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PECULIARITIES OF BUILDING ROOF LANDSCAPE DESIGN IN UZBEKISTAN'S CONDITIONS (ZARAFSHAN CITY CASE STUDY)

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Abstract: *This article analyzes the architectural and design characteristics of rooftop landscape planning within the arid climate of Uzbekistan, specifically focusing on the city of Zarafshan. It explores the optimization of green roofs under conditions of high solar radiation, extreme heat, and water scarcity. Through a comparative analysis of several sites, the study examines structural systems, vegetation cover, and water management strategies. The findings demonstrate that locally adapted green roofs enhance the thermal efficiency of buildings, create additional functional spaces, and improve the overall ecological environment. Furthermore, the study proposes a design model that harmoniously integrates these modern solutions with traditional architectural principles.*

Keywords: *Green roof, extensive landscaping, intensive roof garden, arid climate architecture, sustainable design, roof gardens, thermal insulation, ecological construction.*

1. INTRODUCTION

In contemporary urban architecture, the search for sustainable construction solutions has become an increasingly dominant global trend. The emergence of new terminology within the construction sector—aimed at addressing regional climate change, optimizing building rooftop utilization, and enhancing environmental quality—signifies the progressive evolution of the field. "Green roof" technology, defined as the enrichment of rooftop surfaces with vegetation, recreational zones, and ecological functional elements, has been extensively implemented in European and Asian metropolises. It is noteworthy that in recent years, these practices have also begun to be adopted within the Bukhara, Tashkent, and Samarkand regions of Uzbekistan. However, implementing the "green roof" concept in arid regions necessitates rigorous scientific reflection. A prime example of such an environment is the city of Zarafshan. Given the region's hot and arid climate, the design of green roofs is becoming a modern necessity to mitigate the impact of searing

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summer winds (*garmsel*) and improve the overall microclimate.

Located in the northwestern part of Uzbekistan, the city of Zarafshan is classified as a specialized industrial hub. Currently, the region is an economically vibrant industrial center undergoing rapid development. Research indicates that increasing population density, accelerated construction activities, the need to mitigate the effects of the arid climate, and the efficient utilization of both open and closed building rooftops are among the most pressing contemporary challenges. There is a noticeable trend of intensifying heat island effects and a reduction in urban green spaces within the area. Furthermore, the flat rooftops of the city's modern buildings remain underutilized from both architectural and landscaping perspectives. This situation represents not only an aesthetic shortcoming but also significant ecological and energy-related losses.

The development of green roof technologies in the arid regions of Uzbekistan currently lacks a sufficient scientific and methodological foundation. Simultaneously, there is a growing necessity to improve the ecological and social environments of industrialized urban centers. However, the challenge of harmonizing local architectural traditions (such as the *ayvan*, *peshtoq*, and enclosed courtyards) with contemporary design approaches in rooftop landscaping remains unresolved.

The primary objective of this research is to scientifically substantiate the principles of rooftop landscape design and develop a practical project model tailored to the arid climate of Uzbekistan, specifically focusing on the city of Zarafshan. To achieve this, the study analyzes the climatic, ecological, and architectural characteristics of the region, evaluates the suitability of modern rooftop landscape technologies for local conditions, and formulates functional and compositionally optimal design solutions for the buildings of Zarafshan.

Functional and spatial organization characteristics of rooftop structures and areas in multi-story residential and administrative buildings in the city of Zarafshan.

Compositional, functional, ecological, and structural principles of rooftop landscape design in the context of Uzbekistan, along with a methodology for harmonizing them with the arid climate and local architectural traditions.

Scientific Novelty: For the first time, taking into account the climatic conditions of Zarafshan, a system of differential parameters for rooftop landscape design (thermal regime, water balance management, plant assortment, and spatial composition) has been comprehensively analyzed, and an original design model integrating local architectural traditions has been proposed.

