**Saya Sakenova, Dina Amandykova**

**(Almaty, Kazakhstan)**

**BIOCLIMATIC ARCHITECTURAL AND COMPOSITIONAL APPROACHES TO RESIDENTIAL DESIGN IN THE URBAN ENVIRONMENT OF ALMATY**

**1. Introduction**

The urban transformation of Almaty is accompanied by the rapid development of residential construction, including both high-rise housing complexes and low-rise club-style residences. The city’s continental climate—characterized by hot summers, cold winters, low humidity, and abundant sunshine—creates specific requirements for the organization of residential environments. The wind regime is dominated by northeast and southwest flows, which must be carefully considered in architectural design. In addition, Almaty's foothill landscape contributes to microclimatic heterogeneity, influencing temperature and wind conditions across different districts.

One of the most prominent trends of the past decade has been the active construction of low-rise club residences. Housing projects such as "The Hills Residence" in the Medeu District, "Arman Village" in the Nauryzbay District, and "Alatau Village" at the mountain foothills exemplify the integration of architecture into the natural context. These buildings typically have 2–4 stories, are oriented south or southeast, and feature well-designed internal navigation and courtyard systems. Their composition reflects principles of bio-oriented design: effective insolation, buffer zones, green roofs, natural materials, and areas promoting natural ventilationIncontrast, central parts of the city experience increasing densification through infill construction, often leading to the deterioration of microclimatic conditions. The contrast between low-rise, spatially thoughtful architecture and dense, climate-insensitive development highlights the urgent need to apply bioclimatic principles at the early stages of design.

The objective of this study is to identify which architectural and compositional solutions contribute to the bioclimatic efficiency of residential buildings in Almaty's unique context, and how these strategies can be integrated into contemporary sustainable design practices.

2. Materials and Methods

This research involves a comprehensive analysis of the compositional organization of residential buildings that have been constructed or are currently being designed in Almaty. The following methods were employed:

2.1. Morphological Analysis: Examination of the spatial structure, building forms, number of stories, articulation, and scale of architectural elements.

2.2. Insolation Analysis: Simulation of façade and interior lighting levels using local climatic data.

2.3. Aeration Analysis: Evaluation of ventilation efficiency and the interaction of development patterns with dominant wind flows (northeast and southwest).

2.4. Typological Comparative Analysis: Comparison of various residential layouts (linear, perimeter, block-based) based on their bioclimatic characteristics.

2.5. GIS and Remote Sensing Analysis: Assessment of density, spatial distribution, and thermal anomalies using satellite imagery and open-source data.

3. **Results**

The results indicate that buildings with well-planned south and southeast orientations provide better levels of natural insolation during the winter season. A compact spatial structure with internal courtyards helps to create wind-protected zones and improves heat retention. Perimeter block developments with landscaped inner courtyards proved to be the most effective in terms of bioclimatic parameters. In contrast, high-density configurations and inconsistent building orientations lead to local overheating and stagnation of air.

**1. Morphological Analysis**

**The Hills Residence (Medeu District):** The complex consists of low-rise blocks (2–3 stories) arranged in a terraced layout, adapted to the foothill terrain. The building volumes are visually fragmented, creating a pedestrian-friendly scale. The structures are placed along the slope with minimal disruption to the natural terrain, emphasizing organic integration with the landscape.

**Arman Village (Nauryzbay District):** The complex features a predominantly linear structure composed of two-story residential blocks. The volumes are orderly, and the façades are segmented into simple geometric forms. The layout is open, emphasizing visual and physical connections with green spaces.

**Alatau Village (at the foothills):** A variable block structure of buildings ranging from 2 to 4 stories in height. The architecture emphasizes horizontal composition. Inner courtyards and transitional spaces (arcades, terraces) create gradients between interior and exterior environments(Figure 1).

