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e-mail: petrosyan.evghine@gmail.com, ikukina@inbox.ru, alex.lipovka@gmail.com***MULTI-LAYER ANALYSIS OF MORPHOLOGY
OF THE CITY OF KRASNOYARSK BASED
ON CONCEPT URBAN LANDSCAPE UNITS**

Abstract: *The Conzenian concept of the urban landscape unit is one of the most diverse approaches to the study of urban morphology: (Hiroyuki Yoshida 2004, Manabu Omae 2004, Kai Gu 2013, J.R. Shi 2015, other). Large cities around the world are growing that is why diversity of the urban landscape units is forming within the city's boundaries. That entails an inevitable change of the urban form and the complication of the city morphology. In the fast-growing and changing world, the analysis of urban morphology is relevant. Morphology of each city could be understood as the dynamic system of the interlinked urban landscape units. This research introduced the study of urban morphology based on the concept of an urban landscape unit, relying on the methods of big data. Understanding of the city as the combination of the different in the "context" urban landscape units is important for the strategic planning of the further development historically justified morphological structure. The uniqueness of the urban morphological structure is forming under the pressure of the anthropogenic and natural factors in accordance with historical sequence. The main purpose of the paper is to study the interrelation of the urban landscape units forming and the morphological structure of the city of Krasnoyarsk. The study identified the main morph types of the city of Krasnoyarsk: a historical block of the urban core, micro districts of the different periods of construction (1950-60, 1970-80), various forms of individual housing construction, a modern block. The result of the study is a multi-layer information model based on open data and geographic information systems. The understanding of the morphological structure of the city of Krasnoyarsk through the morphologic electronic model will help the urban designer to evaluate qualities of the future development.*

Keywords: *urban morphology, landscape units, Krasnoyarsk, micro district, big data, urban landscape.*

Introduction

The research is devoted to the study of the relationship between landscape units and the formation of the urban morphological structure in the example of the city of Krasnoyarsk. Urban landscape units are different structural elements of the city, which consist of physical and geographical features of the terrain and features of the development of a different historical period. It is the landscape characteristics and heterogeneity of the landscape that form the uniqueness of the urban morphological structure. The urban landscape can be considered as a dynamic system consisting of urban landscape units.

The analysis of the urban morphology of Krasnoyarsk is based on the concept of urban landscape units based on the methodology of statistical analysis of the input data using geoinformation systems and visualization of open big data. The main morph types of the city development were determined. They comprise: a historical block of the urban core, micro districts of the different periods of construction (1950-60, 1970-80), various forms of individual housing construction, a modern block. Understanding of the city as the combination of the different in the "context" urban landscape units is important for the strategic planning of the further development historically justified morphological structure.

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The result of the study is a conceptual multi-layer information model based on open data and geographic information systems (GIS). Technically, GIS technologies allow us to obtain a large amount of data, including information on spatial units before urban planners put the task of processing, analyzing and visualizing open data, maps and charts, based on geoinformation systems.

A multilayer model of morphological characteristics is needed to manage the development and formation of building of the city. Understanding the morphology of the city of Krasnoyarsk through a morphological electronic model will help the urban planner to assess the quality of future development. The information model allows collecting, analyzing and comparing various morphological characteristics such as floor area ratio, altitude, land use, character of a relief. These characteristics are formed on the basis of the morphological features of the city. And the uniqueness of the urban morphological structure is formed under the pressure of anthropogenic and natural factors in accordance with historical sequence.

Methodology

The study is based on the methodology of a multilayer analysis of the urban morphology on the basis of the concept of urban landscape units and is displayed in computer modeling using open big data and geoinformation systems. The information model of the morphological structure consists of several spatial layers. The composition of the layers can vary based on the characteristics of the city. The main layers that are included in the multilayered analysis of the morphology of Krasnoyarsk: the urban framework, the fabric of the city, geographical features.

Each layer in turn is divided into sublayers. The urban framework: network of open urban spaces, network engineering infrastructure, influence of the street-road network on morphology. The fabric of the city: historical periods of the formation of the morphology of the city building, a large-scale analysis of the spatial-planning structure of the urban form and the morphology of the building, analysis of the urban morphology on the basis of studying the structure of land use. Geographical features: network natural landscape, analysis of urban landscape units.