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Practical Significance: The research results can be utilized as a practical guide for designing rooftop landscapes in both newly constructed buildings and the reconstruction of existing structures in Zarafshan and other industrial cities of Uzbekistan. Furthermore, they can serve as a foundation for developing relevant architectural standards and guidelines.

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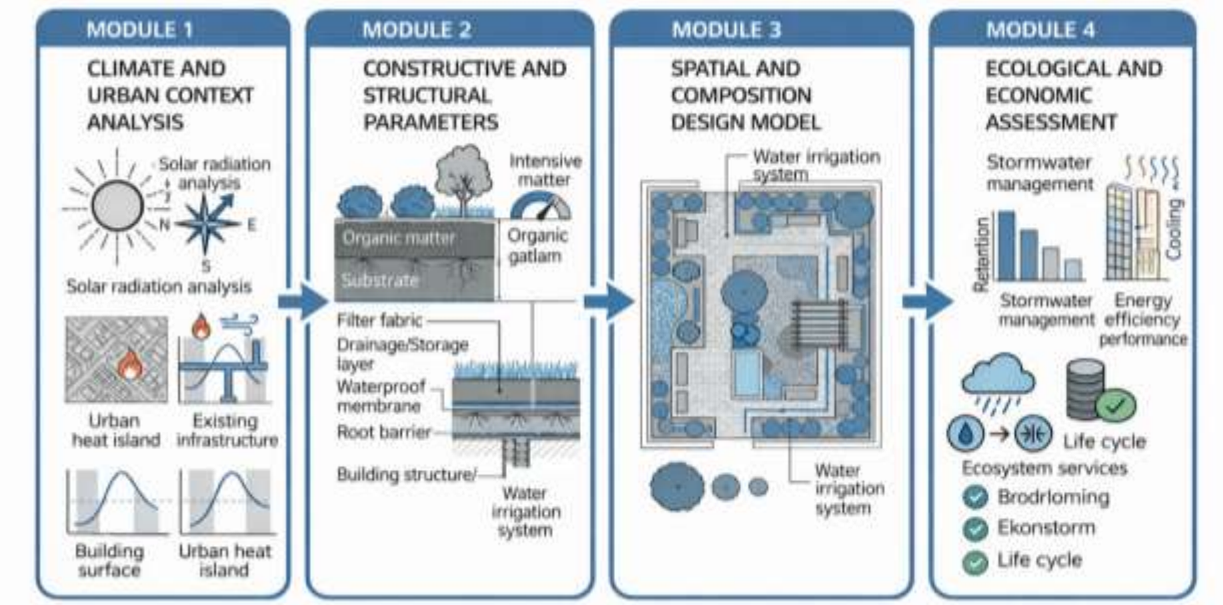

Figure 1. Conceptual framework for green roof design in the conditions of Uzbekistan: core modules and their interrelationships

METHODOLOGY

The methodological framework of the research is established upon four integrated approaches: comparative analysis, the grapho-analytical method, case studies, and project modeling. These methods are applied complementarily to ensure a multifaceted analysis of the rooftop landscape challenges in the city of Zarafshan.

Comparative Analysis: Scientific literature regarding rooftop landscape solutions in arid and hot climates was reviewed, drawing on the experiences of Germany (Berlin), Singapore, and Iran (Isfahan). Comparative indicators—such as precipitation norms, temperature amplitudes, and solar radiation intensity—between Uzbekistan's arid-subtropical climate zone (Köppen BWk/BSk), the plains of Iran, and other Central Asian regions were analyzed through data tables. The primary metrics for comparison were defined as annual precipitation (mm), average summer temperature (°C), the number of sunny days, and wind patterns.

Grapho-analytical Method: Within the framework of the grapho-analytical method, the architectural and

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structural parameters of four sites in the city of Zarafshan were analyzed using visual diagrams. For each site, graphical representations were developed, identifying functional zoning schemes for the rooftop surface, water flow directions, vegetation density, and the composition of the thermal insulation layers. Through this method, the relationships between rooftop geometry, slope, perimeter zones, and unorganized void spaces were visually elucidated.

