BG Pulse Journal USA

ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg

BG PULSE JOURNAL

# CLIMATE-RESPONSIVE ARCHITECTURAL AND PLANNING PRINCIPLES FOR MODULAR LOW-RISE RESIDENTIAL BUILDINGS IN UZBEKISTAN

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Doi: https://doi.org/10.5281/zenodo.24240998

**Abstract:** This article examines the architectural and planning organization of modular low-rise residential buildings under the diverse natural and climatic conditions of Uzbekistan. The study aims to systematize design principles that link climatic factors with the site layout, building orientation, plan configuration, functional zoning, and outdoor spaces of modular housing. The study analyzes the current national regulatory document ShNQ 2.01.01-22, an international report on climate risks in Uzbekistan, and scholarly literature on bioclimatic architecture, building and urban climatology, off-site/modular construction, and courtyard microclimates. The methodology combines regulatory document analysis, a systematic review of scholarly sources, an interregional comparative approach, and architectural-typological analysis. Based on the analysis, a conceptual design sequence was developed, comprising climatic data, architectural response parameters, modular configuration, functional organization, and assessment stages. The proposed approach seeks to adapt selected architectural elements to local climatic conditions while retaining the standardization potential of the modular system. The article does not claim quantitative energy-efficiency results; such conclusions should be verified at a subsequent stage using meteorological data, dimensioned design drawings, and calculation or simulation results.

**Keywords**: modular housing; low-rise residential buildings; climate-responsive architecture; architectural and planning solutions; bioclimatic design; passive strategies; building orientation; Uzbekistan.

**Abstract:** This paper examines architectural and planning approaches for modular low-rise housing under the diverse climatic conditions of Uzbekistan. It aims to organize design principles that connect climatic factors with site layout, building orientation, plan configuration, functional zoning and semi-open spaces. The study draws on the national climatic design code ShNQ 2.01.01-22, an international climate risk profile for Uzbekistan, and peer-reviewed literature on bioclimatic architecture, building climatology, off-site construction and courtyard microclimates. The methodology combines regulatory document analysis, a focused literature review, comparative climatic reasoning and architectural typological analysis. The resulting conceptual framework links climatic input data, architectural response parameters, modular configuration, functional organization and performance assessment. The paper does not claim measured energy savings or validated thermal performance; these require weather data, dimensioned drawings and subsequent calculation or simulation.

**Keywords**: modular housing; low-rise residential buildings; climate-responsive architecture; architectural planning; bioclimatic design; passive strategies; Uzbekistan.

## Introduction

Modularization in residential construction is an approach that enables the repeated use of structural or spatial units, coordination of manufacturing and assembly processes, and systematization of planning. Scholarly reviews of off-site construction identify manufacturing and assembly processes, structural connections, project management, and performance assessment among the principal research topics in this field [5]. However, the architectural quality of modular construction is not determined solely by the standardization of components. The positioning of modules, façade configuration, openings, outdoor spaces, and functional zoning should correspond to the climatic conditions of the site where the building is located.

Climatic indicators vary across the regions and seasons of Uzbekistan. The current national document defining climatic and physical-geological data for design is ShNQ 2.01.01-22. It specifies parameters used in the preparation of master plans, the design of building heating and ventilation systems, and the selection of construction materials [1]. The climate risk profile for Uzbekistan prepared by the Asian Development Bank (ADB) and the World Bank summarizes the country's climatic characteristics, natural hazards, the impacts of climate change, and adaptation priorities [2]. Accordingly, climatic data should not be considered separately from the initial architectural decisions in residential design.

In the field of bioclimatic design, V. Olgyay considers building orientation, air movement, site selection, and material properties in relation to climate [3]. B. Givoni, within the framework of building and urban climatology, analyzes the influence of climate on human comfort, building location, construction materials, and passive heating and cooling strategies [4]. These approaches provide a theoretical basis for identifying architectural variables that respond to local conditions while maintaining a standardized structural system in modular housing.

Courtyards, aivan/veranda spaces, shaded transitional spaces, and intermediate zones designed for seasonal use—features found in traditional residential architecture—can also be analyzed as spatial means of responding to climate. A scholarly review of courtyard microclimatic characteristics identifies solar exposure, humidity, and natural ventilation as key factors; the courtyard's length-to-height ratio is also noted as an important geometric indicator affecting its microclimate [6]. However, the effectiveness of such solutions should be examined separately for each location, geometry, and pattern of use.

