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Features of architectural environment formation: A case study of public spaces in the regional context of Northern Kazakhstan

Abstract. The purpose of the study was to analyse the changes in approaches to the design and organisation of urban environment by comparing architectural solutions of the past and the present. The study examined key elements of the urban environment, including parks, squares, embankments, squares and boulevards, and their role in improving the quality of life of the local population. The methodology included analysing climatic conditions such as temperature fluctuations, precipitation levels and wind activity, as well as their influence on the choice of building materials and architectural solutions. The main results showed that the use of modern heat and moisture resistant materials is important to ensure the durability of facilities in the harsh climate of the region. The paper analyses the formation and development of public spaces in the cities of Northern Kazakhstan with a focus on architectural solutions and spatial organisation of urban environment. Modern approaches to design, including integration of natural elements into the urban environment, creation of pedestrian zones and improvement of transport accessibility are studied. The efficiency of multifunctional spaces was assessed, and examples of reconstruction of public spaces in such cities as Kokshetau, Pavlodar, Petropavlovsk, Kostanai and Astana were analysed. The results of the study showed that the introduction of environmentally friendly materials and technologies contributes to the creation of a sustainable and comfortable urban environment. The paper concludes on the importance of creating inclusive spaces that take into account the needs of different population groups, thus improving the quality of life in the harsh climate of the region. The results obtained can be used to develop recommendations for improving public spaces in similar climatic zones

Keywords: multifunctional zones; integration of natural landscapes; sustainable development; inclusive environments; urban infrastructure; climate adaptation; cultural heritage

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INTRODUCTION

The formation of the architectural environment in the regional context of Northern Kazakhstan represents a complex challenge, requiring the consideration of both climatic and socio-economic factors. The region is characterised by harsh climatic conditions, including extreme winter temperatures, strong winds, and significant seasonal fluctuations in weather patterns. These natural features directly influence the choice of building materials, architectural forms, and technologies employed in the design of public spaces. Ensuring the sustainability and durability of structures becomes a key priority when creating an urban environment that provides comfort and safety for residents throughout the year. The study of architectural environment formation in Northern Kazakhstan has gained particular relevance in the context of changes occurring from 1991, when Kazakhstan gained independence, to 2024. Over this period, the urban environment has undergone significant evolution – from typical Soviet-era developments to modern solutions prioritising harmony with the natural surroundings and meeting emerging needs for the creation of comfortable public spaces (Schults *et al.*, 2016).

Existing studies provide theoretical insights and practical recommendations, contributing significantly to the development of this subject. In particular, the research of S. Donchenko & K. Samoilov (2020) on urban planning complexes in Almaty offer valuable perspectives on the processes of modernisation and the integration of architectural solutions, which are also relevant for cities in Northern Kazakhstan. The approaches described by G. Abdrassilova (2023) in her study of Soviet-era residential buildings emphasise the importance of preserving architectural heritage during the modernisation of urban spaces, a consideration that is equally pertinent to other regions with similar architectural features. The study by M. Kikimbayev (2023) on the creation of new public spaces illustrates contemporary design practices and their importance in establishing cultural and social hubs in the region.

S. Mamedov (2020) examines the principles of architectural and planning development of residential complexes within the changing social structure of cities in Northern Kazakhstan. The study highlights those transformations in the social structure directly influence architectural solutions, ensuring the functionality and aesthetic appeal of residential and public spaces. The research by A. Kornilova & A. Zeynullina (2021), which explores factors affecting the organisation of recreational zones in residential districts, complements this analysis by focusing on the selection of materials and technologies adapted to regional characteristics. The study emphasises that architectural solutions in Northern Kazakhstan must consider not only climatic factors but also social dynamics, such as population growth and increasing demands for quality urban environments. This approach is particularly important in the planning of public spaces, which must be both comfortable and multifunctional. G. Karabaev (2020) describes the use of spatial-structural modules as a means of optimising the design of public spaces in Northern Kazakhstan, where climatic conditions necessitate flexible and adaptive solutions to create sustainable and durable architectural structures. Existing research provides essential theoretical and practical foundations for the study of architectural transformations in the region. However, insufficient attention has been given to the formation of the architectural environment within the context of historical and cultural evolution, particularly concerning Northern Kazakhstan. The absence of a comprehensive approach that integrates the study of historical architectural solutions with contemporary trends represents a significant scientific challenge.

This study analysed the transformation of the architectural environment of public spaces in Northern Kazakhstan from a historical perspective. The research focused on comparing past and present architectural approaches to identify key trends influencing the development of urban spaces.

MATERIALS AND METHODS

A comprehensive approach to data collection and analysis was employed to achieve the research objective. The study focused on the landscape organisation of cities such as Kokshetau, Pavlodar, Petropavlovsk, Kostanai and Astana. Particular attention was given to analysing the development of public spaces, the reconstruction of historical sites, and the integration of modern architectural solutions into the urban environment, considering the region's climatic conditions. Specifically, the research examined projects involving the redevelopment of squares, the creation of new pedestrian zones, and the enhancement of riverfront areas. Evaluating the accessibility of public spaces for all population groups, including individuals with reduced mobility, played a crucial role, as it represents a key aspect of improving inclusivity within the urban environment.

The research methodology included an analysis of urban planning documentation, which facilitated the collection of information on the current state and reconstruction of public spaces in each of the cities studied. Particular emphasis was placed on the restoration of historical sites from the 19th and 20th centuries, as well as projects for the creation of new recreational areas such as parks, squares, and embankments. The architectural solutions and approaches employed in reconstruction and construction projects were examined, with special attention to the harsh climatic conditions of Northern Kazakhstan. The study utilised various materials, including the Resolution of the Government of the Republic of Kazakhstan No. 722 (2022) and the Master Plan of Astana City up to 2035 (Makhmetova *et al.*, 2022). International reports were also considered, such as the Climate Risk Country Profile: Kazakhstan (2021) and the Kazakhstan – country climate and development report (World Bank, 2021). Additionally, reports on strategic environmental assessments for the General Plan of Kokshetau until 2040 (n.d.) and the Profile of a smart sustainable city Nur-Sultan, Kazakhstan (2020) were incorporated.