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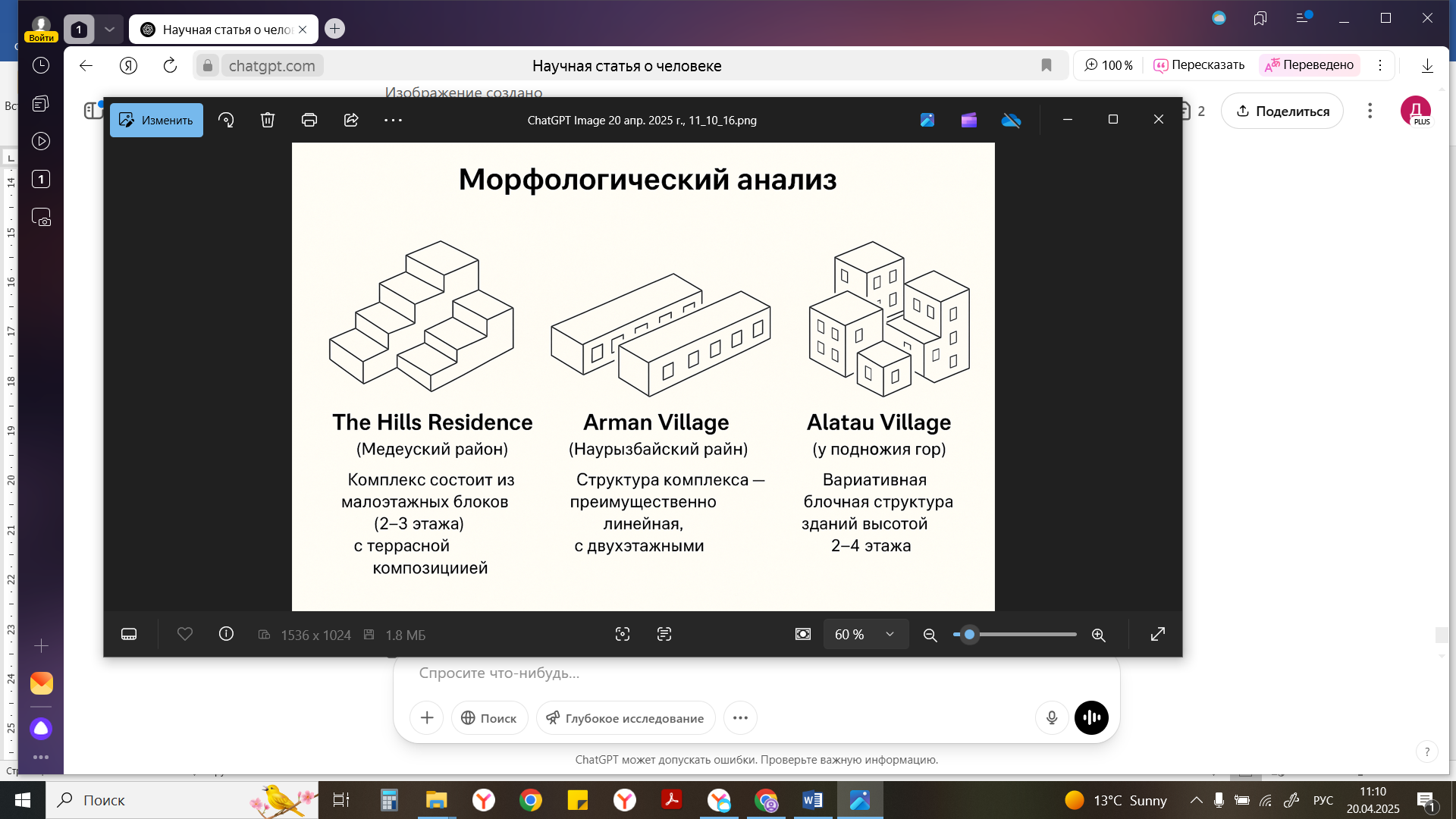


Figure 1.**Morphological Analysis**

**2. Insolation Analysis**

**The Hills Residence:** The residential blocks are mainly oriented to the south and southeast, providing optimal insolation during the colder season. Large window openings and horizontally staggered façades allow for deeper penetration of sunlight.

**Arman Village:** Insolation is balanced. The spacing between buildings is sufficient to prevent self-shading. Façades use canopies and overhangs to reduce summer overheating.

**Alatau Village:** The composition is designed to ensure that most residential spaces receive morning and daytime sunlight. Glass façades and suspended glazing elements are combined with shading elements and vegetation to control overheating(Figure 2).