The study is based on the following methodology:

- Theoretical study of international experience of theoretical and practical application of the concept of urban landscape units in the analysis of urban morphology.
- Methods of analysis of landscape physical and geographical conditions on the basis of urban landscape units.
- Methods of structuring the historical periods of formation of the morphology of urban development
- The methodology of multiscale analysis of the urban morphology and the morph types of urban development
- Methods of analysis of the urban morphology on the basis of studying the structure of land use
- Methods of the analysis of the urban morphology based on the study of the urban framework. Identification of the dependence of the urban morphology on the transport and engineering networks
- Statistical analysis of input data using geographic information systems

Technique of computer modeling of a multilayer model based on the analysis of the morphology of the city of Krasnoyarsk.

Measurement and analysis

1. The layer of the analysis of the morphology of urban fabric

1.1 Historical periods of the formation of the morphology of the city building

One of the factors affecting the formation and transformation of the urban morphology is the cultural and historical periods of the city's development and the stages of the development of construction technologies in accordance with historical sequence. This layer is especially relevant in the multi-layer model for the city of Krasnoyarsk, which has a history of the formation of a

structure of almost 4 centuries. Historically, the urban environment is valued higher than the modern one. The value of historical development and environment lies in its gradual and long-term formation.

The historical city, as an architectural environment, for many people is represented as an ideal. Everything seems to him perfect, past selection by time, and therefore requires protection [1].

The historical center of the city is already a spatially developed part of the city's organism, which has a deficit of free territories. And its further functional and spatial development is impossible without spatial transformations [5].

The architecture of the city enables residents to identify their belonging to the culture of a certain historical period, to fix their place in the world, to preserve their identity. Historical cities with the existing urban environment face the challenges of the times. Without new construction, including in the historical center, it is not enough [4]. Since historical centers have a developed integral morphological structure, under new construction, the compacting changes and thereby complicates, sometimes even forms new morphological types of development.

The emergence of modern architecture in the historical part causes numerous protests of city protectors. At the same time, public opinion does not have a clearly formulated idea, in which direction development is possible, how to build a new one without destroying the old, what should be modern architecture in the center of the historic city. Consideration of international experience shows that the answers to these questions cannot be unambiguous. All of them are connected with the analysis of the morphology of the urban environment in terms of identifying signs that allow preserving or changing its identification [4]. When analyzing the morphological structure of the city, a layer of historical periods of the city's development is necessary to understand the vector of the further development of the historical core and preserve the integrity of the city center.

The gradual development of land and the nature of the structure of land use are affected by geographical and landscape features of the territory. The geometric form of the city can be constant within a certain period, whereas social activity is a historically changeable phenomenon that causes transformation. Therefore, the continuity of the form of the city and its genesis directly depend on the qualitative transformation of the way people behave within a certain period of time.

With time, the formation of the city, depends on its variety of forms, and hence the wealth of its urban landscape. In order to understand the processes of formation and change of a modern city, it is necessary to trace the interconnection of all layers with historical periods, imposing different layers on each other.

For its 390 year history, Krasnoyarsk has been developing landscape units gradually. The historical center of the city was formed on a flat territory between two rivers. The historical core of the city of Krasnoyarsk is its central part, a characteristic structure of the European type of cities. The center of the city, being the carrier and translator of cultural norms, is of paramount interest. The historical core of the city underwent changes in different time periods. In addition to the central part of the city, other parts were developing and changing.

The study identified 8 periods of morphology transformation of urban tissue.

1 period – the foundation of the city: irregular building, construction of the fortress – Krasnoyarsk sopka.

2 period – the formation of a new regular city with a quarter building.

3 period – the construction of a railway, the growth of the core of the city center to the west side behind the railway. There is the development of Afontovo Mountains. The dominant morph type of development is a low-rise individual residential development.

4 period – the beginning of the Second World War, the development of the right bank of the Yenisei River; construction of industrial enterprises. The appearance of a new morph type of Krasnoyarsk is a micro district and superblock.

5 period – the further development of the right bank, the emergence of perimeter and mixed buildings.

6 period – the development of new lands on the left bank of Krasnoyarsk. The border of the city was expanding both to the west - the construction of universities, the area of Akademgorodok, and to the east – the Severny District, the micro-district Vzletka. The emergence of new quarter buildings and new neighborhoods.