The study included an analysis of modern construction materials such as metal, glass, and environmentally friendly composites used in the design of new structures. Particular attention was given to materials with high resistance to thermal deformation, which is essential in a continental climate characterised by sharp temperature fluctuations. The research also examined the implementation of energy-saving technologies, including thermal insulation materials, ventilation systems, and rainwater harvesting systems, which contribute to reduced energy consumption and the creation of a comfortable microclimate within buildings. Geographic Information System (GIS) technologies, specifically Quantum GIS (QGIS), were employed to visualise changes in public spaces. Using QGIS, zoning maps of public spaces and green areas were created for each city, enabling the representation of spatial changes and the impact of new projects on the urban environment. The maps were based on topographic data, ensuring precision in depicting the terrain and urban structure.

The research also developed a model framework for improving public spaces in Northern Kazakhstan, which included the creation of principles and approaches for designing more comfortable, environmentally sustainable, and accessible recreational and social interaction areas, tailored to the region's specific conditions. The model aimed to enhance the efficiency of urban land use and integrate modern technologies, allowing for the consideration of the needs of various population groups and ensuring the balanced development of infrastructure.

RESULTS

Public spaces in the cities of Northern Kazakhstan encompass a wide range of areas designed to meet the social, environmental, and cultural needs of residents. Parks and squares play a pivotal role, serving not only as recreational areas but also as essential ecological components of the urban environment. In a continental climate with extreme temperature fluctuations, the presence of green spaces and open areas contributes to improved microclimates. In summer, these spaces provide natural cooling through tree shade and evapotranspiration. They also mitigate the impact of pollutants, as green areas contribute to air purification and increased humidity levels, which is particularly important for cities located on the plains of Northern Kazakhstan, where climatic inversions often lead to stagnant polluted air.

Squares and boulevards serve as vital public hubs where pedestrian routes intersect and cultural and social events are organised. These spaces function as important transportation and communication nodes, providing access to key points within the city and fostering social interaction. In Northern Kazakhstan, where the climate can be harsh for a significant part of the year, squares are designed with the need for climate adaptation in mind. For instance, the presence of wind and snow-protected areas, combined with well-planned lighting and infrastructure, makes these public spaces more comfortable and accessible for use throughout the year.

Embankments and pedestrian zones constitute another significant category of public spaces, offering not only recreational opportunities but also enhancing the quality of the urban environment. These areas are a crucial part of the infrastructure of cities in Northern Kazakhstan, where natural conditions can vary from harsh winters to hot summers. Along these promenades, walking paths, resting areas, and spots for nature observation are created, contributing to a higher quality of life for residents. A key aspect is the integration of these spaces with the surrounding landscape, preserving the region's natural beauty and harmoniously incorporating them into the urban fabric. Embankments often become venues for city festivals, sporting events, and public gatherings, highlighting their importance as social and cultural hubs of urban life.

The climate of Northern Kazakhstan, characterised by its extreme continental conditions, significantly influences the selection of materials and design approaches. In such environments, thermal resistance and the ability of building materials to withstand extreme temperature fluctuations are of paramount importance. Winters in the region are marked by severe frosts, reaching as low as 48°C in the northeaster part, necessitating the use of materials with high frost resistance and the ability to withstand abrupt temperature changes. Conversely, summers can be very hot, with temperatures reaching 41°C, demanding materials with thermal stability to prevent deformation and damage caused by high temperatures. A key design approach in these conditions is considering the thermal properties of materials. To ensure efficient energy use and maintain a comfortable indoor climate, modern thermal insulation materials are employed to minimise heat loss in winter and overheating in summer. Ventilated facades also play a crucial role, allowing buildings to "breathe" and preventing moisture accumulation in the building structure (Zhangabay *et al.*, 2023).

Winds, frequently reaching speeds of 10-15 m/s, particularly in spring, impose additional constraints on material selection and design solutions. Constructing buildings in windy regions necessitates the use of materials and technologies that can withstand high wind loads. The prevalence of strong winds dictates the need for reinforced roof and facade structures to prevent damage and ensure the long-term stability of buildings (Bugaevsky *et al.*, 2020). In northern latitudes, the protection of buildings against wind erosion must also be considered, especially in areas with lower precipitation where soils can be susceptible to wind-driven erosion (Table 1).

Based on the provided climatic data, the influence of climatic conditions on material selection and design approaches in Northern Kazakhstan is linked to the need to consider extreme climatic conditions, including temperature fluctuations, precipitation, and humidity levels. Average monthly temperatures in Petropavlovsk range from 15°C in January to 20°C in July, indicating significant seasonal temperature variations. This necessitates the use of materials with high resistance to thermal deformations to prevent damage in both winter frosts and summer heat. Frost-resistant materials and effective thermal insulation solutions become essential for ensuring the longevity of buildings.

Table 1. Climate data for Petropavlovsk based on 30-year average figures

Month	Average monthly air temperature, °C	Average monthly precipitation, mm	Average monthly relative humidity, %
January	-15	13	81
February	-13.5	12	81
March		-5	15
April	6	24	66
May	14	28	59
June	18	46	62
July	20	68	66
August	18	49	67
September	11	29	71
October	3	25	76
November	-7	19	81
December	-13	13	82

Source: created by the authors based on the General Plan of Kokshetau until 2040 (n.d.)

The average monthly precipitation increases significantly during the summer months (reaching 68 mm in July), necessitating careful consideration of water-resistant and corrosionresistant materials to protect against moisture. Reliable waterproofing of structures and efficient rainwater drainage systems are crucial, especially during periods of heavy rainfall. Concurrently, the average relative humidity, fluctuating between 59% in May and 82% in December, impacts the durability of building materials, demanding the use of moisture-resistant coatings and corrosionresistant structures (World Bank, 2021).

