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THE HISTORICAL STAGES OF DEVELOPMENT IN UZBEK NATIONAL ARCHITECTURE: AN ANALYSIS OF SPATIAL-COMPOSITIONAL AND FUNCTIONAL TRANSFORMATIONS

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Abstract: This scholarly article presents a comprehensive investigation into the evolution of national architecture on the territory of Uzbekistan, spanning from antiquity to the contemporary period of urban development (2020–2025). Within the framework of the IMRAD structure, the research analyses the spatial, ergonomic, compositional, and functional dimensions of architectural form. The distinctive character of Uzbek architecture is manifested in its geographical position at the crossroads of the Great Silk Road, its climatic adaptability, and the mathematically precise geometric proportions that define its ornamental systems, notably the girih and muqarnas. The article examines the architectural renaissance of the Timurid period, the regional architectural schools that flourished under the Khanates, and the role of green architecture and Building Information Modelling (BIM) technologies in the restoration processes of the post-independence era. The research findings present scholarly conclusions regarding the application of historical architectural traditions to contemporary design and urban planning practices.

Keywords: Uzbek national architecture, Timurid Renaissance, history of urban planning, passive cooling, digital restoration, BIM technologies, girih, islimi.

Introduction

The national architecture of Uzbekistan possesses a history spanning many centuries, having contributed immeasurably to the development of civilisation not only across Central Asia, but throughout the wider world. This heritage constitutes the material expression of the social, political, economic, and cultural processes of successive historical epochs. The territory of Uzbekistan has long served as a crucible for the interaction and synthesis of diverse cultural traditions - Persian, Turkic, Islamic, and Graeco-Bactrian - a confluence that provided fertile ground for the emergence of a distinctly original architectural language. In the contemporary context of globalisation, the study of this heritage has acquired particular urgency, driven by the necessity of preserving national identity, fostering the sustainable development of the urban environment, and employing modern digital technologies in the conservation of historical monuments.

Architectural monuments serve not merely as witnesses to the past, but as enduring sources of inspiration for contemporary design and architecture. The passive cooling systems refined over centuries in extreme climatic conditions, together with such ergonomic spatial elements as the courtyard and the *ayvon*, correspond fully to the principles of present-day green architecture. This research aims to conduct a systematic analysis of the historical stages of development in Uzbekistan's national architecture, to identify the spatial-planning and compositional regularities that govern it, and to assess the transformation of these traditions within the context of contemporary architectural practice.

In pursuit of this aim, the following objectives were established:

1. To examine the evolution of architectural styles from antiquity to the present day in terms of their spatial organisation and functional characteristics;

2. To analyse the geometric-proportional systems and constructive innovations - including domes, arches, and glazed tilework - employed in the architecture of the Timurid and Khanate periods;

3. To investigate the effectiveness of BIM, three-dimensional scanning, and artificial intelligence technologies in contemporary restoration and design processes.

The object of the research comprises the architectural ensembles, cultural heritage sites, and residential buildings of Uzbekistan's historic cities - Samarkand, Bukhara, and Khiva - as well as contemporary centres of urbanisation. The subject of the research encompasses the spatial-planning structure, ergonomic parameters, compositional solutions, and construction technologies of these objects. The scientific novelty of the study lies in its comprehensive analysis of national architecture not solely from an art-historical perspective, but through the prism of engineering-geomatic methods, energy efficiency assessment, and the concept of digital twins. Its practical significance resides in the methodological guidance it provides for the regeneration of historic cities, the appropriate incorporation of national elements in new building design, and the preservation of cultural heritage in digital formats.