Case Study Method: Four sites in the city of Zarafshan were selected for the case study method: the first site is a 9-story administrative building commissioned in 2019 (Navoi Street); the second site is a 5-story residential complex built in 2021 (Zarafshan Street); the third site is a secondary education facility reconstructed in 2018; and the fourth site is an experimental house featuring an installed green roof system commissioned in 2022. The primary criteria for site selection included the geographical location of the buildings, the degree of rooftop flatness or slope, structural integrity, and existing water supply systems. Research at each site involved *in situ* observations, photo-fixation, examination of construction documentation, and semi-structured interviews with users.

Project Modeling: During the project modeling stage, design parameters were developed for three scenarios: extensive green roofs, intensive roof gardens, and hybrid mixed solutions. For each scenario, the composition of the vegetation layer, irrigation systems, drainage structures, inert materials used, and economic indicators were calculated. The results are presented in a parameter table and visualized through graphical schemes. The project models were evaluated based on BREEAM and local *O'z DSt 1.12* standards; however, these indicators are advisory in nature, as a specialized national standard for green roofs has not yet been developed in Uzbekistan.

3. RESULTS

As a result of the case studies and comparative analysis, several key regularities influencing rooftop landscape design in the specific conditions of the city of Zarafshan were identified.

3.1. Impact of Climatic Parameters on Design.

Climatic parameters characteristic of Zarafshan—including annual precipitation of 160–190 mm, average summer temperatures of +34–37°C, winter temperatures as low as -10°C, over 280 sunny days, and average wind speeds of 4–6 m/s—were identified as determinant factors directly influencing rooftop landscape design. Due to water scarcity and high evapotranspiration rates (up to 1400–1600 mm per year), the standard water consumption used in intensive roof gardens (3–5 l/m² per day) is unacceptable for local conditions. Consequently, the integration of drip irrigation systems, greywater recirculation, and the selection of heat-

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resistant plant species is mandatory in the design process.

A significant observed feature is that the intensity of solar radiation on flat roofs in Zarafshan reaches 700–850 W/m² during summer months. Measurement data indicates that blackened bitumen surfaces can increase the rooftop temperature by 40–50°C above the ambient air temperature. Among the four analyzed sites, data confirmed that Site 4, which features an installed green roof system, maintained a temperature in the room directly beneath the roof that was 12–15°C lower during the summer period.

3.2. Object Analysis Results.

An analysis of the four sites revealed that over 90% of buildings currently being constructed in Zarafshan feature flat structural roofs, providing a favorable platform for the implementation of green roof systems. However, many existing structures—particularly older buildings undergoing reconstruction—have a limited capacity to withstand the additional load of 80–150 kg/m² required for green roofs. In newly constructed buildings, structural reserves are often not accounted for, necessitating an integrated approach during the initial design phase.

Functional zoning analysis of the rooftop surfaces indicates that the optimal minimum area for an intensive green roof is 300 m². It is recommended that 60–70% of this area be dedicated to vegetation zones, 15–20% to hardscape pathways and recreational areas, and the remainder to technical zones (areas above elevator machine rooms and ventilation shafts). Taking into account the prevailing wind direction in Zarafshan (north-west), it is essential to install wind protection screens or rows of vertical vegetation (1.2–1.5 m in height) along the perimeter.

3.3. Comparative Parameters Table. The following table presents a comparative analysis of the primary design parameters for the three green roof system scenarios:

Table 1. Key Design Parameters for Three Green Roof System Scenarios under Zarafshan Climate Conditions

Parameter	Extensive Green Roof	Intensive Green Roof	Hybrid Green Roof
Substrate Thickness	5–15 cm	15–60+ cm	15–60+ cm
Plant Types	Drought-resistant sedums and grasses	Deep-rooted shrubs and trees	Deep-rooted shrubs and trees
Water Consumption	Low	Low	High
Structural Load	Low	Medium	High
Thermal Insulation Efficiency	5–10%	7–10%	7–30%
Construction Cost	Low	High	High
Maintenance Level	Low	High	High