7 period – consolidation of urban morphology by point construction on both the left and the right banks, expansion of the city boundaries in all directions (west, east, north, south). Extensions of morph types of touching. The appearance of townhouses, freestanding skyscrapers, European quarters, etc.

8 period is nowadays. Construction of a new 4th bridge across the Yenisei River, in the west of the city. The change in the morphological structure of the historical territory is Nikolaevskaya Sloboda. Construction of new neighborhoods on both sides of the bridge. More active land development. At present time, the morphology of urban development becomes more complicated. Appearance of combined morph types. The city has the potential of urban morphology development and there is a need for new morph types. The areas of transport-oriented development (TOD) are beginning to form.

1.2 A large-scale analysis of the spatial-planning structure of the urban form and the morphology of the building

This study uses a multiscale analysis of satellite images of the city. The use of different scale allows creating a flexible structured data system to meet several needs of spatial analysis and planning, allows decomposing city forms on three different levels:

- a. Urban level – landscape areas, the planning structure of the urban form
- b. District level – at the level of "spots" of neighborhoods, neighborhoods, etc. morphological city fabric
- c. Local level – the form of buildings (point, perimeter, etc.) building morph types

These layers will help determine the morph types of development and reveal the urban morphological zones, and the shape of the city.

Urban level. The planning structure reflects the distribution of the main parts of the city. The city's planning structure is a geographical drawing of the city's territory, characterized by a high concentration of various facilities and infrastructure. The planning structure of the settlement is a schematized model, which is an ordered composition of space elements in their interrelation, hierarchical dependence, integrity. The most common types of the planning structure of the city: compact, dissected, dispersed, multi-core, ring and linear.

The city of Krasnoyarsk has a dismembered type of the planning structure of the city form. The city is crossed by a large river and a transit railway. The territory of the railway and the river occupy more than 50% of the total area of the city. The river divides the city into two parts; the two banks are connected by two automobile bridges and two automobile-railway bridges. The railroad line divides the fabric of the city into two parts, both on the left bank and the right bank, thereby forming ruptures of urban fabric; vertical - on the right bank, horizontal – on the left bank. It turns out that the body of the city is divided into four spatial planning areas, which in turn also have divisions due to landscape-geographical conditions.

District level. The main morph types of urban development were identified. They comprise: a historical block of the urban core, micro districts of different periods of construction (1950-60, 1970-80), various forms of an individual housing construction, a modern block. The city began to form new morph types of development - areas of transport-oriented development.

Local level. Wind flow and sun orientation context studies will guide to design a building form which will influence location of openings, patterned shadow and building height weather will affect surrounding neighborhoods. Topography is important to know the slope site and landscaping which need to consider trees and shrubs to propose so that the cool and hot air can be utilized.

1.3 Analysis of the urban morphology on the basis of studying the structure of land use

Every planner of the city certainly faces the land use structure in his professional environment. The land use map is relevant for centuries, despite its simplicity. In the process of changing land use dependence on the needs of the city is unceasing. Land use and interaction between the territories directly affect the shape of buildings, the density of use, the road network, the appearance of the urban landscape and, of course, the morphological structure of the city as a whole. Land use also reflects the impact of human activities on the urban landscape network (J.R. Shi, 2016).

One of the methods of expressing a city is the analysis of the structure of land use that shows the relationship between built-up and unoccupied spaces. The configuration of land plots determines the vector of development of the territory and the morphological structure of urban development. The configuration of the land use structure can tell us a lot about the city. Depending on such characteristics as the area, shape, location, use of the land, it is possible to judge the historical belonging and the possibilities for further development.

The form of building is subject to constant changes in a relatively short time, while the configuration of land use changes much less frequently. This affects the economic component of land use. Therefore, the structure of land use makes it possible to draw conclusions for various characteristics of the city and the meaning underlying them: the structural age of the territory, the historical structures of power, socially and politically influencing construction programs, their historical development, the principles of organizing the activities of residents, density and so on.

In addition, the map of the land use structure instantly conveys a comprehensive picture of the morphological structure of the city - while studying literature and other maps would take considerably more time.

The structure of land use is a spatial-temporal and historical category. For each territory, historically, there were special conditions for the use of land. The main ones were natural and socio-economic factors [6].