Methods

An interdisciplinary approach was adopted throughout the research process, enabling the

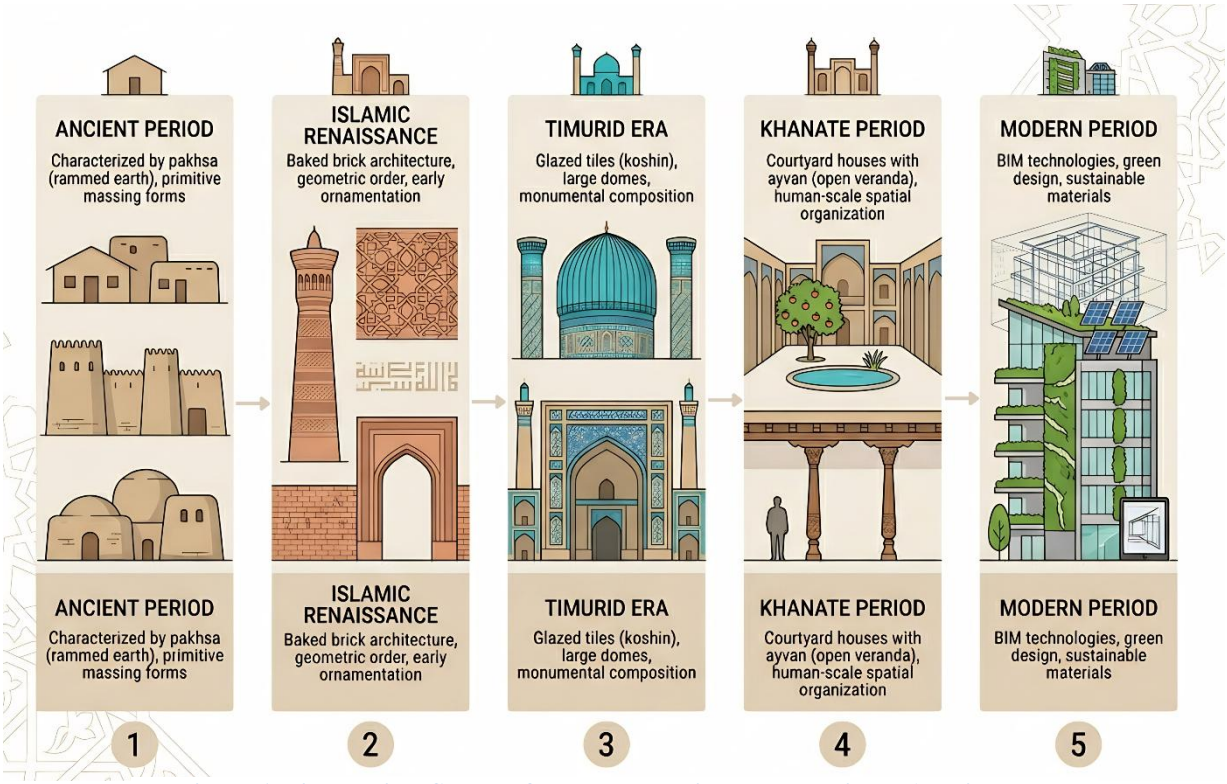


Figure 1 Hierarchical Stages of Development in Uzbek National Architecture

assessment of architectural objects from both historical and technical perspectives. Diachronic analysis was selected as the methodological foundation through which the transformation of

architectural forms across successive historical periods and the relationships between them were examined. In addition, the following specialised methods were employed.

First, grapho-analytical modelling was applied to reconstruct the proportional systems of historical buildings. In Uzbek architecture, particularly during the Timurid period, building dimensions were governed by root-based proportional ratios and complex geometric grid systems. Through this method, the curvature of domes and arches, as well as the height-to-width ratios of portal façades, were subjected to rigorous mathematical analysis.

Second, geomatic and three-dimensional scanning methods played a leading role in the study of contemporary restoration practice. Through the examples of the Amir Palace in Kogon and the historical monuments of Bukhara, the integration of data obtained by Terrestrial Laser Scanning (TLS) and Unmanned Aerial Vehicle (UAV) photogrammetry was examined. This method enables the construction of a virtual building model from a millimetre-precise point cloud, thereby affording an accurate assessment of the structural condition of the object.

Third, comparative-typological analysis was employed to investigate the connections between the architectural traditions of Central Asia and neighbouring regions - notably Iran and India - with particular attention to the typologies of the *charbagh* garden and the mausoleum as manifested in Timurid and Mughal architecture.