The research problem lies in the need to harmonize structural standardization and regional climatic adaptation within a unified architectural and planning system for modular housing. The aim of this article is to systematize the principles for the climate-responsive organization of modular low-rise residential buildings in Uzbekistan on the basis of scholarly sources and national regulatory requirements.

Research questions:

- Which climatic parameters should be considered when designing modular low-rise housing in Uzbekistan?
- How are climatic factors related to building orientation, plan configuration, and functional zoning?

- How can courtyards, aivan/veranda spaces, and shaded intermediate spaces be integrated into modular architecture?
- What design sequence can ensure regional adaptation while retaining a standardized modular system?

**Main Body**

**2.1. Research Sources**

The regulatory basis of the study is ShNQ 2.01.01-22 [1]. This document was selected as the current regulatory framework defining the climatic and physical-geological parameters required for design in Uzbekistan. The Uzbekistan Climate Risk Country Profile prepared by ADB and the World Bank was used to establish the international context [2]. The theoretical sources analyzed include foundational publications on bioclimatic architecture and building climatology [3, 4], a scholarly review of off-site construction [5], and a research article on courtyard microclimates [6].

**2.2. Research Methods**

The study was conducted using four interrelated methods: (1) regulatory and legal analysis—to identify the role of national climatic standards in the design process; (2) scholarly literature review—to identify research perspectives on bioclimatic design, modular construction, and courtyard microclimates; (3) comparative systems analysis—to establish links between climatic parameters and architectural decisions; and (4) architectural-typological analysis—to conceptually assess the relationships among modular configuration, functional zoning, and semi-open spaces.

**2.3. Climatic and Architectural Indicators under Analysis**

The climatic input data considered in the study include outdoor air temperature, solar radiation, wind direction and speed, relative humidity, and seasonal variations. Their exact values should be obtained for the selected city and meteorological station from ShNQ 2.01.01-22 and the relevant official meteorological data [1]. No unverified intercity temperature table has been included in the present version of this article.

The architectural assessment criteria comprise the orientation of the building and its principal rooms; plan geometry and compactness; module dimensions and their connection sequence; functional zoning; façade openings; external shading; natural ventilation paths; and the placement of courtyards, aivan/veranda spaces, loggias, and other transitional spaces. These criteria were considered in conjunction with the climatic data.

**2.4. Scope and Limitations of the Assessment**

This study is a conceptual architectural analysis based on regulatory and scholarly sources. It does not claim that energy consumption, the heat transfer coefficient, indoor air temperature, or natural ventilation rates have been measured for a specific building. Calculating such indicators requires

dimensioned plans, elevations and sections, construction layers, window specifications, the north orientation, patterns of use, and relevant meteorological files.

## 3. Research Results




Figure 1. Residential concept based on a central courtyard, shading elements, and a modular volumetric composition. Source: project presentation provided by the author; conceptual visualization.

### 3.1. From Climatic Data to Architectural Decisions

Based on the analysis of the sources, a structured table was developed to link climatic parameters with architectural and planning decisions. The solutions presented in the table are not fixed prescriptions applicable to all regions; rather, they are design directions that must be verified against regulatory and meteorological data for each project site.

| Climatic parameter | Architectural impact area | Design solutions to be considered |
|---|---|---|
| Outdoor air temperature and seasonal variation | Building envelope, plan compactness, room layout | Thermal protection, seasonal-use zones, compact plan |
| Solar radiation | Façade orientation, windows and openings | External shading devices, screens, and balancing openings by orientation |
| Wind direction and speed | Natural ventilation and outdoor | Relative positioning of openings; wind-protected |

| | | |
|---|---|---|
| | spaces | courtyards and entrance areas |
| Relative humidity | Indoor microclimate and material selection | Ventilation, moisture-resistant construction layers and finishes |
| Seasonal use requirements | Relationship between indoor and outdoor spaces | Aivan/veranda, loggia, shaded walkway, and semi-open transitional spaces |

