



Typological features of design solutions for buildings in areas with the same background climate indicators

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Abstract. Accounting for climatic conditions in the design of buildings in urbanized areas is gaining practical importance, especially in the context of climate change and exacerbating extreme weather events. The purpose of the study was to systematize architectural and urban planning methods and techniques for protecting buildings from climatic impacts and to develop a classification of climatic adaptation tools by scale levels. The adopted qualitative and quantitative research approach includes literature analysis, case analysis of eight architectural objects from six countries representing four types of macroclimate, and an expert survey of 72 architects and designers. The results of the study outline the influence of macroclimate on the main parameters of development and demonstrate the importance of macroclimate-forming factors. Architectural objects are proposed to be classified into three groups: thermoregulation of site microclimate, thermoregulation of building microclimate, and resistance to extreme influences. A matrix of correspondence between seven types of weather and the recommended architectural and construction solutions is compiled. Substantiation is provided for the order of accounting for the impact of macroclimate in the design process: from the analysis of background factors to the identification of extreme impacts and then the assessment of long-term climatic changes.

Keywords: macroclimate, climatic conditions, weather type, macroclimate-forming factors, urban development, climate adaptation of buildings, thermal adaptation, bioclimatic architecture

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1. INTRODUCTION

Factoring in climatic conditions in construction gains particular importance when designing buildings for urbanized areas. The architectural, structural, and technological solutions of buildings should ensure a long service life under significant loads and impacts, including climatic ones [1, 2]. This attention to climate factors is especially warranted for the northern region of Kazakhstan, since the northern cities strongly differ from the south of Kazakhstan in their climate and natural features [3].

The architecture of the 21st century searches for methods and techniques to protect buildings from negative climatic conditions, relying on modern innovative engineering achievements in this area. Nevertheless, the analysis and application of the past and present experience of countries with different climates remains relevant [4-6]. In particular, this experience sheds light on the so-called "soft" means of protection, meaning natural and passive measures against the impact of climatic conditions on the building [7].

At the core of building design with attention to climatic conditions lies the principle of maximum adaptation to the natural environment, which produces architecture that aligns with the features of the natural ecosystem [8-10]. The design of the building should rely on an analysis of many aspects of the climate, as well as their daily and seasonal changes. Therefore, solutions for the climatic design of buildings rely on determining climate parameters and the possibility of their assessment. Climate assessment consists in determining the positive and negative impacts of various climatic factors and identifying the potential of the territory for rational use in construction [11-13].

Climate as a long-term weather regime in a given area (combinations of temperatures, humidity, precipitation, and the direction and speed of wind) can be assessed at three levels [14]:

Macroclimate – meteorological conditions on a significant territory of a planetary scale distinguished by common climatic characteristics, which are classified into the following types: arctic, antarctic, subarctic, subantarctic, temperate, subtropical, tropical, subequatorial, and equatorial (according to B.P. Alisov);

Mesoclimate (local climate) – climatic features of insignificant territories with relatively similar conditions (climate of the region, city, or city district);

Microclimate – characterizes small areas within the local climate (microclimate of a development area or premises) [15].

The present study will examine macroclimatic characteristics that give a first glimpse of the climate background of design, as well as the possibility of factoring in long-term forecasts of climate change during construction. From the point of the development of building architecture, it is useful to consider the experience of building construction in different macroclimatic conditions, because this analysis makes it possible to develop the typological features of design solutions for buildings in areas with the same background climate parameters [16].

As noted by Khromov and Petrosiants [17], the climate has long been associated with the angle (inclination) of the sun's rays to the Earth and the height of the sun, which depends on the latitudinal belt of the Earth. Deeper studies of the Earth's climate found that the conditions of climate formation are influenced by circulation factors (solar radiation, atmospheric circulation, and moisture turnover), the nature of the earth's surface (relief, the characteristics of the soil surface, snow, and vegetation cover), and the influence of the sea [9, 18].

Classifications of the Earth's climates proceed both from the immediate climatic characteristics (classification of W. Köppen) and the features of general atmospheric circulation (classification of B.P. Alisov) or the characteristics of geographical landscapes (classification of L.S. Berg) [19].