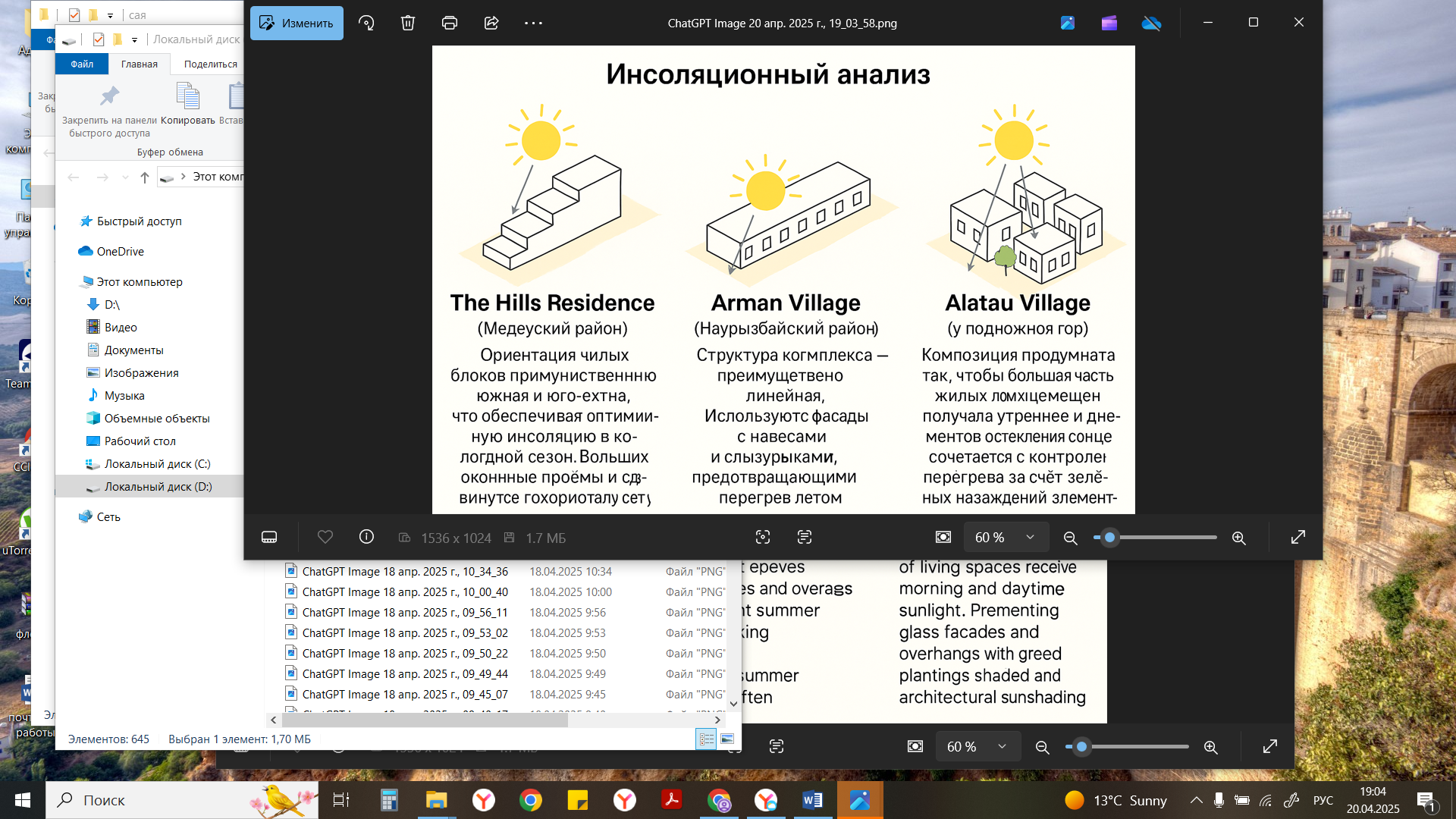


Figure 2.**Insolation Analysis**

**3. Aeration Analysis**

**The Hills Residence:** The slope placement and varied elevation facilitate natural ventilation. Moderate building density preserves cross-ventilation corridors-oriented northeast–southwest.

**Arman Village:** Internal driveways and park axes follow the prevailing wind directions, enhancing airflow. Open-type courtyard ventilation is supported by low-density development.