In major cities of Northern Kazakhstan, such as Kokshetau, Petropavlovsk, and Astana, there is a growing trend towards improving the quality of the urban environment and enhancing residents' quality of life. For instance, in Kokshetau, the administrative centre of the Akmola Region, the focus is on creating spaces for public interaction and recreation, driven by its significance in transportation and tourism infrastructure. A key aspect of shaping public spaces in Kokshetau is preserving the natural landscape and integrating it into the urban fabric. Surrounded by picturesque forests and lakes, the city necessitates the incorporation of natural elements into the design of public areas. Parks, squares, and green spaces have become an integral part of the urban infrastructure, not only enhancing aesthetic appeal but also improving the ecological situation amidst rapid urbanisation (Brovina & Sallaku, 2024). Additionally, Kokshetau is actively developing multifunctional public spaces, such as squares and pedestrian zones, which play a vital role in the city's social life. These spaces are becoming venues for cultural and community events, such as festivals and exhibitions, fostering cultural engagement among residents and attracting tourists. A crucial element of these spaces is accessibility for all population groups, including those with reduced mobility, contributing to a more inclusive urban environment (General Plan of Kokshetau..., n.d.). The role of transportation infrastructure in the organisation of public spaces should also be noted. As a major transportation hub, Kokshetau requires special attention to ensure connectivity between public places and the city's main transport arteries. This necessitates the provision of comfortable pedestrian and cycling routes, enabling residents and tourists to move freely around the city and interact with various public spaces.

In the mid-1950s, spaces such as the Park of Culture and Recreation were established in Kokshetau, reflecting their importance in shaping the urban environment (Table 2). These areas, designed in the style of Soviet architecture with elements of classical design, are characterised by ordered forms and clear compositional lines. At that time, building materials such as brick and concrete were prevalent, reflecting an emphasis on durability and affordability. Functionally, these zones served as places for recreation and mass events, contributing to the development of the city's social life. However, in subsequent decades, they lost part of their infrastructure and green spaces, necessitating their renovation and adaptation to modern conditions.

Table 2. Analysis of new projects and reconstructions of public spaces in Kokshetau

Street/Object	Purpose	New projects/Reconstructions	Materials used
Park of Culture and Recreation	Recreation and public events	Renovation with restoration of green areas, creation of pedestrian routes	Natural materials (wood, stone)
Nazarbayev Avenue	Transport artery	Renovation with the improvement of transport infrastructure and landscaping	Asphalt, concrete, landscaping elements
Abylai Khan Avenue	New neighbourhood construction	Expansion with new residential and commercial buildings	Modern construction materials (concrete, glass)
Entrance Highway	Transport highway	Modernisation, expansion of pedestrian zones	Road surfaces, landscaping
Park on the shore of Lake Kopa	Coastal recreation area	Creation of forest park zones and a new business centre	Eco-friendly materials, glass, metal

Source: created by the authors based on the General Plan of Kokshetau until 2040 (n.d.)

Between 2015 and 2023, the reconstruction and creation of new public spaces in Kokshetau, including the refurbishment of entrance highways and the development of new districts, demonstrate a shift towards more integrated and multifunctional design. These projects consider not only social but also environmental, cultural, and transportation aspects. For instance, the General Plan of Kokshetau until 2040 (n.d.) envisions the creation of a business centre on the shores of Lake Koba, incorporating green spaces and boulevards. In this context, modern materials such as glass and metal are used to create lightweight structures adapted to the region's climate. A comprehensive study of architectural objects and public spaces in Pavlodar highlights their historical layering, where buildings from different eras coexist harmoniously. A crucial aspect is the preservation of the cultural and architectural value of old public spaces while modernising them using contemporary technologies and materials.

The organisation of public spaces in Pavlodar aims to harmonise natural and urban elements. Contemporary public spaces include the reconstruction of embankments, the creation of parks, boulevards, and squares, which cater to residents' needs for recreation and cultural leisure. Particular attention is paid to preserving the natural landscape within the city and adapting these spaces to modern standards of convenience and multifunctionality (Table 3).

Table 3. Analysis of renovations and modern public space projects in Pavlodar

Street/Object	Original purpose	New projects/Reconstructions	Materials used
Pavlodar Regional Museum of History and Local Lore	Trading house of merchant Artemy Derov	Renovation into a museum, preservation of the façade in the style of Siberian modernism	Brick, stucco, wrought iron grilles
Cathedral of the Annunciation	Religious building	New building constructed in 1999	Gilded domes, stone
Main Post Office	Main postal office	Renovation without altering major elements, tower with clock	Concrete, asphalt
Mashkhur Jusup Mosque	Religious building, built in 2001	Modernisation, addition of madrassas and cultural spaces	Modern materials, shanyrak, glass
Pavlodar Regional Drama Theater named after Chekhov	Trading house of merchant Surikov, later a cinema and infantry school	Renovation into a theatre, preservation of historical appearance	Brick, restoration of Soviet-style elements

Source: created by the authors based on D. Demidenko (2021)

The development of public spaces in Pavlodar demonstrates a balance between preserving cultural heritage and introducing innovative architectural solutions. Significantly, many of these reconstructions aim to create multifunctional spaces that meet contemporary standards of comfort and accessibility. An analysis of Petropavlovsk's architectural development reveals a multi-layered urban structure where historical buildings seamlessly coexist with modern architectural projects and reconstructions. Older parks and streets, such as Constitution Street (formerly Lenin Street), are essential elements of the city's architectural heritage, showcasing changes in styles, building materials, and functional characteristics. On this street, buildings constructed in the 19^{th} and 20^{th} centuries, including merchant houses, stand out for their use of traditional materials like brick and wood. These buildings not only served as residences but also functioned as commercial and community spaces, forming the core of the urban environment (Table 4).