According to Mikheev et al. [20], construction climatology conventionally divides all types of climates on Earth into four types: cold, moderate, hot-dry, and warm-humid. The research of Saifudeen and Mani [21], Al-Shamiri Abdul Kader [22], and Ulrikh et al. [23] outlines the most universal urban planning conditions for each type of climate that deal with protecting humans from hypothermia and overheating, protecting the territory from wind, snow, dust storms, high humidity, and downpours, and ensuring the insolation of the territory [24].

The influence of climate is taken into consideration in many architectural and construction tasks: the choice of development area [25, 26], planning and design solutions [27-29], and the location of the building on the site, including orientation relative to the cardinal directions [30], illumination [31], insolation, and aeration [32].

Kuzhin [33] argues that the architecture of buildings and structures must be carefully considered at the stage of design and selection of materials, incorporating both the design and engineering perspectives based on all climatic conditions. Undesirable processes during the construction and operation of buildings and structures can only be prevented by forecasting and modeling all factors [34], resulting in a safe, comfortable, and functional building [35, 36].

The available climatic data should be analyzed both by architects and designers in order to assess the climate of the construction area and determine typological recommendations for the designed buildings [37, 38]. Practical construction recognizes seven types of weather based on different combinations of monthly average temperatures, humidity, and wind speed (hot dry, hot, warm, comfortable, cool, cold, and harsh) [39]. The classification of weather types has been applied to develop the operating modes of buildings, which provide general recommendations for the use of architectural, structural, and engineering tools in the design [40-42].

Notably, Nguyen et al. [43] highlight the main characteristics of the modes of operation of buildings in various types of weather. However, the issue of designing buildings taking into account climatic conditions and loads during their operation has not been sufficiently covered, although the importance of factoring them in has been stressed [44, 45].

The focus of the present study lies on one of the main problems of construction in urbanized areas – the analysis of the features of accounting for climatic conditions to increase the service life of buildings and structures and the systematization of existing architectural and urban planning methods and techniques for protecting buildings from climatic influences.

2. METHODS AND MATERIALS

To achieve the research goal, the study employed a qualitative and quantitative approach with three interconnected stages: literature analysis, case analysis of architectural objects, and an expert survey. Section 4 presents the results for each step (Tables 1-6) and the examples of buildings. Following this, section 5 discusses the data obtained in comparison with the analyzed literature, and theoretical and practical conclusions are formulated in section 6.

2.1. Literature Review and the Typology of Macrocclimate Factors

The systematic analysis of scientific publications and monographs covered domestic and foreign works on construction climatology, bioclimatic architecture, and urban planning. Based on the synthesis of the obtained data, macroclimatic conditions were classified by their impact on development parameters, and macroclimate-forming factors were categorized by the nature of their impact, positive or negative, on urbanized areas. The present study focuses on the macroclimatic level, approaching its impact on two scale levels of architectural solutions: the site level and the building level. Within each level, the adaptation tools were distinguished into the groups of thermoregulation and protection against extreme climatic influences (water, wind, and icing).

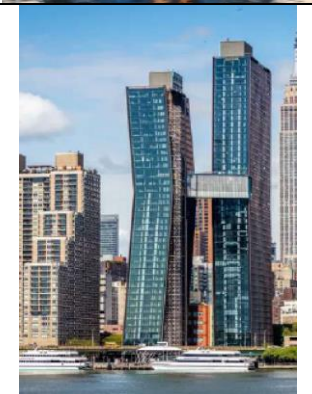
2.2. Selection and Analysis of Architectural Objects

The selection criterion was the presence of elements demonstrating the adaptation of the building to climatic conditions. The objects were identified through a review of professional literature and open architectural databases. Each object was examined in terms of compliance with the study problem and assigned to one of the three groups by the nature of climatic load and the scale of employed solutions. A total of 8 objects from 6 countries representing 4 types of macroclimate were selected (Table 1).

Table 1. Architectural objects comprising the empirical basis of the study.