Fourth, climatic-functional simulation was applied to evaluate the performance of traditional passive cooling systems - including the courtyard, the *ayvon*, the *badgir* (wind-catcher), and the *sardoba* (cistern) - against contemporary green building standards.

This methodological framework served to examine architecture not merely as a work of art, but as a complex technological system adapted to a specific climatic and social environment. Recent advances in the field of restoration, including the mapping of material composition and degrees of structural degradation through BIM technologies, constitute an integral component of this methodological apparatus.

Results

Prehistoric and Antique Architecture: The Formation of Spatial Planning

The earliest residential and architectural forms on the territory of Uzbekistan trace their origins to the Mesolithic and Neolithic periods. Following the use of natural shelters such as the Teshiktash cave, the Kaltaminor culture gave rise to timber-framed, conical dwelling structures. By the Bronze Age, the first fortified urban settlements had begun to emerge in the regions of Surkhandarya - notably at Sapalli-tepa - and Khorezm, at Jonbos-qala. The architecture of this period was defined primarily by its defensive function: settlements were enclosed by high rammed-earth walls and organised according to a strictly regulated spatial plan.

The antique period, spanning approximately from the fourth century BCE to the fourth century CE, is characterised by the development of monumental construction in Uzbek architecture. The defensive walls of the Afrasiab settlement, extending some 5.5 kilometres in length, together with its sophisticated water supply system, bear testament to the remarkable level of engineering thought attained during this era. Residential structures of the period were built in the form of the *kushk* - elevated upon high platforms - serving as an expression not only of defensive necessity, but of social stratification. The example of the Bolaliqtepa rural fortress near Termez, with its rooms oriented towards an inner courtyard and walls embellished with mural paintings, attests to the emergence of the earliest ergonomic and aesthetic principles that would come to define Uzbek vernacular architecture.

The Islamic Renaissance and Constructive-Artistic Innovations (9th–12th Centuries)

From the tenth century onwards, a new era commenced in the architecture of Central Asia - the Islamic Renaissance. During this period, fired brick became the primary building material, affording architects the capacity to devise complex structural solutions and richly ornamented surfaces. The Samanid Mausoleum in Bukhara, dating from the ninth and tenth centuries, represents the most accomplished exemplar of this epoch, in which brick functions not merely as a structural element, but as a medium of textural decoration in its own right.

The Karakhanid period witnessed the continued formation of monumental architectural ensembles. The Kalyan Minaret in Bukhara, erected in 1127, and the Magoki Attori Mosque stand as the highest achievements of fired brick architecture of this era. By this time, the principal building typologies of Islamic architecture - the mosque, the madrasa, the mausoleum, the caravanserai, and the bathhouse - had been fully established. Within the madrasa plan, the arrangement of a central courtyard surrounded by a two-storey system of individual cells became standardised, ensuring a harmonious integration of educational and residential functions. In urban planning, the tripartite settlement structure - comprising the *ark* (seat of political authority), the *shahriston* (residential urban quarter), and the *rabad* (artisans' district) - became firmly consolidated as the organising principle of the Central Asian city.

The Timurid Period: Grandeur, Geometry, and Symmetry (14th–15th Centuries)

The era of Amir Timur and the Timurid dynasty is regarded as the golden age of Uzbek architecture. The architecture of this period is distinguished by its extraordinary monumentality, its polychrome glazed tilework, and the consummate precision of its geometric proportions. The Registan ensemble in Samarkand, the Gur-e-Amir mausoleum, the Bibi-Khanym Mosque, and the Shah-i-Zinda necropolis stand as the foremost expressions of Timurid architectural thought.

Among the principal technical innovations of Timurid architecture is the system of double-shell domes. The outer dome, clad in turquoise glazed tiles, served as the visual landmark of the city, whilst the inner dome regulated the acoustic and thermal conditions of the interior space. The portal façades - *peshtoq* - were constructed to extraordinary heights, designed to inspire in the beholder a sense of awe before the power of the state. During this period, the mathematical foundations of architectural design reached a remarkable degree of sophistication: *girih* patterns - geometric interlocking nodes - and *muqarnas* - stalactite vaulting - were produced as the outcome of complex mathematical calculation.