**Alatau Village:** Open zones between blocks and the radial arrangement relative to the terrain promote airflow. Low density positively impacts microclimatic conditions(Figure 3).

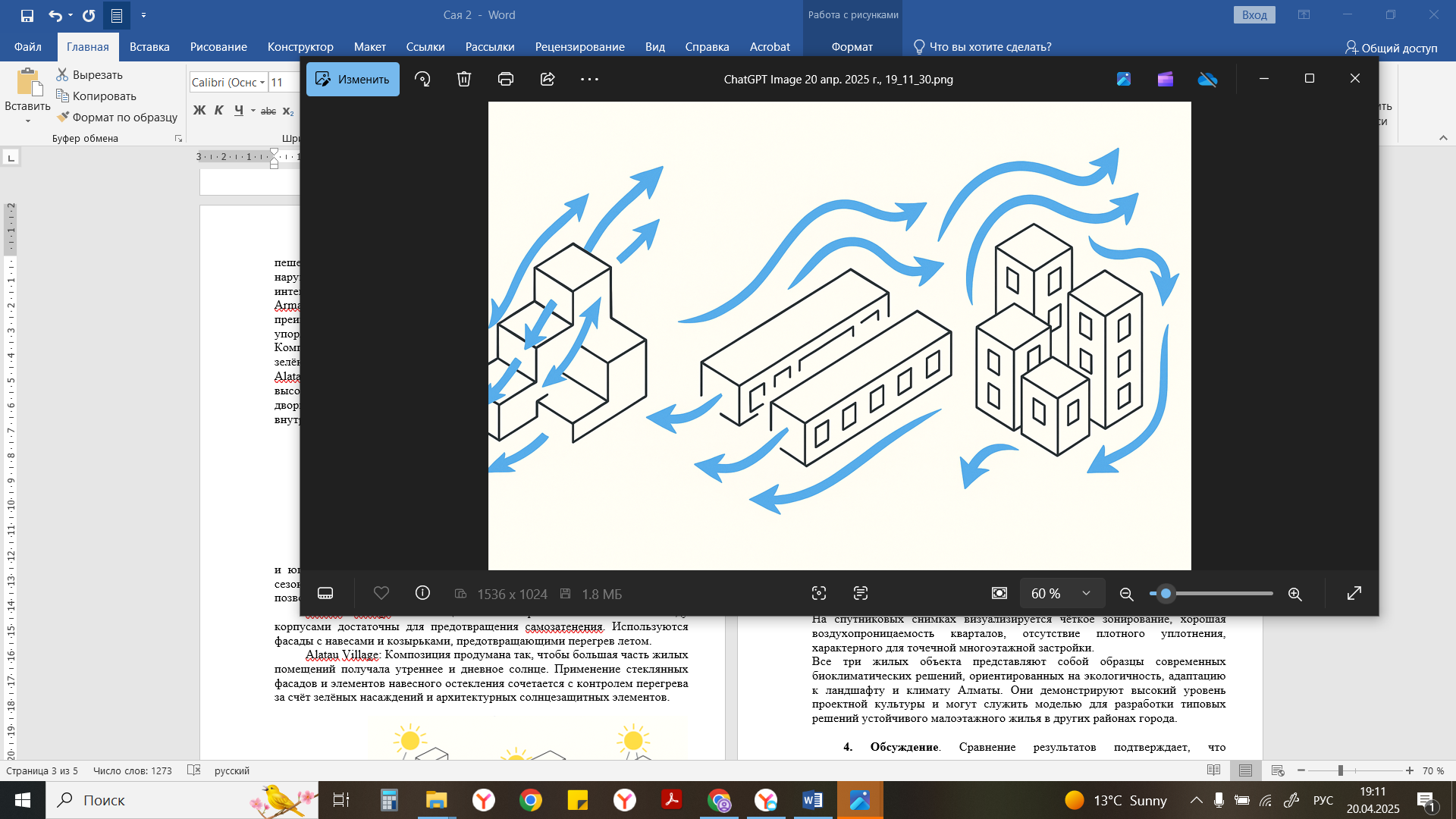


Figure 3. **Aeration Analysis**

**4. Typological Comparative Analysis**

**The Hills Residence:** A mixed layout—terraced and partially linear. Suitable for sloped sites. Bioclimatically efficient due to stepped configuration.