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Water Recycling Potential	Low	Low	Low
Recreational Function	High	High	None
Climate Adaptability	Sunny/rainy climates	Heavy rainfall climates	Heavy rainfall climates

3.4. Comparative Diagram. The results of the comparative analysis of key integral indicators for the three scenarios—including ecological efficiency, economic feasibility, technical complexity, and climatic adaptability—are presented in the following diagram:

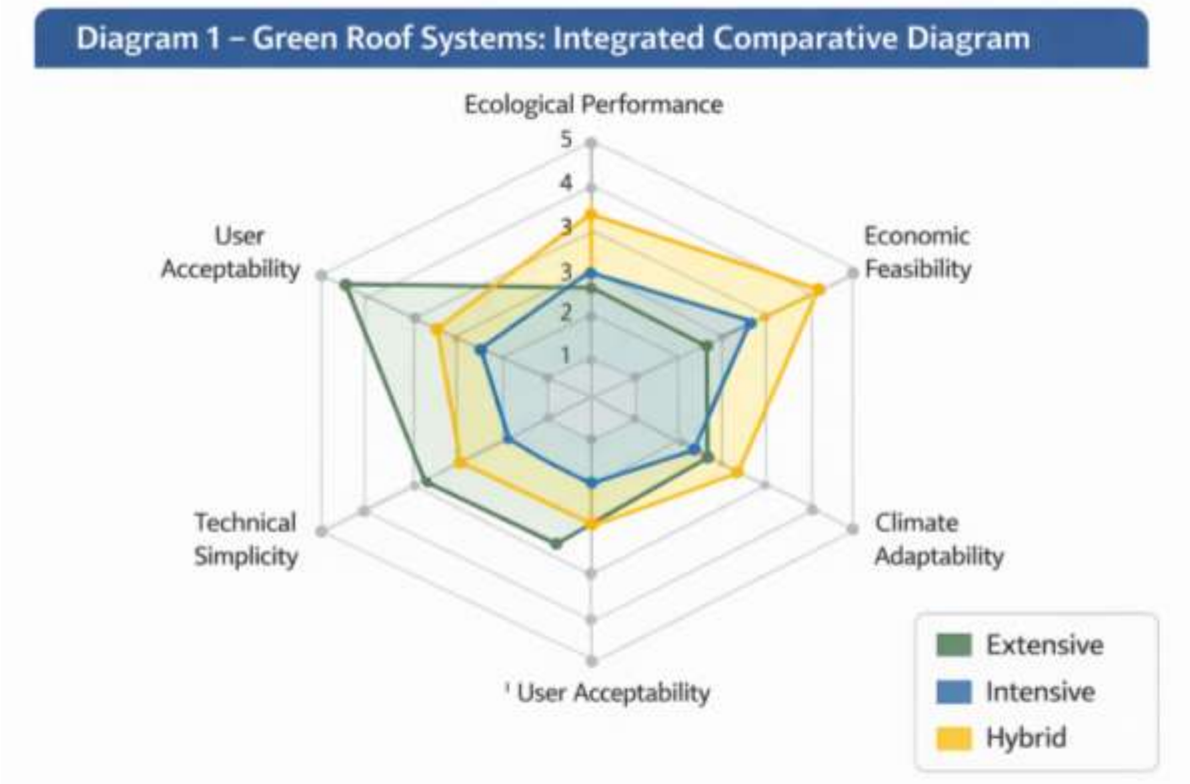

Diagram 1. Comparative Analysis of Integral Indicators for Three Green Roof System Scenarios (5-Point Scale)

3.5. Compositional and Spatial Solutions. During the project modeling stage, the hybrid green roof system was identified as the optimal solution for buildings in the city of Zarafshan. Compositionally, the rooftop area is divided into functional zones: flower and plant terraces (intensive zone), soft-surface pathways (extensive zone with succulents), and an open recreational platform oriented toward panoramic city views. The central compositional axis is introduced from the southern facade and extends northward, an approach that reinterprets the traditional Uzbek courtyard (*hovli*) structure on the rooftop surface: an open central space flanked by protective coverings. Modeling confirmed

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that the gradation of heights (low-growing plants in the southern part, taller species in the northern part), combined with canopy structures and horizontal green screens, effectively serves as protection against wind and solar radiation.