Group 1. Thermal regulation of site microclimate		
Image	Description	Key adaptation technique
	AL-TAMEER Center, Riyadh, Saudi Arabia Macroclimate type – hot-dry tropical Climate risk – overheating, excessive insolation Scale – site	Complex plan configuration with passages and patios creating an extensive network of shadowed spaces
	University Mohammed VI Polytechnic, Ben Guerir, Morocco Macroclimate type – hot-dry Climate risk – overheating, direct insolation Scale – site	A canopy over the central courtyard creating controlled thermal conditions on the site
	Taroudant University, Taroudant, Morocco Macroclimate type – hot Climate risk – excessive insolation Scale – site	Covered arcades and passages between departments creating a continuous shady pedestrian network
Group 2. Thermal regulation of building microclimate		
Image	Description	Key adaptation technique
	Equator Tower (380 m, 80 floors), Kuala Lumpur, Malaysia Macroclimate type – hot equatorial Climate risk – overheating (35–45°C), excessive insolation, 24–40% humidity Scale – building	A retractable external screen made of reinforced fiberglass on a cable structure – passive protection of the glass from overheating
	O-14 (114 m), Dubai, UAE Macroclimate type – hot arid Climate risk – overheating, intensive insolation Scale – building	Perforated reinforced concrete exoskeleton (40 cm) + 1 m ventilation gap between the cover and the glass core

Continuation of Table 1

Group 3. Resistance to extreme climatic impacts		
Image	Description	Key adaptation technique
	Lakhta Center, St. Petersburg, Russia Macroclimate type – cold temperate Climate risk – ice formation, extreme frosts, wind load Scale – building	Mesh spire + electro-impulse de-icing + facade buffer zones + glazing heating
	Monad Terrace, Miami, USA Macroclimate type – oceanic Climate risk – hurricanes (category 5), flooding Scale – building	The ground floor raised by 3.5 m + hurricane-resistant structures + water removal pump system
	American Copper Buildings, New York, USA Macroclimate type – oceanic Climate risk – floods, storm surges Scale – building	Waterproof cladding of lower floors + protective park area + drainage perimeter + emergency power supply above the flood line

Source: original development.

The list of factors included in the expert survey questionnaire was formed by synthesizing the data from the literature review and the characteristics of the chosen objects, meaning that each of the four factors in Table 3 is present in at least one of the considered climatic contexts.

2.3. Expert Survey

At the second stage of the study, a sample of respondents was formed from among practicing architects and designers. Respondents were recruited via e-mail invitations outlining the purpose and program of the study. The resulting survey sample consisted of 72 experts.

The study participants were asked the following research question: "In your opinion, which of the following macroclimate-forming factors have the greatest impact on the development of urbanized areas?"

A rank and a weighting factor were calculated for each factor. The sum of the weights for all factors amounted to 1.00. The results were processed in MS Excel.

3. RESULTS AND DISCUSSION

3.1. Impact of Macroclimate on the Main Development Parameters

Proceeding from the literature analysis, data on the influence of five types of macroclimate on the parameters of urban development were systematized (Table 2).

Table 2. The influence of macroclimate on the development parameters of urbanized areas.

Climate type and characteristics	Development and planning	Technical solutions
Hot <i>dry equatorial, subequatorial, tropical</i> Overheating High humidity Frequent precipitation	Cardinal orientation, shadowed spaces, natural ventilation	Shadowing, aeration, air tightness, dust protection
Hot humid <i>equatorial, subequatorial, tropical</i> Overheating High humidity Frequent precipitation	Open development, maximum ventilation, multi-storey buildings	Shadowing, greening, protection against precipitation
Cold and harsh <i>arctic, antarctic, subarctic, subantarctic</i> Snow and wind Low temperatures Ice formation	Controlled confined areas, weather protection	Aerodynamic forms, special solutions for roofs, construction on supports
Oceanic <i>maritime, monsoon</i> Snow and wind Low temperatures Ice formation	Moderately open development, wide streets	Wind protection structures, protection against flooding
Temperate <i>temperate climatic zone</i> Temperature differences Precipitation Seasonal winds	Combination of open (summer) and closed (winter) areas	Active and passive heating systems, wind protection

For each type, we determined the characteristic climatic impacts, the corresponding features of development and planning, and appropriate technical solutions.

This data formed the typological framework for the subsequent analysis of objects and adaptations.