**Arman Village:** Predominantly linear scheme, with clear orientation and regular façade rhythm. Ensures a good balance of insolation and ventilation.

**Alatau Village:** Perimeter-block layout with elements of courtyard planning. Forms enclosed inner yards protected from wind, allowing for microclimate management within clusters.

**5. GIS Analysis and Remote Sensing**

According to open-source satellite data (Google Earth, Sentinel), all three sites:

Are located in low-density development zones;

Show low levels of thermal anomalies (unlike central Almaty areas);

Contain a high proportion of greenery and open spaces;

Exhibit clear zoning and good air permeability on satellite imagery;

Lack the dense infill typical of high-rise point developments.

All three residential developments represent examples of modern bioclimatic design, oriented toward environmental sustainability and adaptation to the landscape and climate of Almaty. They demonstrate a high level of design culture and can serve as models for developing standard solutions for sustainable low-rise housing in other areas of the city.

**4. Discussion**

Comparison of different development patterns confirms that architectural composition directly influences not only the indoor microclimate but also the formation of the external environment, including ventilation, insolation, and thermal comfort in adjacent open spaces.

Terraced forms, such as those in The Hills Residence, promote efficient use of natural topography, which, combined with bioclimatic strategies, significantly reduces heat loss in winter and overheating in summer. Airflows freely circulate between stepped levels, while southern façade orientation ensures high-quality insolation. This is particularly valuable in the complex terrain of Almaty's foothill zone.

Linear layouts, as seen in Arman Village, provide an optimal balance between structural simplicity and effective natural ventilation. Repeating modules with consistent orientation allow for climate control at both building and neighborhood scales. This solution is particularly efficient in areas with predictable wind patterns and limited development space.

Conversely, perimeter-block clusters such as in Alatau Village provide protection of interior spaces from adverse external conditions (wind, noise, dust), creating favorable conditions for comfortable inner microclimates. However, there is a risk of reduced natural airflow and excessive shading, especially in dense developments without proper consideration of climatic and geographic factors.

International studies (Emmanuel, 2005; Givoni, 1998) confirm the universality of these principles, showing that climate-adapted architectural forms in various regions reduce energy demands for heating and cooling, while increasing comfort and resilience in urban environments.

The specificity of Almaty lies in its combination of a sharply continental climate and foothill landscape. Accurate adaptation of architectural solutions to these complex natural conditions is crucial. Temperature fluctuations, strong mountain winds, and pronounced seasonality require a comprehensive approach—considering orientation, terrain, building density, and prevailing wind directions. In such conditions, the application of bioclimatic principles is not only desirable but essential for sustainable urban design and improving quality of life for city residents.

5. **Conclusion**

Architectural and compositional decisions play a fundamental role in shaping a **bioclimatically sustainable and energy-efficient living environment.** These decisions influence not only the aesthetic quality of the built environment but also key functional parameters such as **thermal comfort, natural lighting, ventilation, and protection from adverse climatic conditions**. The conducted analysis confirms that the choice of urban typology—whether terraced, linear, or perimeter-block—directly affects the microclimatic characteristics at both the building and neighborhood scales.

In the context of **Almaty,** with its**harsh continental climate, strong solar radiation, and complex foothill topography**, integrating landscape and climatic conditions into the design process is essential. It is particularly important here to **strike a balance between shielding from external environmental stressors and maintaining access to sunlight and natural airflow,** which requires careful attention to building form, orientation, and layout.

The study demonstrates that **integrating bioclimatic principles at the early stages of architectural design** not only enhances the overall quality of the living environment but also significantly improves the resilience of residential areas to climatic challenges. This approach reduces reliance on mechanical systems and energy consumption while contributing to the creation of healthier, more sustainable urban neighborhoods.

The findings of this research offer **practical value for architects, urban planners, developers, and sustainability professionals,** as they can serve as a foundation for developing **new planning standards and regulatory frameworks,** and for promoting the **wider adoption of bioclimatic strategies in architectural practice**. In the long term, this direction may become essential for the development of climate-adaptive cities, especially in light of global climate change and the growing need for resilient urban environments.

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