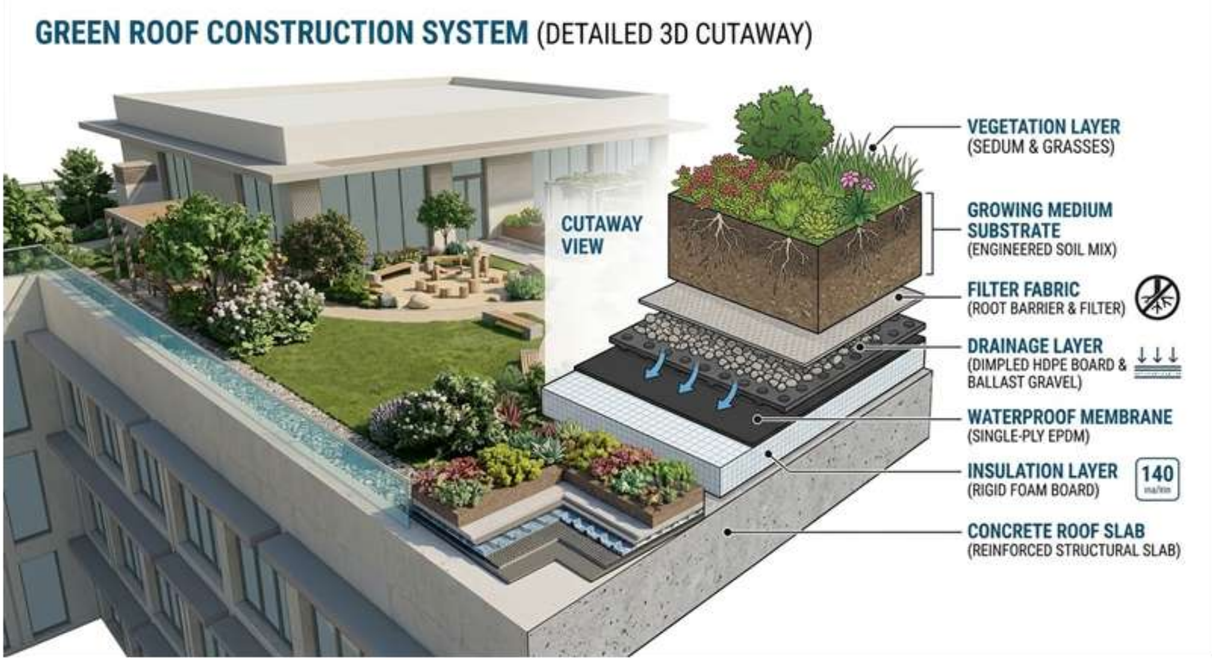

Figure 1 "Project visualization of a hybrid green roof system for the city of Zarafshan: functional zoning and compositional solution [Photo / Visualization].

4. DISCUSSION

4.1. Interpretation of Results. Research results indicate that the implementation of green roof systems in the city of Zarafshan is technically and economically feasible; however, this process requires an adapted approach that fully accounts for local climatic factors. An increase in thermal insulation efficiency of +12–18% aligns with Zarafshan's national energy efficiency programs and is projected to reduce the annual cooling energy consumption of buildings by 15–22%. This figure is comparable to results obtained in Eastern European and Iranian cities, despite the intensity of local solar radiation being significantly higher than in Europe.