Table 4. Analysis of new projects and reconstructions of public spaces in Petropavlovsk

Street/Object	Purpose	New projects/Reconstructions	Materials used
Siberian Trading Bank Building	Commercial bank, later administrative building	Central Department Store (CDS), façade renovation	Brick, modernised elements
Romanov School	Educational institution, later a school and technical college	Humanities and Technical College, preservation of historical appearance	Brick, restoration of original elements
House of Merchant Strelov	Trading house, later military enlistment office and general goods store	Museum, preservation of architectural monument	Brick, historical materials
Hotel "Kyzyl Zhar"	Hotel, once the city centre	Hotel modernisation, room and infrastructure updates	Modern building materials, glass, metal
Memorial to Military and Revolutionary Glory	Burial site for victims of the Civil War	Creation of memorial complex, addition of commemorative elements	Memorial materials, marble

Source: created by the authors based on Once upon a time: How Petropavlovsk has changed in 269 years (2021)

Petropavlovsk's architectural styles encompass elements of Siberian Modernism, as well as later Soviet architectural forms. Examples of merchant architecture, such as the House of Merchant Strelov, highlight meticulous attention to detail, including decorative wrought-iron grilles and stucco, indicative of rich finishes and high-quality construction. Such buildings reflect the multifunctional nature of the urban architecture of that time, combining residential and commercial functions. Contemporary trends in Petropavlovsk's architecture focus on preserving historical heritage while incorporating modernisation. For instance, the reconstruction of the "Kyzyl Zhar" Hotel, a significant building from the 1970s, showcases the use of modern building technologies and materials such as glass and metal, allowing the building to adapt to new conditions while retaining its original functions. Additional functional zones, such as restaurants and fitness centres, are created within modernised buildings, enhancing their appeal to both residents and tourists (Once upon a time: How Petropavlovsk..., 2021).

The development of public spaces in Petropavlovsk is focused on creating convenient and multifunctional zones for relaxation and leisure. The reconstruction of Constitution Street, one of the largest pedestrian zones in Kazakhstan, which took place between 2018 and 2020, exemplifies this approach. This car-free street has become a central venue for urban events and tourist activities, contributing to the city's cultural life. It is also important to note the modernisation of historically significant buildings, such as the former Siberian Trade Bank, which was renovated in 2019 and now serves as a central department store in 2024. New public space development projects include measures to improve transport accessibility, making the urban environment more comfortable for residents and visitors. The interaction between new public spaces and the natural environment, such as the streets along the Ishim River, helps to preserve the city's unique natural features. Thus, Petropavlovsk maintains a balance between preserving its historical appearance and introducing modern architectural solutions, creating a comfortable and attractive environment for living and leisure.

An analysis of Kostanai's urban development highlights the significance of historical, natural, and contemporary factors in shaping the city's architectural environment. The specific characteristics of construction along the Tobol River played a crucial role in the development of urban spaces, defining the structure of the city's-built environment. Early buildings were constructed from brick and wood, typical of 19th-century architecture. Notable examples include the real school and merchant houses, which reflect the classical architectural style and the use of local materials. These structures not only served as residences but also formed public spaces, becoming important elements of the city's central districts. In the 20th century, particularly during the period of intensive Virgin Lands campaign, Kostanai experienced significant population growth, leading to a substantial increase in high-rise construction. Among the buildings constructed between 1950 and 1970, the railway station and central department store are notable examples of functional Soviet architectural style. These buildings used materials such as concrete and glass, reflecting the construction approaches of that era. In contemporary times, the city's public spaces are developing with a focus on creating a comfortable environment for residents, including renovated residential complexes and squares (Table 5).

Table 5. Analysis of new projects and reconstructions of public spaces in Kostanai

Street/Object	Purpose	New projects/Reconstructions	Materials used
Central Square	Administrative centre of the city	Renovation to create a pedestrian zone, landscaping	Asphalt, concrete, decorative elements
"Airport" Microdistrict	New development on the site of Lake Tarelochka	Infrastructure renovation, creation of residential complexes	Modern materials, plastic, concrete

Table 5. Continued

Street/Object	Purpose	New projects/Reconstructions	Materials used
"Bereke" Microdistrict	New development in the north-western part of the city	Addition of recreational areas, improvement of drainage system	Asphalt, concrete, metal
"Yubileiny" Microdistrict	Mixed zone with industrial facilities	Improved transport accessibility, construction of residential and commercial buildings	Glass, metal, plastic
Square in front of the "Chemist"	Cultural centre of the city	Renovation of the square to create a public space	Concrete, decorative elements, glass

Source: created by the authors based on the Development Strategy of Kostanay till 2050 is being elaborated (2019)

Contemporary projects for developing new microdistricts, such as "Airport", "Bereke", and "Yubileiny", focus on creating housing complexes that take into account the region's natural and climatic conditions. The use of modern materials, such as glass, metal, and plastic, enables the construction of energy-efficient and durable buildings, meeting the demands of modern urban development. However, issues such as flooding and infrastructure shortages remain pressing and require further attention (Development Strategy of Kostanay…, 2019). A contemporary approach to reconstructing and creating public spaces aims to improve transport accessibility and integrate new developments into the city's natural landscape, thus preserving its unique character. Therefore, the development of Kostanai's architectural environment is based on preserving historical heritage and introducing modern architectural solutions, contributing to the creation of a comfortable and attractive urban environment for both residents and visitors.

Urban development in Kostanay is focused on preserving historical landmarks, renovating public spaces, and creating new residential complexes that meet contemporary architectural and environmental standards. A key element is the functional zoning of microdistricts (Fig. 1), which allows for diverse resident needs to be accommodated and ensures accessibility to residential, social, educational, and recreational areas. This contributes to the creation of a harmonious and comfortable urban environment, essential for the sustainable development of the city.

