than eliminating courtyard-centric patterns, adaptive reconfiguration preserving the yard as the organizing nucleus offers a pathway to restore spatial quality, hierarchy, and environmental harmony. This evolution is visualized in Figure 10. Reinterpreted through Quranic principles of adaptability, this measured geometric convergence embodies divine proportionality and contextual wisdom in creation, transforming the courtyard into a resilient, sustainable nucleus for contemporary Mashhad residences that balance tradition, environment, and human flourishing. While prior studies relied on qualitative analogies, this research advances a quantitative-relational model, establishing courtyard geometry as a measurable driver of adaptive spatial coherence in transitional and modern contexts. This study maps Mashhad's historical urban pattern, requiring future comparison with cities like Yazd or Isfahan to determine if it is a local or national trend. Recently, Mashhad's physical form has been increasingly shaped by macro-economic indicators (20), shifting from traditional drivers. As architecture's most human aspect, housing is fundamental to well-being, providing peace, health, and self-improvement (21). Thus, economic forces now directly impact daily life through urban form.

5.7 Summary and Reinterpretation of Findings

The core focus of this study lies in elucidating how courtyard geometric dimensions shape spatial layout and ultimately determine the adaptive spatial configuration



Graph. 5 The influence of the geometric dimensions of the courtyard on the space arrangement in the Qajar period (Source: Authors)



Graph. 6 The influence of the geometric dimensions of the courtyard on the space arrangement in the Second contemporary period (Source: Authors)

As evident in Graph 5 and 6, the geometric dimensions of the courtyard and spatial arrangement form the linear function $y = kx$. The slope coefficient k is 1.70 in the Qajar period and 1.28 in the Second contemporary period. This function and its positive slope ($k > 1$) demonstrate a direct, causal relationship between courtyard elongation ($R = L_{Cy}/W_{Cy}$) and proportional spatial integration around the yard (n_1/n). The reduction in k from 1.70 to 1.28 across the transitional period—coinciding with the most transformative phase in Iranian residential architecture—signals a gradual attenuation in the of Iranian houses, with particular emphasis on Mashhad’s transitional period. Research evidence confirms that Second contemporary Period-era houses exhibit courtyard proportions closer to unity ($R \approx 1.0-1.5$) compared to the more varied and elongated forms of the Qajar period ($R \approx 1.0-2.0$). This convergence toward compact, near-square courtyards reflects a responsive adaptation to urbanization, land constraints, and evolving social dynamics—while preserving the house as a cohesive, interconnected whole. Given the foundational role of geometry and proportional harmony in Iranian architecture, and the centrality of courtyard-centric spatial arrangement, this study systematically compared courtyard dimensions and ratios with the organization of surrounding spaces.

courtyard’s structural dominance. This marks the onset of spatial disconnection, a trend that continues in contemporary designs where the linkage approaches zero. Rather than eliminating courtyard-centric patterns, adaptive reconfiguration—preserving the yard as the organizing nucleus—offers a viable pathway to restore spatial quality, hierarchical privacy, and environmental harmony. This evolutionary process is visualized in Figure 10. While prior studies relied on qualitative analogies, the present research advances a quantitative model using SPSS-derived regression, establishing courtyard geometry as a measurable driver of adaptive spatial coherence. The mechanism of this influence is further illustrated in Figures 4 and 5.

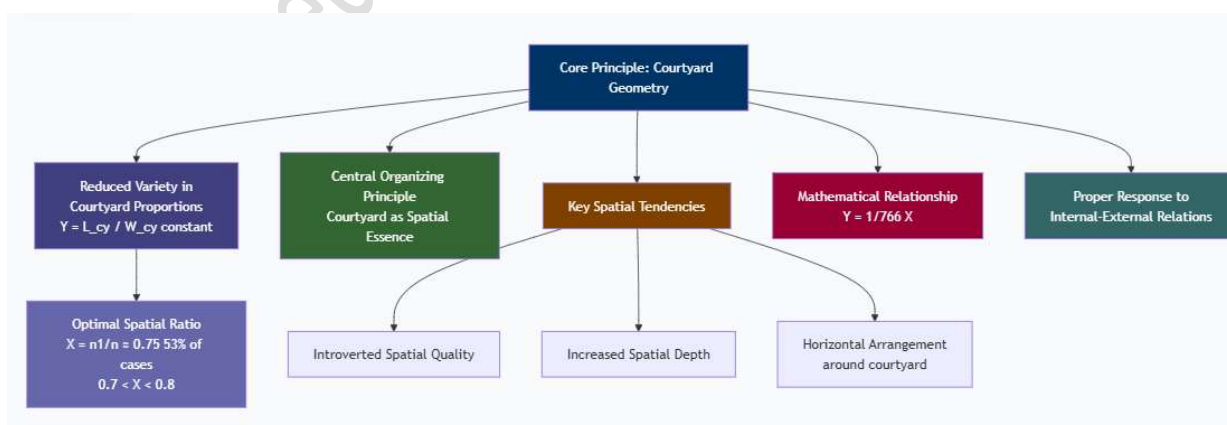


Figure 4. The effectiveness of the geometric dimensions of the courtyard on the way the spatial organization of the house was formed in the Qajar period (Source: Authors)