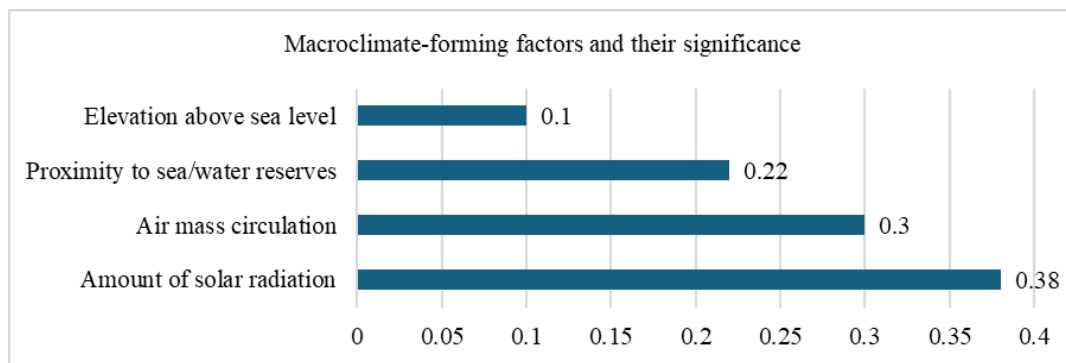
3.2. Macroclimate-Forming Factors and their Significance

The results of the expert survey (n = 72) indicate the significance of the four microclimate-forming factors affecting the development of urbanized areas (Table 3). The factors are ranked in descending order of the weighting factor.

Table 3. Macroclimate-forming factors influencing the development of urbanized areas.

Macroclimate forming factors	Positive influence	Negative influence	Rank	Weight
Amount of solar radiation	Access to renewable energy (solar)	Overheating or overcooling	1	0.38
Air mass circulation	Access to renewable energy (wind)	Destructive forces of typhoons, tornadoes Overheating or overcooling	2	0.30
Proximity to sea or ocean, fresh water reserves	Access to renewable energy (tidal energy) Access to water	Destructive forces of storms, tsunamis, floods	3	0.22
Elevation above sea level	Access to clean air	Overcooling	4	0.10

Source: original development

**Fig. 1.** Macroclimate-forming factors and their significance.

The highest weighting factor was given to the amount of solar radiation (0.38) and the smallest – to height above sea level (0.10) (Fig. 1). The total weighting factor for all factors amounts to 1.00, which confirms the accuracy of survey data processing. The weighting factors in Table 3 served as a basis for prioritization in the matrix of architectural solutions (Table 5).

3.3. Site and Building-Level Thermal Adaptations

The analysis of architectural objects and literary sources has allowed us to systematize the tools of thermal adaptation of buildings using vegetation and water at two large-scale levels: site and building (Table 4).

Table 4. Plants and water as building thermoregulation tools.

Object	Means of thermal adaptation	Methods of thermal adaptation
AL-TAMEER Center, Riyadh, Saudi Arabia	Site greening, water systems	Planting trees and shrubs on the site; building fountains and decorative reservoirs; lawns to reduce the area of artificial paving and reduce soil surface overheating
Monad Terrace, Miami, USA	Site greening as a protective barrier	Creating a green buffer zone along the perimeter of the building; choosing of salt-resistant plant species that reduce the site surface temperature and prevent the penetration of flood waters
American Copper Buildings, New York, USA	Site greening accounting for extreme climatic conditions	Creating a park zone with plants resistant to salt water; using vegetation cover as a passive protective shield against stormwater surges and to reduce thermal impact on the lower floors of the building

Source: original development.

The analysis has identified three groups of tools: site greening and water structures, incorporation of vegetation and water into the exterior of the building, and using vegetation and water in the interior of the building.

3.4. Techniques for Creating Shadowed Microspaces

Based on the case analysis of group 1 objects (thermoregulation of site microclimate), architectural and planning methods for creating shadowed microspace in hot climate conditions were systematized (Fig. 2).