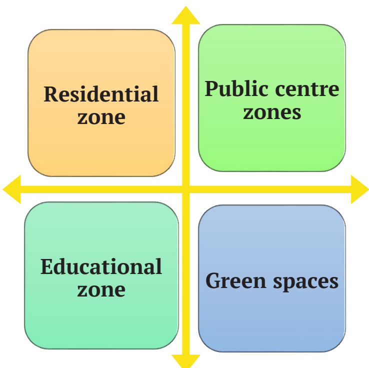

Figure 1. Functional zones in the urban development of Kostanai
Source: created by the authors based on the Development Strategy of Kostanay till 2050 is being elaborated (2019)

The residential zone plays a pivotal role in ensuring a comfortable living environment, accommodating a diverse range of housing types from multi-family apartments to single-family homes. Optimal building density and its distribution to other zones provide convenience for residents, minimising strain on the city's transportation network and improving accessibility to key infrastructure. This is particularly crucial for the effective planning of new residential areas.

Public centre zones encompass a range of commercial, cultural, and administrative facilities, providing various services. The even distribution of such centres across microdistricts is crucial, as it fosters the development of all city areas and reduces the strain on the central district. This ensures a balanced distribution of social activities and enhances the overall quality of the urban environment. Educational zones, including schools and kindergartens, provide accessible education within walking distance, particularly beneficial in the region's northern climate. Locating these institutions near residential areas reduces travel time, creating a more comfortable living and learning environment. Green spaces with recreational facilities are vital for improving the city's ecological conditions, providing opportunities for relaxation and sports activities. They contribute to better air quality, noise reduction, and comfortable outdoor recreation year-round, which is especially important in Kostanay's harsh continental climate. Thus, a comprehensive approach to Kostanay's development, incorporating modern architectural design and functional zoning, fosters a sustainable and attractive urban environment.

Astana's public spaces offer a unique blend of historical and contemporary architectural approaches, reflecting the city's evolution from a Soviet settlement to the modern administrative centre of Kazakhstan. Preserving the architectural heritage of the Soviet period, including the influence of its urban planning, is crucial for understanding the city's architectural development. For instance, structures like the late 19th-century Gostiny Dvor exemplify the typical building style of that era, characterised by the use of stone and brick. Public spaces of this period were distinguished by their functional purpose and commercial orientation, aligning with the economic needs of the time.

Astana's contemporary architecture is focused on innovation and harmonious integration with the natural environment. Projects such as the Baiterek monument, the

Palace of Peace and Reconciliation, and the Elbasy Library showcase pioneering architectural approaches, where technological advancements, modern building materials, and sustainability principles play a pivotal role. These structures symbolise the significant sociocultural and political changes occurring in the country and create new avenues for cultural and public life, transforming them into platforms for events, cultural development, and recreation. For instance, the Palace of Peace and Reconciliation integrates religious and cultural functions, underscoring the society's openness and diversity (Profile of a smart sustainable..., 2020).

A key characteristic of the new architecture is its seamless integration with the natural landscape and the use of environmentally friendly materials such as glass and metal, contributing to a sense of lightness and openness. Structures like Khan Shatyr exemplify the use of modern technologies to maintain a comfortable microclimate within the building, which is particularly important in the continental climate of the capital. Such architectural approaches not only foster the harmonious development of the urban infrastructure but also provide comfortable conditions for residents and visitors alike, taking into account the region's climatic features (Table 6).

Table 6. Comparative analysis of functional changes in public spaces

Aspect	Old architectural solutions	Modern architectural solutions
Functionality of public spaces	Integration into the urban environment	Multifunctionality: commerce, entertainment, leisure, meetings, social events
Materials	Use of traditional materials: stone, brick	Use of modern materials: glass, steel, concrete, environmentally friendly materials
Integration into the urban environment	Spaces that divided different parts of the city or had specific isolation	Complete integration with the urban environment, and creation of accessible public spaces

Source: created by the authors based on Profile of a smart sustainable city Nur-Sultan, Kazakhstan (2020)

Astana's early 20th-century built environment was primarily oriented towards commercial and administrative functions. Structures such as the Gostiny Dvor, Green Rows, and buildings owned by the Kubrin merchants played a pivotal role in the city's economic activity. They served as significant centres of trade and administration, meeting the city's economic and social needs. In contemporary times, the functionality of public spaces has expanded significantly, becoming more multi-faceted. These spaces are now geared not only towards commercial purposes but also towards social, cultural, and recreational aspects of urban life. Examples of such transformations can be seen in buildings like the Palace of Peace and Reconciliation and Khan Shatyr, which combine cultural, entertainment, and community functions. This fosters the creation of new focal points for both locals and tourists, enhancing social engagement and providing venues for interaction and leisure.

Historically, Astana's buildings were primarily constructed using brick and stone, ensuring structural integrity but often overlooking the region's specific climatic conditions, such as extreme temperature fluctuations and strong winds. Contemporary architectural approaches in the city have embraced the use of cutting-edge materials like metal, glass, and innovative composites, enhancing buildings' resilience to harsh weather. In particular, the implementation of energy-efficient technologies, as seen in the Elbasy Library and the glass facades of the Palace of Peace and Reconciliation, contributes to reduced energy consumption, thereby minimising the buildings' environmental impact on the urban setting.

Astana's successful integration of new architectural solutions into its urban fabric is evident in the harmonious blend of modern technology with historical and cultural motifs. For instance, the Khan Shatyr entertainment centre showcases a unique design reminiscent of traditional Kazakh yurts, underscoring the region's cultural identity. Another iconic landmark, the Baiterek monument, presents a symbolic architectural form that combines contemporary technology with elements of Kazakh mythology, creating a striking visual centrepiece in the city's landscape (Profile of a smart sustainable..., 2020). Beyond architectural innovations, significant greening projects have been pivotal in shaping Astana's contemporary development. For instance, Resolution of the Ministry of Ecology and Natural Resources of the Republic of Kazakhstan (2021) aims to significantly expand green spaces in Astana. By mid-2024, the "Zhasyl Kazakhstan" initiative led to the planting of around 200,000 trees and shrubs. These changes not only enhance the ecological sustainability of the capital but also ensure a harmonious blend of natural and urban environments, contributing to the city's appeal to both residents and tourists.