### 3.2. Conceptual Stages for Climate-Responsive Adaptation of Modular Housing

The analysis suggests dividing the design process into five consecutive stages. At the first stage, the climatic input data for the project site are identified. At the second stage, the corresponding architectural responses—orientation, plan geometry, shading, and ventilation strategies—are determined. At the third stage, the selected responses are integrated into the module dimensions and connection system. At the fourth stage, functional zones, courtyards, and semi-open spaces are organized. At the fifth stage, the project is assessed through regulatory verification, solar analysis, ventilation analysis, and, where necessary, energy simulation.

| Stage | Main content | Outcome to be verified |
|---|---|---|
| 1. Climatic diagnosis | Collection of temperature, radiation, wind, humidity, and seasonality data | Verified climatic dataset for the project site |
| 2. Architectural response | Selection of orientation, geometry, shading, and ventilation strategies | Several comparable plan and façade alternatives |
| 3. Modular integration | Adaptation of module dimensions, connections, and spatial combinations | Balance between structural standardization and climatic adaptation |
| 4. Functional organization | Arrangement of rooms, service areas, courtyard, and semi-open spaces | Functional and seasonal-use scheme |
| 5. Assessment | Regulatory verification, solar/wind analysis, and simulation where necessary | Design option validated through calculations |

### 3.3. Relationship between Standardization and Regional Adaptation

In a modular system, standardization can be applied to structural dimensions, connections, manufacturing sequences, and engineering interfaces. However, building orientation, external shading, the proportion of openings, entrance zones, courtyard configuration, and semi-open spaces may vary according to local conditions. Accordingly, a two-level approach is proposed for modular housing: a stable structural-modular core and an architectural envelope and spatial organization adaptable to the region.




Figure 3. Conceptual façade solution for modular housing, focusing on shading and material composition.




Figure 4. Spatial organization of courtyards and semi-open spaces.

**Discussion**

The proposed approach considers modular construction not merely as a manufacturing or assembly technology, but as an architectural system intrinsically connected to climatic conditions. Scholarly reviews of off-site construction show that technological, organizational, and performance-related issues have been widely studied in this field, while the integration of sustainability and other design approaches remains an ongoing research topic [5]. From this perspective, incorporating climatic data at the initial stage of modular planning is important.

The literature on bioclimatic design emphasizes the need to assess building orientation, solar protection, air movement, and material selection as interrelated factors rather than as isolated considerations [3, 4]. Research on courtyard microclimates also demonstrates the relationships among courtyard geometry, solar exposure, humidity, and natural ventilation [6]. Therefore, incorporating traditional courtyard and aivan/veranda elements into contemporary modular housing should not merely reproduce a historical image; their microclimatic function should be tested under the specific conditions of the project.

An important limitation of this article is that the current version does not include dimensioned design data, meteorological time series, or simulation results for a specific modular housing prototype. Therefore, the proposed stages should be interpreted as conceptual findings based on scholarly sources and regulatory requirements. They are not presented as quantitative proof of reduced energy consumption or as a definitive optimal solution for a particular region.

In the next empirical stage, several climatically distinct regions should be selected, meteorological data covering the same period should be collected for each, and a modular model with an identical residential program should be developed. Variables such as orientation, window area, shading geometry, and courtyard configuration can then be compared under controlled conditions, and solar exposure, natural ventilation, and, where necessary, energy consumption can be calculated.

**Conclusion**

When designing modular low-rise residential buildings in Uzbekistan, structural standardization should be considered together with regional climatic adaptation. The current ShNQ 2.01.01-22 serves as the principal national regulatory source for determining the climatic parameters of a project site [1], while the international climate risk profile provides a broader context for understanding the country's climatic characteristics and adaptation challenges [2].

Based on the analysis of scholarly literature, a conceptual design sequence integrating climatic diagnosis, architectural response, modular integration, functional organization, and assessment has been proposed. Within this approach, the structural-modular core is standardized to the greatest extent possible, whereas orientation, façade design, shading, openings, and outdoor spaces are adapted to the climatic conditions of the project site.

To determine the practical effectiveness of the proposed principles, future studies should conduct comparative calculations and simulations using official meteorological data, dimensioned drawings, construction layers, and patterns of use. This article establishes a methodological and conceptual basis for such empirical verification.

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