Landscape and garden design also attained a high level of refinement during the Timurid period, as exemplified by the *charbagh* - the formal quadripartite garden. The gardens surrounding Samarkand, including the Bagh-i-Dilkusha and the Bagh-i-Chinar, were founded upon the harmonious integration of geometric symmetry, water channels, and fruit-bearing trees. This tradition was subsequently transmitted to the Indian subcontinent through the Mughal dynasty, where it reached its most celebrated expression in the Taj Mahal.

The Khanate Period: Regional Architectural Schools (16th–19th Centuries)

From the sixteenth century onwards, the emergence of the Bukhara, Khiva, and Kokand Khanates on the territory of Uzbekistan gave rise to distinct regional architectural schools. The Bukhara school is distinguished by its mastery of ensemble composition, exemplified by the *qush* - or paired - method of spatial organisation. The Sherdor and Tillakori madrasas on the Registan square were constructed in deliberate axial correspondence with the earlier Ulugh Beg Madrasa, their collective arrangement forming one of the most celebrated public squares in the world.

The architecture of Khiva, as embodied in the Ichan-Qala inner city, is recognised for its remarkable spatial cohesion and the distinctive qualities of its rammed-earth and *pakhsa* construction tradition. The Friday Mosque within the Ichan-Qala, with its extraordinary colonnade of 213 individually carved wooden columns, stands among the oldest and most singular architectural monuments in Central Asia.

The Kokand school, by contrast, attained renown principally in the domain of residential and palatial architecture, characterised by its elaborate *ganch* plasterwork and the application of richly coloured decorative panels. The architecture of this period directed greater attention towards vernacular traditions and climatically responsive residential design, as expressed most prominently in the *ayvon*-fronted dwelling house - a building type refined through generations of adaptation to local environmental conditions.

The Russian Imperial Period and the Amir's Palace in Kogon (Late 19th – Early 20th Century)

The arrival of the Russian Empire in the second half of the nineteenth century introduced European architectural styles - notably Neoclassicism, Eclecticism, and Art Nouveau - into the built environment of Central Asia. In cities such as Tashkent, Samarkand, and Bukhara, distinct "New Town" quarters were established alongside the existing historic fabric. Among the most remarkable monuments of this period is the palace constructed in the city of Kogon by order of the Emir of Bukhara, completed in 1895.

Designed by the Russian architect Aleksei Leontyevich Benois, the building represents a synthesis of Moorish, Arab, and Russian Baroque stylistic traditions. The interior arrangement and decorative programme of the palace combine traditional *ganch* plasterwork with distinctly European elements, including fireplaces, stained-glass windows, and an *enfilade* system of sequentially aligned rooms. The Kogon Palace is regarded as one of the earliest examples of the integration of Central Asian architecture into the broader currents of global cultural exchange.

Soviet Modernism and the Reconstruction of Tashkent (1966–1990)

The 1966 Tashkent earthquake marked a pivotal turning point in the city's architectural development. Within a remarkably short period, Tashkent was reconstructed in its entirety, becoming a testing ground for Soviet modernist architectural experimentation. The architecture of this period - exemplified by the Palace of Arts, the Tashkent Metro, and the Hotel Uzbekistan - is characterised by the extensive use of concrete, monumental formal compositions, and the transposition of national ornamental motifs onto prefabricated concrete panels.

Tashkent Modernism represents a distinctive synthesis of the International Style with local architectural elements, most notably the sun-shading lattice screen - the *panjara*. A considerable number of the buildings erected during this period are now receiving recognition as architectural heritage of significance, and scholarly research into their conservation has become an active and growing field of inquiry.