Figure 2, created using Quantum GIS (QGIS), aims to characterise the landscape organisation of Astana, with a particular focus on green spaces and the improvement of public areas. The map divides the city into various administrative districts, displaying their boundaries, which allows for a visual representation of the distribution of green spaces and greening efforts in each district. This mapping approach aids in urban planning and the development of environmental strategies by providing data on the spatial distribution of green zones to enhance public spaces.

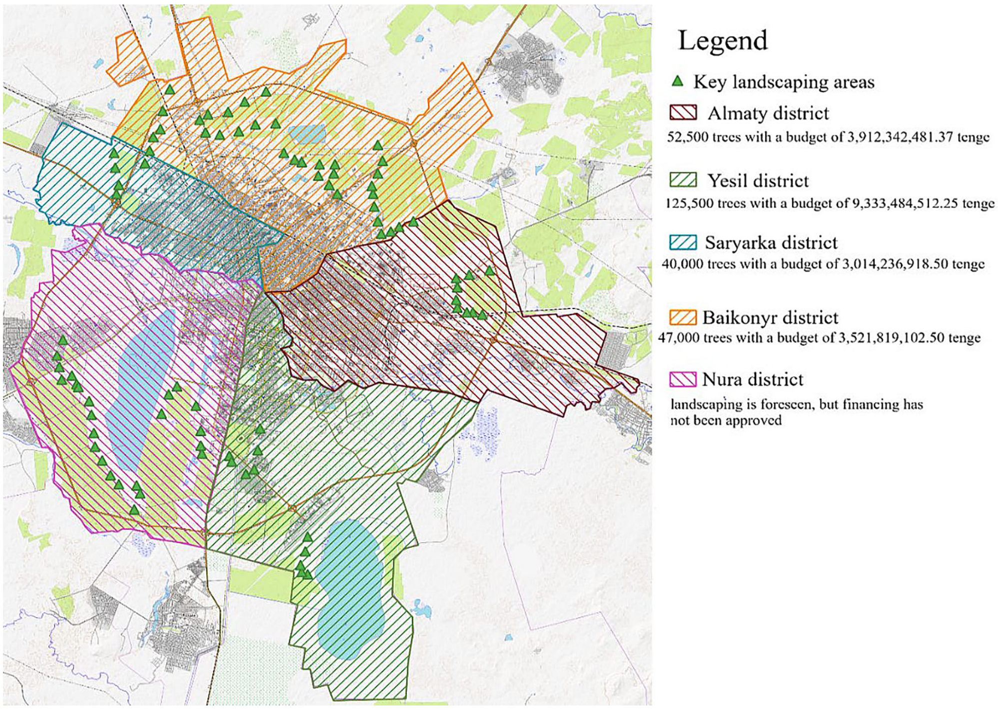

Figure 2. Zoning of Astana and the landscape organisation of green spaces
Source: created by the authors

The development of Astana's built environment requires consideration of the region's climatic and social characteristics. In a harsh continental climate with extreme temperature fluctuations and strong winds, the creation of covered pedestrian zones and windbreak green barriers is recommended. Public spaces must serve not only recreational but also cultural functions, fostering social integration. Contemporary projects should utilise environmentally friendly materials such as self-healing concrete and glass, and incorporate energy-saving technologies including solar panels and rainwater harvesting systems. A harmonious integration with the landscape involves creating green boulevards and providing easy access to public spaces, which may include developing cycling paths and eco-friendly transportation. These measures will enable Astana to combine comfort, innovation, and environmental sustainability within the context of its regional specificities. Therefore, developing a model for improving public spaces is crucial for the development of cities in harsh climates and with evolving social needs (Fig. 3).

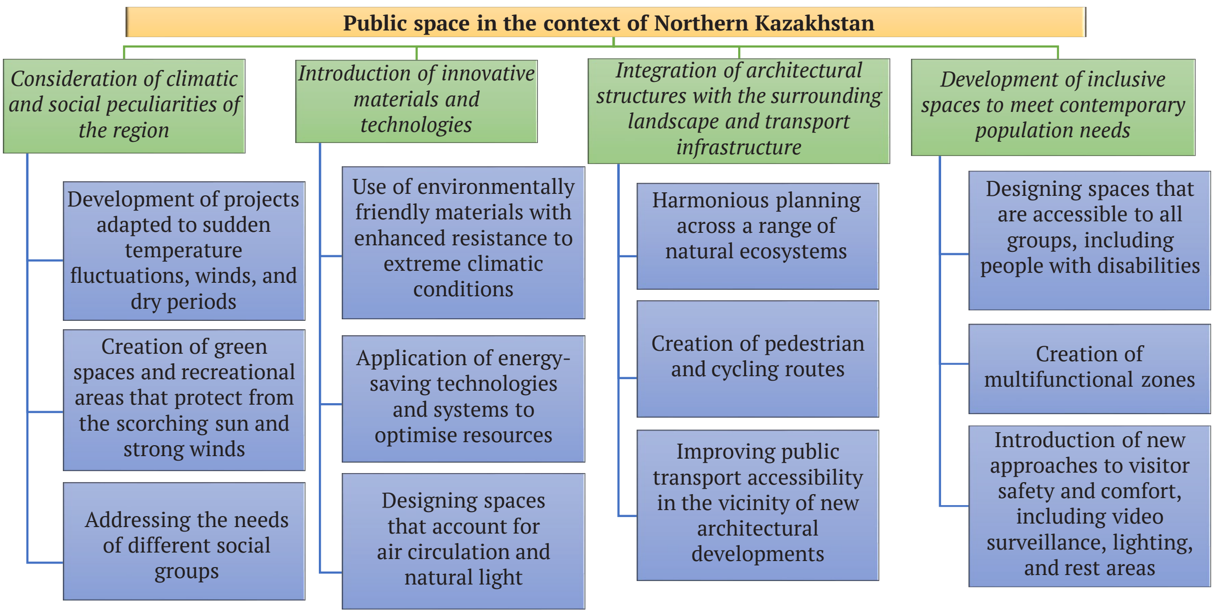

Figure 3. Structure of the model for improving public spaces in Northern Kazakhstan
Source: created by the authors