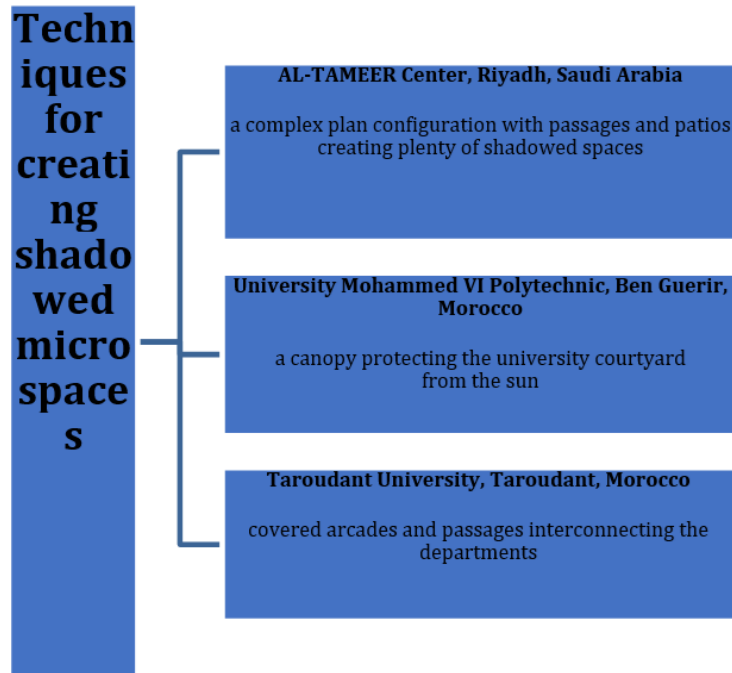


Fig. 2. Techniques for creating shadowed microspaces. *Source: original development.*

The three objects reviewed demonstrate fundamentally different approaches to site shadowing: plan configuration (AL-TAMEER Center), canopy courtyard shadowing (University Mohammed VI Polytechnic), and covered connecting walkways (Taroudant University). At the same time, all three techniques serve the same objective of limiting direct insolation and reducing surface overheating at the site level.

3.5. "Weather Type – Recommended Architectural Solutions" Matrix

A correspondence matrix for the seven types of weather and the recommended architectural and construction solutions was compiled based on the available data [39, 40] and the analysis of research objects (Table 5). The solutions were prioritized on a three-point scale: 3 – mandatory, 2 – recommended, and 1 – optional.

Table 5. "Weather type – Recommended architectural solutions" matrix.

3 mandatory	2 recommended	1 optional				
Weather type	Shadowing and insolation	Aeration and ventilation	Heat protection	Protection against precipitation	Wind protection	De-icing
Hot dry	3	3	2	1	2	–
Hot	3	3	1	2	1	–
Warm	2	2	2	2	1	–
Comfortable	1	2	2	2	1	–
Cool	1	1	3	2	2	1
Cold	–	1	3	3	3	2
Harsh	–	–	3	3	3	3

Source: original development based on [39, 40].

The presented matrix reflects the relationship between the type of weather conditions and the priority of architectural and construction solutions. With the transition from hot to harsh weather, not only does the set of employed tools change, but so does their hierarchy – from shadowing and aeration to thermal protection and de-icing.

3.6. Assessment of Climatic Adaptation Techniques by Research Objects

Table 6 brings together the three dimensions of classification: macroclimate types from Table 2, adaptation tool groups from Table 1, and the scale of the solution. This provides a clear picture of how each specific architectural object fits into the general typological scheme of the study.

Table 6 systematizes data on the applied adaptation methods, their scale, and the nature of climate risks for each of the eight empirical objects.

Table 6. Methods of climate adaptation by research objects.

3 Group 1 – site	2 Group 2 – building (heat)	1 Group 3 – extreme impacts
Scale/Climate	Hot climate	Cold/Oceanic
Site level	AL-TAMEER, Riyadh Passages and patios	No objects
	University Mohammed VI Polytechnic, Ben Guerir Canopy over the courtyard	
	Taroudant University, Taroudant Covered arcades	
Building level	Equator Tower, Kuala Lumpur Retractable facade screen	Lakhta Center, St. Petersburg De-icing system
	O-14, Dubai Exoskeleton + ventilation gap	Monad Terrace, Miami Elevation + hurricane-proof structures
		American Copper Buildings, New York Water protection perimeter

Source: original development.