Contemporary Architecture: Digital Technologies and Sustainability (2020–2025)

During the years of independence, and particularly over the past five years, Uzbek architecture has attained a new level of technological and aesthetic sophistication. The Tashkent City and New Tashkent projects make extensive use of glass, steel, and smart technologies in the formation of contemporary metropolitan environments. Concurrently, Uzbek architects are collaborating with internationally renowned firms - among them Zaha Hadid Architects - to reinterpret national materials and geometric forms through the application of parametric design methodologies.

Two principal trends may be observed in the current period.

The first is sustainable - or green - architecture, characterised by the integration of passive cooling strategies inherited from historical building practice, including thick masonry walls and natural ventilation systems, with contemporary energy-efficient technologies.

The second is digital restoration, involving the application of Building Information Modelling and the creation of digital twins for the conservation of cultural heritage sites. In the restoration of historical monuments in Samarkand, for instance, artificial intelligence is being employed to reconstruct lost tilework patterns and to monitor the structural integrity of buildings in real time.

Discussion

Geometric-Proportional Analysis of Architectural Forms

The distinctive character of Uzbekistan's national architecture resides in its profound mathematical foundations. Research demonstrates that the architecture of the Timurid period was governed not by the golden section, but by root-based proportional systems - most notably the √2 and √3 ratios - which determined the visual equilibrium between a building's height, the width of its portal façade, and the dimensions of its courtyard.

As may be observed in the example of the Tillakori Madrasa in Samarkand, its external dimensions of 70 by 70 metres and its internal courtyard of 50 by 50 metres are founded upon the square - the *murabba* - a geometric form whose proportional harmony evokes in the observer a sense of repose and structural stability. However, in the construction of the Sherdor Madrasa between 1619 and 1636, the architects failed to account for the fact that the ground level of the Registan square had risen by some two metres over the preceding two centuries. As a consequence, the proportions of the Sherdor Madrasa appear somewhat compressed, or shortened, in relation to the Ulugh Beg Madrasa that faces it. This finding constitutes a significant illustration of the manner in which the accumulation of cultural strata in historic cities is capable of exerting a tangible influence upon architectural composition.

Table 1 Architectural Parameter Analysis of the Registan Square Ensemble

Parameter	**Ulugh Beg Madrasa**	**Sherdar Madrasa**	**Tilakari Madrasa**
Year of Construction	1417 -1420	1619 -1636	1646 -1660
Dimensions (metres)	~56 x 81	~70 x 70	70 x 70
Courtyard Dimensions	30 x 30	30 x 30	50 x 50

Principal Characteristic	Originally four towers; two preserved today	Bilateral symmetry	Harmonious with the adjacent Jome Mosque
Architect / Patron	Ulugh Beg	Yalangto‘sh Bakhodir	Yalangto‘sh Bakhodir
Decorative Style	Geometric star patterns	Animal figure (Tiger)	Gilded *kundal* ornamental decoration

Spatial Organisation and Ergonomics: The Role of the Courtyard and the Ayvon

In Uzbek national architecture, spatial ergonomics evolved directly in response to climatic conditions. Within the residential building, the courtyard - the *hovli* - constitutes the heart of the dwelling, functioning as the principal element for the regulation of the local microclimate. The *ayvon*, in turn, serves as the summer living zone - ergonomically the most suitable space for open-air social interaction and productive activity.

Research demonstrates that traditional *ayvon* structures were oriented towards the south or north in deliberate accordance with the angle of solar incidence. This orientation ensured the provision of shade during the summer months whilst admitting direct sunlight for the warming of interior spaces during winter. The application of these passive cooling strategies in contemporary design has the potential to reduce dependence on mechanical air-conditioning systems by as much as 30 to 40 per cent - a finding of considerable significance for the advancement of energy efficiency in modern architectural practice.

The Synthesis of Structural Materials and Ornamentation

In Uzbek architecture, structure and decoration have never been conceived as separate entities. Ganch plasterwork and glazed tilework served not merely as decorative treatments, but simultaneously as protective layers of the building fabric. Glazed tiles, for instance, shielded the underlying fired brick from moisture penetration and surface erosion.