Adapting projects to extreme temperature fluctuations and climatic challenges can enhance the quality of life for residents and increase the resilience of urban areas to adverse natural conditions. The implementation of innovative materials and energy-efficient technologies helps reduce operational costs and minimise the environmental footprint, aligning with contemporary sustainable development goals. The harmonious integration of architectural structures with the natural landscape and transportation infrastructure improves accessibility and connectivity within the urban environment, creating comfortable conditions for citizens to move around and relax. A particular focus on the inclusivity of public spaces ensures that the needs of all population groups are considered, fostering social integration and enhancing the quality of urban interactions. Thus, this model represents a comprehensive approach aimed at creating a more sustainable and comfortable urban environment capable of addressing the challenges of climate change and the growing demands of society.

DISCUSSION

The contemporary context of rapid urbanisation, increasing urban populations, and climate change demands a comprehensive approach to planning urban areas in Northern Kazakhstan. It is crucial to consider not only socioeconomic but also environmental aspects, particularly in the region's harsh climate characterised by extreme temperature fluctuations, strong winds, and prolonged winters, which present significant challenges to the design and operation of public spaces. The integration of green infrastructure and the application of energy-efficient technologies can not only improve the microclimate but also enhance the overall resilience of the urban environment, making it more comfortable for living and development (Askaraliev *et al.*, 2024). This is particularly significant in regions with extreme climatic conditions, such as Northern Kazakhstan, where winters last for more than half a year and summer temperatures can exceed 30°C. Studies conducted in Lahore, Pakistan, by R. Khalid & M. Sunikka-Blank (2020) and D.H.I.L. Mohamed (2021) highlight the importance of efficient energy use in the residential sector. However, this research focuses on adapting these approaches to public spaces, which is particularly relevant for cities with cold and variable climates.

S.O.S.E. Ermgassen *et al.* (2022) proposed solutions to meet housing needs with minimal impact on ecosystems in England. These approaches can be adapted to Kazakhstan, where infrastructure development must balance economic growth with environmental conservation. In Northern Kazakhstan, where preserving unique natural landscapes and biodiversity is of strategic importance, it is essential to develop measures aimed at creating green corridors and urban green spaces, which can improve the microclimate and provide comfortable living conditions for residents. The specific local climatic conditions, including strong winds and significant temperature fluctuations, necessitate adaptive solutions to create sustainable green areas. E. Manahasa & O. Manahasa (2020) analysed the impact of socioeconomic changes on the built environment in Tirana, highlighting the role of societal changes in shaping the urban environment. In Northern Kazakhstan, similar processes related to migration, changes in employment structure, and adaptation to new economic conditions also influence the development of public spaces. However, there is a greater need to focus on environmental aspects here, as the transition to a market economy and urbanisation have increased the burden on natural resources and ecosystems. Adapting green spaces to harsh climatic conditions requires the use of specific plant species resistant to cold and wind, allowing for the creation of harmonious public spaces with minimal environmental impact (Kucherenko *et al.*, 2024).

This research highlights the significance of economic zones in driving urban development in Kazakhstan. E. Kumera & B. Woldetensae (2023) examine the impact of economic growth in Ethiopia's special economic zones on urban development. Unlike Ethiopia, Northern Kazakhstan requires stricter controls on preserving natural areas due to its vulnerable ecosystem, imposing additional constraints on economic growth. S. Kumar & H. Banerji (2022) and H. Sami Belmahdi & A. Djemili (2022) employ Bayesian networks to analyse urban resilience, enabling the quantitative assessment of urban areas' adaptive capacity. This study applies similar approaches to evaluate the resilience of public spaces while considering the region's cultural and social characteristics, facilitating the development of more tailored sustainability strategies. A. Senetra & P. SzarekIwaniuk (2020) and M. Wang *et al.* (2022) emphasise the importance of sustainable development in small towns, investigating the Cittaslow network in Poland. These approaches are beneficial for small towns in Northern Kazakhstan, but additional attention is needed to adapt greening methods due to the harsh climate and temperature fluctuations.

This study explores the potential for expanding green spaces in urban areas with limited space, which can improve the microclimate and create more comfortable living conditions for residents. B. Olczak *et al.* (2022) and G.C. de Mendonça *et al.* (2022) also highlight the use of agroforestry systems for landscape restoration, a practice that could be adapted to Kazakhstan's urban environments. C. Basnou *et al.* (2020) and A. Majewska *et al.* (2022) investigate the integration of green infrastructure within the EU, contributing to improved biodiversity in urban settings. This research adapts the principles of creating parks and green corridors to the specific conditions of Northern Kazakhstan, considering the continental climate and the need for green spaces to withstand extreme conditions.