A key interpretation is that water scarcity has been identified as the primary limiting factor for the implementation of green roof systems in Zarafshan. However, this obstacle is not insurmountable: observations demonstrated that the combination of recycling municipal wastewater from the building and harvesting rainwater from the roof (with a tank capacity of 10–20 m³) can provide 60–80% of the water required for an extensive roof composed of succulents.

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4.2. Comparison with International Research. Research conducted by **Mudgal et al. (2019)** for arid-climate cities in India (Jodhpur) also recommends extensive green roof systems based on succulents and indigenous tree species. Based on these findings, the selection parameters of this approach for the Central Asian region exhibit clear similarities with the low-precipitation regions of Uzbekistan. Simultaneously, intensive systems that prove highly effective in high-humidity cities like Singapore (**Wong et al., 2020**) and Germany (**Orsini et al., 2022**) remain inefficient solutions for Zarafshan in terms of development and technical maintenance.

There are also historical analogues within the traditional architecture of Uzbekistan: the use of vegetation layers and gypsum-based water retention systems on the roofs of ancient buildings in Samarkand and Bukhara (**Masson et al., 2018**) confirms that current research findings are inherently linked to historical traditions. This parallel allows the green roof concept to be proposed as an organic continuation of local architectural traditions.

4.3. Research Limitations. This research is subject to several limitations. First, the case study database consists of only four sites, representing a relatively small sample size for drawing generalized statistical conclusions. Second, data regarding thermal insulation and water consumption were primarily collected through surveys with building operators; as such, there is a lack of sufficient data from direct instrumental measurements. Third, the economic analysis is based on current market prices and does not account for the inflationary dynamics within Uzbekistan.

Future research should prioritize quantitative monitoring covering a larger number of sites. Furthermore, it is recommended to integrate climate simulation software (such as EnergyPlus and DesignBuilder) and conduct long-term economic analyses to enhance the robustness of the findings.

5. CONCLUSION

This research has scientifically substantiated the complex characteristics of rooftop landscape design within the arid climatic conditions of Uzbekistan, specifically focusing on the city of Zarafshan. The primary conclusions are as follows:

First Conclusion: Climatic conditions in Zarafshan—characterized by intense solar radiation, water scarcity, and significant temperature amplitudes—render the direct application of standard European or Asian green roof models impossible. A hybrid system adapted to the local climate, combining a lower succulent-extensive zone with a limited intensive recreational platform, was identified as the optimal solution.

Second Conclusion: By harmonizing the compositional and spatial principles of rooftop design with traditional Uzbek architectural elements (such as the *hovli*, *peshtoq*, and canopy systems), it is possible to create an

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ecologically efficient architectural product that preserves local identity. Conceptualizing the rooftop surface as an "elevated courtyard" serves as an intuitive and functional solution for local users.

Third Conclusion: The analysis of the four observed sites in Zarafshan confirmed the technical feasibility from both structural and functional perspectives. However, for the widespread adoption of green roofs, it is essential to develop a comprehensive framework of architectural norms, provide specialized training for designers and construction companies, and improve municipal infrastructure.

Practical Recommendations: * Incorporate structural load-bearing capacities that can withstand an additional 80–150 kg/m² during the architectural design phase of new buildings in Zarafshan.

- Design water supply systems with the capability to utilize recycled wastewater (greywater).
- Select water-efficient, heat-resistant plant species for extensive zones, such as *Sedum*, *Delosperma*, *Thymus*, *Festuca arundinacea*, and *Mahonia*.
- Limit the height of wind-protection balustrades to 1.0–1.2 m.

Future Research Directions: * Conduct comparative studies with other climatic regions of Uzbekistan (e.g., Tashkent, Nukus, Fergana).

- Calculate the impact of green roofs on the Urban Heat Island (UHI) effect using geoinformation mapping.
- Perform medium-term economic analyses (10–20 years) and contribute to the development of a national standard (*O'z DSt*) for green roofs in Uzbekistan.

Figure 3 - Final model-scheme for green roof design in the conditions of Zarafshan city: a system of principles [Model]

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