Land use and interaction among the territories, directly affects the shape of buildings, the density of use, road network, the appearance of the urban landscape and of course the morphological structure of the city as a whole. The chaotic development of land entailed the appearance of gaps in urban fabric. Various zones are formed - business, warehousing, commercial. These areas are gradually displacing housing. Accordingly, in these zones, the density of the building is changing. And this affects the changes in density in transport development.

2. The layer of the analysis of the planning structure of the urban framework

2.1 Network of open urban spaces

Open public urban spaces are unique, especially important elements of the urban planning system, as they create a unique image of the city, contribute to a clearer understanding of its structure, reflect the level of its development and culture, an indicator of the quality of its social life [7].

The trend of active urban growth entailed the compaction and distortion of the spatial environment. Such dynamics pushed into the background secondary functions of urban spaces - to serve as a unit that provides a full-fledged living conditions for citizens (in the physical and psychological sense) and forms the cultural and artistic appearance of the city.

Despite the fact that open spaces are assigned such an important role in the organization of the city, the problem of their qualitative organization in the cities of Russia today is very acute, in particular, because insufficient attention is paid to the formation of public fragments of the urban environment.

When addressing issues related to the organization of urban spaces, special attention should be paid to the procedure for their study. One way to explore urban spaces is morphological analysis [7].

The network of open urban spaces includes: public areas, pedestrian streets, urban recreation facilities, courtyard areas, car parks, open economic areas.

The main characteristics for assessing the urban space system: an area, discontinuity, use, configuration, a level. The characteristics for the morphological analysis of the objects of the urban space system are also highlighted: a geometric form, a spatial form, a degree of closure, scale.

2.2 Influence of the street-road network on morphology

The street-road network of cities is an important part of the city infrastructure, linking the totality of the branches of the city economy and the corresponding organizations that provide for the life of the city [10]. The city's road network is being created for decades and it takes time and significant investment to change it. The most important and most expensive measure is the development of the city's road network [11]. In Krasnoyarsk, as in most Russian cities, the transport network developed during the times of the Soviet Union and during the development of the territory of Siberia. And since then the basic framework has not changed. At the same time, over the past decades there have been changes in the city infrastructure and the street-road network has received a long-term development, which is not embellished now.

The main characteristics for the morphological analysis in this layer are the density of the road network, the density of traffic flows, the carrying capacity, the ratio of uses of streets, the capacity, the density of construction along roads, the methods of formation.

The street-road network cannot but affect the planning structure of the city and the change in its morphology. There are three key factors in the influence of the transport network on the transformation of morphology:

1. Spatial - planning. The street-road network is a relatively rigid and formed skeleton of the city, which is formed in a long time frame. The shape of the buildings is more flexible and subject to change, as the laying of new networks is extremely expensive. Therefore, a new building appears near the existing street-road network. It is for this reason, in large cities, more popular and appropriate sealing of the building fabric of the city inside the existing street-road skeleton.

2. Economic. Depending on the density of the road network and the degree of its use, it depends which functions (land use types) arise along the streets, which entails a change in the morphology of the development. Depending on the value of the road and its density, a different morphology of the same functional use of the building is formed. For example, residential development along urban roads, where the density of the street-road network is high, a multi-storey building is formed, densely facing each other. And along the roads of regional and local importance, less dense residential buildings are mostly medium-storey. But it should be noted that in Krasnoyarsk, when building new residential neighborhoods in areas with unformed infrastructure, both road and engineering, because of the large investment in the construction of the road network and engineering networks along roads of local and regional importance, a multi-storey, fairly dense development appears, which is also an example of the impact of the economic factor of the road network on the morphology formation of the city.

3. Part of the street-road network is public transport. While public bus routes indirectly affect the morphology of the city, offset the creation of passenger traffic and increase the density of street use. Public electric transport has a direct impact on the morphological structure of the city at different levels, because it is the most rigid planning transport system. At the city level, the lines (rails) and the railroad diversion strip change the planning structure of the city's shape, creating urban fabric tears. At the district level, such public transport as a tram and a trolleybus, less flexible for route changes as they are geographically fixed electrical systems have a greater impact on the morphology of the building and its functional use.

2.3 Network engineering infrastructure

One of the determining factors affecting the development of modern cities is the availability of engineering infrastructure and the possibility of its reorganization, taking into account the

changing needs in a particular resource [8]. Communal systems cover all spheres of the city life. They include, in particular, water supply, sewerage, waste management, electricity, heat supply, gas supply, collection and treatment of surface runoff [9].