The development of Astana's built environment necessitates a particular focus on adapting urban infrastructure to the harsh climate. This involves creating covered pedestrian areas, windbreak green barriers, and utilising innovative building materials and energy-efficient technologies, thereby enhancing quality of life and reducing heating costs. These findings align with those of K. Xu *et al.* (2020), who studied spatial planning for the restoration of agricultural landscapes, emphasising the importance of integrating green spaces into public areas. However, this research focuses on adapting agroforestry systems to the urban conditions of Northern Kazakhstan, enabling improvements to the microclimate in extreme weather conditions. The creation and development of public spaces in Northern Kazakhstan requires consideration of the region's specific climatic conditions to achieve optimal comfort. In this context, particular attention is given to creating wind-protected zones, using materials resistant to extreme weather, and adapting green spaces to the regional climate. These conclusions resonate with the study of Y. Chi *et al*. (2020), who focused on integrating ecological functions into urban planning. Unlike the aforementioned approach, this study emphasises the importance of creating zones capable of withstanding abrupt temperature changes and strong winds. Additionally, it highlights the significance of a multi-tiered approach to establishing ecological networks, thereby enhancing interactions between various urban ecosystems. These findings align with those of R. Caro & J.J. Sendr (2021) and Y. Yang *et al*. (2022), who proposed similar solutions for creating resilient urban spaces in China. However, this research adapts these methods to the harsh climate of Northern Kazakhstan. Incorporating a multitiered approach enables the creation of a more resilient urban environment that accounts for the region's specific characteristics and promotes sustainable development. Consequently, the study demonstrates that integrating green infrastructure in Astana and other cities in the region is a crucial component of sustainable urban planning. While similar to the conclusions of V. Hermoso *et al*. (2020) and Y. Hu *et al*. (2020) regarding the importance of green infrastructure, this research underscores the need for green spaces adapted to Northern Kazakhstan's extreme climatic conditions. This contributes to the development of cities in the region in line with sustainable development principles and improves the quality of life for local residents.

As of the second half of 2024, there is no consensus among scientists on the optimal approach to optimising public spaces in the extreme climate of Northern Kazakhstan. However, all the studies reviewed emphasise the need for a comprehensive approach that considers ecological, socioeconomic, and cultural factors. The implementation of energy-efficient technologies and the adaptation of green infrastructure to the region's climatic conditions enable the creation of a sustainable urban environment. Although researchers differ in the details of methods and priorities, it is clear that the resilience of urban spaces depends on the ability to integrate environmental, social, and technological approaches. To ensure sustainable development, it is essential to apply multi-level strategies that consider the specific climate and socioeconomic realities, thereby enhancing the adaptability of urban spaces to environmental changes and creating favourable living conditions in the harsh climate of Northern Kazakhstan.

CONCLUSIONS

This study analyses the formation and development of public spaces in the cities of Northern Kazakhstan, considering climatic, social, and architectural factors. It has been established that public spaces, including parks, squares, and promenades, play a significant role in creating a comfortable environment for residents in conditions of a sharply continental climate. Quantitative data, including average temperature and precipitation levels in cities such as Petropavlovsk, indicate the need to account for extreme climatic conditions during the design process. For instance, the average annual temperature ranges from 15°C in January to 20°C in July, influencing the choice of materials and design approaches for buildings and public areas. This also applies to the increased precipitation in summer, which necessitates the use of waterproof materials and drainage systems. Renovations and new projects in cities such as Kokshetau, Pavlodar, and Astana demonstrate a shift towards an integrative approach that combines social, environmental, and cultural aspects.

The findings underscore the significance of employing modern materials such as glass, metal, and eco-friendly components to ensure the durability and energy efficiency of architectural solutions. This not only reduces operational costs but also minimises environmental impact, which is particularly relevant for regions with harsh climates. Additionally, the role of green spaces is crucial in improving air quality and creating comfortable recreational environments.

Limitations of the study are related to the availability of detailed climatic and economic data for individual cities and the ability to accurately model the impact of climate change on architectural planning. This has affected the ability to formulate universal recommendations for all settlements in the region. Future research should expand the database to include more cities and consider the impact of modern technologies on improving the energy efficiency and environmental sustainability of architectural solutions.

Recommendations for further research include developing models for adapting public spaces to climate change using GIS technologies. This will enable the assessment and prediction of the effectiveness of various architectural solutions under changing climatic conditions. Additional focus should be placed on analysing the inclusivity of public spaces to ensure accessibility for diverse populations and improve the quality of social interaction.

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CONFLICT OF INTEREST

None.

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Особливості формування архітектурного середовища на прикладі громадських просторів у регіональних умовах Північного Казахстану

Анотація. Мета дослідження полягала в аналізі змін підходів до проєктування та організації міського середовища, шляхом порівняння архітектурних рішень минулого і сьогодення. У процесі дослідження було вивчено ключові елементи міського середовища, включно з парками, скверами, набережними, площами та бульварами, а також їхню роль у поліпшенні якості життя місцевого населення. Методологія включала аналіз кліматичних умов, таких як температурні коливання, рівень опадів і вітрова активність, а також їхній вплив на вибір будівельних матеріалів та архітектурні рішення. Основні результати показали, що використання сучасних термостійких і вологостійких матеріалів є важливим для забезпечення довговічності об'єктів в умовах суворого клімату регіону. У роботі проведено аналіз формування та розвитку громадських просторів у містах Північного Казахстану з акцентом на архітектурні рішення та просторову організацію міського середовища. Досліджено сучасні підходи до проектування, що включають інтеграцію природних елементів у міське середовище, створення пішохідних зон і поліпшення транспортної доступності. Проведено оцінку ефективності багатофункціональних просторів, а також проаналізовано приклади реконструкції громадських місць у таких містах, як Кокшетау, Павлодар, Петропавловськ, Костанай та Астана. Результати дослідження показали, що впровадження екологічних матеріалів і технологій сприяє створенню стійкого і комфортного міського середовища. У роботі зроблено висновок про важливість створення інклюзивних просторів, що враховують потреби різних груп населення, що дає змогу поліпшити якість життя в умовах суворого клімату регіону. Отримані результати можуть бути використані для розробки рекомендацій щодо вдосконалення громадських просторів в аналогічних кліматичних зонах

Ключові слова: багатофункціональні зони; інтеграція природного ландшафту; сталий розвиток; інклюзивне середовище; міська інфраструктура; кліматична адаптація; культурна спадщина