The *girih* and *islimi* ornamental systems represent a symbolic expression of the infinity of the cosmos and of divine order. Geometric *girih* patterns are grounded in mathematical logic, whilst *islimi* - the vegetal arabesque - reflects a profound engagement with the natural world. Today, the application of these ornamental traditions to the façades of contemporary buildings - such as the congress halls of Tashkent City - through the medium of parametric and computational design is making a significant contribution to the recognition of Uzbekistan's national architectural identity on the international stage.

The Significance of Digital Technologies in Restoration

Contemporary restoration practice extends far beyond the manual relaying of brickwork. Through the application of geomatic methods - notably three-dimensional laser scanning - it is now possible to identify all structural deficiencies of a given object and to model them with precision in a digital environment. Research conducted at the Amir's Palace in Kogon

demonstrated that laser scanning enabled the detection of concealed cracks and wall deformations to millimetre-level accuracy.

Building Information Modelling technology, furthermore, opens new possibilities for the management of the restoration process. By establishing a comprehensive database encompassing every constituent element of a building - brick, glazed tile, and timber column alike - it becomes possible to plan systematically which components require intervention, at what stage, and with what materials. In addition, artificial intelligence is increasingly being employed to generate proposals for the digital reconstruction of lost architectural details on the basis of historical archival drawings and documentary sources.

Challenges in the Conservation of Architectural Monuments

The preservation of historical monuments is attended by a number of significant challenges. The first concerns natural factors, including seismic activity, salinisation, and the accelerating effects of climate change. The second pertains to inappropriate restoration methodologies - most notably the substitution of modern cement for original historical materials, a practice that impedes the natural breathability of the building fabric and accelerates its long-term deterioration. The third challenge is presented by the mounting pressures of urbanisation and tourism.

As may be observed in the cases of Khiva - specifically the Dishan-Qala outer city - and Bukhara, the construction of new hotels and tourist infrastructure carries the risk of irreparably compromising the integrity of the historic urban environment. For this reason, in accordance with the recommendations of UNESCO, it is necessary to implement the Historic Urban Landscape approach - a conceptual framework that advocates for the preservation of the historic city not merely as an assemblage of individual buildings, but as an integrated socio-cultural entity in its entirety.



Figure 2 Visual representation of parametric girih patterns applied to the façade of the National Library of Uzbekistan within the New Tashkent development project. Source: Directorate for the Construction of New Tashkent City.

Conclusion

Uzbek national architecture has, through an evolutionary process spanning several millennia, developed a consummate spatial-planning and aesthetic system of its own. The research has yielded the following principal conclusions.

First, Uzbek architecture represents a harmonious fusion of mathematical precision and artistic refinement. The system of domes and portal façades, together with the *girih* and *muqarnas* of the Timurid period, continues to the present day to stand as the highest expression of architectural thought, undiminished in its significance.

Second, the traditional courtyard, the *ayvon*, and the passive cooling systems of historical architecture constitute a ready-made technological model for contemporary green and smart building design. The application of these strategies in new construction projects would serve not only to enhance energy efficiency, but to ensure the ecological sustainability of the urban environment as a whole.

Third, digital technologies - including BIM, three-dimensional scanning, and artificial intelligence - must become the leading instruments in the conservation of cultural heritage. These technologies afford the means of transmitting historical monuments to future generations in an unimpaired state, preserved not only in their physical form, but in comprehensive digital formats.

Fourth, the synthesis of national tradition and international modernism in contemporary urban development - as observed between 2020 and 2025 - is giving rise to a distinctive new idiom of Uzbek Modernism, one that serves as a bridge between the past and the future.

In conclusion, the study and safeguarding of Uzbekistan's architectural heritage constitutes not merely a matter of national pride, but a fundamental condition for the country's sustainable economic and cultural development, the enhancement of its tourism potential, and the consolidation of its standing and prestige on the international stage.

This scholarly article is intended to serve the advancement of architectural science in Uzbekistan and to function as both a theoretical and practical reference for specialists in the field.

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