Engineering infrastructure affects the efficient operation of various city systems. They, like the road frame, are fixed, around which various city structures are formed. In Krasnoyarsk, most engineering systems are centralized and require large investments and time for development or change. Therefore, the structure of the city has a strong dependence, for example, on the heating system and the water supply system. A similar situation is observed in other cities of Russia. In this regard, it becomes urgent to analyze the structure of urban engineering networks and to identify the relationship with the formation and development of the morphological structure of the city as a whole. That in turn is necessary for further territorial planning of the city.

3. The layer of the analysis of landscape physical and geographical conditions

3.1 Network natural landscape

An integral part of the morphological structure of the city is the green frame of the city - a network of natural landscapes. Because the natural landscape (water, forest, relief, type of gardening, etc.) is a decisive factor in choosing the spatial location of a particular settlement and in shaping the potential for further development of urban areas. In addition to influencing the planning structure, for example, water areas are the physical component of the city's shape, determining the visual character and aesthetic qualities of a specific "landscape matrix of the city". The shape of the city directly depends on the morphology of the natural landscape and has its own individuality, as a unique and genuine morphological formation with its structural composition and aesthetic specifics, as well as functional uniqueness. The natural landscape network consists of the hydrology of the city, a natural ecological framework, and a network of natural green spaces in the city.

The identification and study of the morphological structure of the urban landscape and recreation is necessary for several reasons. First, the emergence of any settlement, one way or another, is associated with any characteristic natural landscape, whether it is the mouth of the river, the shore of the sea or the foothills. The identification of this natural-historical basis is necessary for understanding urban planning dynamics, that is, for determining the prospects for further development. Secondly, maximum expedient is the development of urban areas. Thirdly, understanding the morphological structure of the landscape will make it possible to competently compile the ecological framework of the city and manage its development.

3.2 Analysis of urban landscape units

This research has studied the morphological structure of the city. The main method for analysis was the morphological approach based on the concept of the urban landscape unit, using open data and geof ormation systems. The basis of this methodology is the geographic-topographic approach. Analysis of the terrain and the designation of other geographical features of the terrain (the absolute height of the peaks in meters, the difference between the highest and the lowest points in meters, the average gradient of inclination in degrees). This layer includes identifiable landscape units, such as mountains, foothills, lowlands, excavations, plains, rivers and lakes.

All the above-mentioned layers of the morphological structure of the city are associated with unique landscape units. On the example of the city of Krasnoyarsk, let's try to determine the relationship between morphology and urban landscape units. Understanding the city as a combination of different in the "context" of landscape units is important for strategic planning for the further development of a historically grounded morphological structure.

For its 390 year history, Krasnoyarsk has been developing landscape units gradually. At different times and in the process of development, the urban landscape shows history, heritage and dynamics in nature. It is the dynamic and temporary changes that make the old city formed by long-term development, expansion, integration of the physical form environment and human factors slowly and spontaneously.

Conclusion

Krasnoyarsk is a historical city, the morphology of which was formed during eight cultural and historical periods. One of the factors forming a unique morphological structure of the city is the feature of the presence of buildings of different historical period. The city of Krasnoyarsk has a dismembered type of planning structure of the city form. The city is crossed by a large river and a transit railway. The territory of the railway and the river occupy more than 50% of the total area of the city.

The historical center of the city was formed on a flat territory between two rivers. In addition, the city has islands that form a special form of urban landscape. The mountains (high points) that surround the city greatly enrich its contour lines at a three-dimensional level, and also provide an urban landscape with many points of view. All of them form a unique natural environment and urban form.

The study identified the main morph types of city of Krasnoyarsk: historical block of the urban core, micro districts of the different periods of construction (1950-60, 1970-80), various forms of individual housing construction, a modern block. The result of the study is a multi-layer information model based on open data and geographic information systems. The understanding of the morphological structure of the city of Krasnoyarsk through the morphologic electronic model will help urban designer to evaluate qualities of the future development.

In the continuation of the scientific work it is necessary to make a deep analysis of the layers of the morphological structure of the city of Krasnoyarsk and create a visual computer information model for all citizens, specialists and government in real time.

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