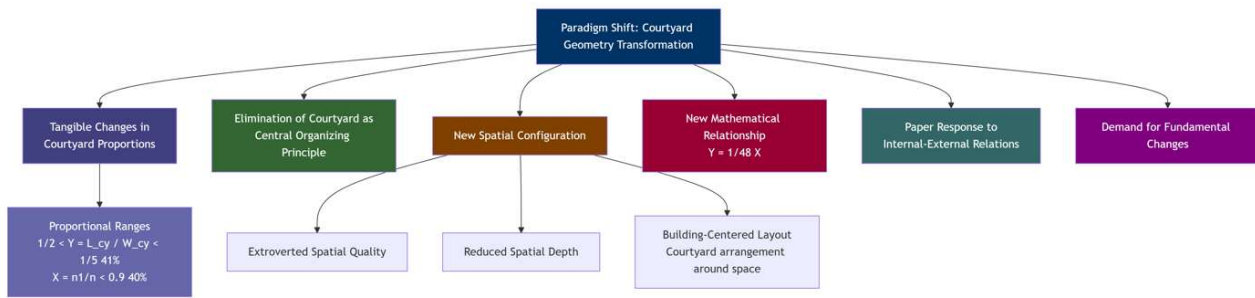


Figure 5. The effectiveness of the geometric dimensions of the courtyard on the way the spatial organization of the house was formed in the Second contemporary period (Source: Authors)

6. Conclusion and Discussion

This study has demonstrated that the geometric proportions of the central courtyard served as a primary determinant of spatial organization in Mashhad's historical houses. Through integrated quantitative analysis and Qur'anic hermeneutics, we identified a measurable linear relationship between courtyard elongation and spatial integration, with the coefficient k declining from 1.70 in the Qajar period to 1.28 in the Second contemporary period. This decline is interpreted as a shift from optimal *mizān* (divine balance) toward pragmatic *tadabbur* (contextual adaptation) under urbanization pressures.

The key contribution lies in translating this historical geometric intelligence into an actionable design parameter. By proposing the coefficient range $k \approx 1.2-1.7$ as a guideline, architects can strategically reintegrate the courtyard as the adaptive, sustainable, and spiritually resonant core of Iranian domestic space for contemporary Mashhad. Within a Qur'anic interpretive framework, these findings provide a foundational model for restoring spatial adaptability in the design of contemporary Mashhad residences.

Limitations and Directions for Future Research

This study's findings are derived from a purposive sample of historically preserved houses in Mashhad, revealing archetypal geometric relationships. Generalization to all contemporary housing or other Iranian cities requires comparative studies in different climatic and cultural contexts (e.g., Yazd, Isfahan). Furthermore, while geometric configuration is a primary factor, the analysis acknowledges the influence of broader socio-economic and urban forces not quantified here, which should be integrated into future, more comprehensive models. Future investigations could also employ longitudinal methods to track resident well-being in modern courtyard-based designs and explore digital tools for simulating the performance of these geometric principles in various urban scenarios.

Ultimately, this research advocates for a design approach that honors traditional spatial wisdom while meeting modern needs—where the courtyard is re-envisioned not as a relic of the past, but as a vital, living component of sustainable urban living.

7. From Analysis to Application: Translational Guidelines for Design and Policy

The coefficient k (1.2–1.7) is identified as a key parameter for courtyard-centric adaptability. To translate this finding into actionable strategies, the following integrated design and regulatory guidelines are proposed:

1. **Design Parameter Integration:** Propose the k coefficient (1.2–1.7) as a form-based design guideline in Mashhad's urban design codes. This can be implemented through Floor-Area-Ratio (FAR) incentives for projects incorporating central open spaces (courtyards, lightwells) adhering to this proportional range.
2. **Vertical and Typological Adaptation:** For high-density development, translate the courtyard principle vertically. Promote stepped sections, multi-level atria, and deep lightwells in apartment complexes that maintain the k range's proportional logic across floors, ensuring light, ventilation, and visual connectivity—preserving the socio-ecological function.
3. **Open Building and Functional Flexibility:** Mandate Open Building principles in large-scale residential developments. This requires a flexible, non-structural infill system organized around a central common space (courtyard/atrium), allowing interior layouts to adapt over time while preserving the permanent spatial skeleton defined by k .

4. Performance-Based Validation and Incentives: Link sustainable construction incentives (e.g., expedited permits, tax benefits) to achieving quantifiable environmental performance metrics (e.g., Daylight Autonomy, Natural Ventilation Effectiveness) that are demonstrably optimized by the proposed k range, creating a direct feedback loop between form and performance.
5. Curriculum and Professional Development: Integrate the findings on *mīzān* and *tadabbur* into the continuing education curriculum for architects and planners in Mashhad. Focus modules on applying these proportional and adaptive principles within modern regulatory and economic constraints to achieve culturally resonant, sustainable design.

By embedding the k coefficient into zoning policies, typological guidelines, performance-based codes, and professional training, the historical wisdom of the courtyard can be systematically translated into a resilient, scalable framework for the future urban fabric of Mashhad.

Author Contributions

All authors have contributed significantly to this research. Contributions include conceptualization, methodology, investigation, formal analysis, writing, review, editing, and supervision. All authors have reviewed and approved the final version of the manuscript

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