The eight examined objects cover four types of macroclimate and two scale levels of architectural solutions. The distribution of solutions by groups shows that the majority of implemented adaptation techniques are building-level measures, while site-level solutions are utilized primarily in hot climates.

The obtained results are generally consistent with the prior studies on the importance of climatic factors in architectural and construction design [21, 33, 35, 46]. However, the present study adds a number of systematized developments to the established provisions.

The expert survey has confirmed the priority of solar radiation (weight 0.38) and air mass circulation (weight 0.30) as factors determining the parameters of urban development. This finding agrees with preexisting data [17, 22]. However, the weight scale proposed in our study is the first tool to order these factors in quantitative terms in relation to urbanized territories.

The proposed classification of objects into three groups (site thermoregulation, building thermoregulation, and resistance to extreme impacts) does not exactly replicate any of the known typologies. For example, Saifudeen and Mani [21], Shilov and Okorafor [40] enumerate adaptation tools without a clear distinction by scale. We believe this distinction to be fundamental, as techniques effective at the site level do not necessarily reach the building level and vice versa. This provision is supported by our analysis of architectural objects – all three objects in group 1 work exclusively with the site space, while objects in groups 2 and 3 solve problems at the level of building structures and cladding.

The "Weather type – Recommended architectural solutions" matrix (Table 2) develops an approach outlined by Erell et al. [39] and Shilov and Okorafor [40], bringing disparate recommendations into a single structure with a quantitative assessment of priority. The transition from hot to harsh weather types is accompanied by a natural inversion of priorities, with shadowing and aeration giving way to thermal protection and de-icing.

Naturally, the conducted study has several limitations. The first limiting factor is that the design of the study is qualitative and quantitative in nature instead of strictly statistical. The samples of research objects (8 buildings) and experts (72 respondents), although sufficient for systematization, do not allow for conclusions on the frequency of application of specific techniques in global practice. The weighting factors given in Table 3 reflect only the opinion of the expert group and need to be verified on a larger sample. Finally, quantitative assessment of the effectiveness of individual solutions, such as reduced energy consumption due to a ventilation gap in the O-14 Tower and the de-icing complex of Lakhta Center, remains a task for further research.

Theoretical conclusions. We would like to argue that the influence of macroclimate in the design of the urban environment should be examined in the following order: first, by analyzing typical background factors with long-term and predictable action; then, identifying extreme impacts (storms, tsunamis, floods, and icing); and finally, analyzing the factors of possible changes in the macroclimate – temperatures, water level, and the characteristics of atmospheric circulation. This kind of sequence has not been explicitly described in any of the analyzed sources and constitutes a unique contribution to the present study.

Practical implications. The research findings allow us to propose the following recommendations for architects and designers:

1. Accounting for macroclimatic conditions before developing design solutions, as soon as at the stage of choosing the site and the type of development.
2. Differentiating between the scales of adaptation tools, as site-level and building-level solutions need to be developed independently and do not substitute one another.
3. Using vegetation and water as priority passive thermoregulation tools in hot climates, considering that they can be used at both scale levels.
4. Orienting buildings and creating shadowed microspaces taking into account the dominant climatic loads dictated by the type of macroclimate.
5. Incorporating specialized design solutions for extreme climatic events, such as floods, hurricanes, and icing, based on the typology presented in Table 6.

4. CONCLUSION

The study systematizes architectural and urban planning methods and techniques for protecting buildings from climatic impacts, drawing on the results of literature analysis, case analysis of eight objects from six countries, and a survey of 72 experts. Adaptation tools are proposed to be classified into three groups and two scale levels – site and building. A matrix of correspondence between seven

types of weather and priority architectural and construction solutions has been compiled. The analysis of macroclimate makes it possible to factor in a set of climatic parameters in the design process, ranging from background characteristics to extreme impacts and long-term climate changes.

A prospect of further research could be a quantitative assessment of the effectiveness of individual solutions, particularly the reduction of energy consumption with passive facade systems and the effect of greening on the temperature regime of the site. This research will make it possible to transform the proposed classification from a typology into a tool for standard calculations.

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