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**Morphogenesis of residential development units of Krasnoyarsk: density, form, function**

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**Abstract**

*When growing, the urban layout of modern Siberian cities is undergoing morphological transformations and, thus, there are new morphotypes of residential development. In the same way, Krasnoyarsk can boast by its residential complexes of different settings and purposes. By analyzing the life of city-planning structure, one can identify several morphological periods for Krasnoyarsk's residential development: land exploration for a large-scale residential project; assimilation of new territories in the 20th century; current renovation and integrated re-development under the federal development programs. The article briefly describes the patterns of residential housing layouts in the city the spatial character of which has been basically influenced by the landscape, and streets and roads networks. Evaluation of the morphometric indicators of development density and settings in Krasnoyarsk yielded certain regularities in their structures. The analysis relies on two parameters: land size to development area ratio (under-buildings area to a residential development unit area), and development density, i.e. building floor surface to residential development area ratio. The research also examines the process of functional enriching the residential units by small and middle-size businesses ("functional flows"), and their spatial capacity for it. The study reveals that inherent urban units have specific functional, administrative, and social characteristics, reflected in the morphotopes layouts. General findings explain trends for brand-new alternatives in the residential development of Krasnoyarsk.*

**Key words:** morphogenesis of spatial structure, morphotypes, morphotopes of residential development, planning units, density.

**Introduction**

Every city has its own set and hierarchy of historically determined development morphotypes, which set the city's architectural uniqueness. In the urban structure of big Russian cities-morphotypes, the basic elements are micro-districts, i.e. layout units of different settings and development density. In the last third of the 20th century, dentistry merely determined the form of cities' layouts, and of certain units, as well as the number of floors in residential buildings; organization of cultural, social, and transport services; quality of utilities and public amenities; time spent on business, and cultural and social trips; it also showed the level of urban comfort and convenience. The changes in socio-economic and functional processes in Russian cities modify their living areas, and, thus, expand the types of residential development and open public spaces, as well as enables spontaneous in-fill construction of new objects in the living environment. Thus, there is a gradual shift in the space-planning nature of development. Contemporary urban planning relies on a relevance of objective conditions for the urbanized territories improvement. By examining the structure of city development plan, the current research analyses the regularities in Krasnoyarsk's residential planning units morphotypes. Moreover, this work introduces typical morphotopes of residential development by identifying the primary geometry and floors-number in buildings. There is also an integrated measurement of morphotopes delivered by the key indicators, i.e. a built-up area to total area ratio (land-to-building ratio), and development density, i.e. all floors surfaces to building area ratio. The study regards the morphotopes' functional density infilled by small and middle-sized businesses (functional flows), and considers the space

syntax relying on availability of the morphologic structure for the pedestrian flow, and its visual coherence. The explanatory analysis identifies the basic trends in Krasnoyarsk's residential housing of different morphological periods.

## **Background**

The theoretical scope of this research relies on the works, which study the evolution of morphological development, and accurate identification of evolution periods. In the theory of urban planning, there are basic periods, which show the dynamics of housing in Russia. The first period of mass housing construction is associated with standardization and industrialization that tapped into the residential neighbourhoods building in the middle of the 20th century. The second stage is the building density increase achieved by multiplication of floors, since the 1970s. The third period, when the state was transiting to the market economy, is recognized as the "downtime in urban planning activities", and the current stage designs the strategies for integrated territories exploration. G.A. Ptichnikova defines two states of the cities' spatial and planning structure: the last decades of the 20th century and the early 21st century (Ptichnikova G.A., 2014). B.A. Portnov notes that the period of city's transition to the market can be characterized as a peak, and, further, he points out the following factors of transitional state: land and real estate transfer to private ownership; tertiary sector privatization; diversification of land use cost indicators; collapse of the state construction industry base; emergence of small and private construction firms (Portnov B.A., 1994). I.V. Kukina specifies the basic patterns of morphological transformation and exploration of the post-socialist urban territories (Kukina, I.V. , 2011). Some works study the vectors of "micro-district" concept transformation in the post-Soviet space (Kukina I.V. Fedchenko, I.G., 2016, 2019). The current research is grounded in geoinformation analysis of the spatial data (exploratory data analysis) – an insight in the main features of the objects under study. As for this research, they are measuring the indicators of residential development, and identifying the general regularities, distributions, and anomalies, using visualized histograms and mapping. The fundamental foundations of the definition of morphological periods and typological processes in the morphology of the city were studied in the works of Whitehand, Conzen (Whitehand, JWR, Gu, K., Conzen, MP and Whitehand, SM, 2014). The works by Vítor Oliveira analyse the evolution of urban morphology, an interdisciplinary scientific discipline, which crosses engineering, technical sciences and architecture. The author explains how to consider the city's physical form, how different agents change its form with time, and how different processes are involved in this transformation (Oliveira V.6 2016). "The Mathematics of Urban Morphology" collects the applied research which couple the universal laws and phenomenological description of the processes. The work examines the case studies of a multidimensional analysis of urban areas through the means of statistical physics, and mathematical calculations (D'Acci, Luca, 2019). The work called "Mapping Urbanities Morphologies" defines the methods for spatial data visualization (Dovey K et al., 2018). Special attention should be also paid to the geoinformation analysis of the dynamics of residential planning units' morphological development (Fedchenko, I.G., 2019).

### ***Background subsection***

More recently, there have been the studies on morphotyping the Russian residential development. In many current publications, the researchers analyse the morphotypes of urban environment using GIS-technologies to identify the following parameters: urban structure density; porosity and ratio of open and closed spaces; number of floors; the nature of mutual buildings arrangement included into a residential group, quarter, etc. In "Morphogenesis of Architectural and Planning Structure and Principles of Reconstruction of Irkutsk's Historical centre", A.G. Bolshakov and S.S. Belomestnykh identify the morphotypes by the residential quarter's mass-to-gaps ratio, and by the number and coherence of open space cells in blocks (Bolshakov A.G., Belomestnykh S.S., 2018). In "Moscow: Towards Polycentrism", regarding the Morpho methodology, the researchers address the influence of Moscow's physical urban form on the viability of planning units

concerning a set of space syntax indicators (Kotov E., Goncharov R., 2018). The research by L.B. Kozhaeva aims the evolution of architectural and historical environment done through possible additional layouts which follow the morphology of Moscow's buildings. The major driver for the morphotype identification is the development density – a universal sign of intensive territory exploration in different parts of the capital (Kozhaeva, L.B., 2011). In the work «Identification, Classification and Assessment of Urban morphotypes» were determined of morphotypes of Yaroslavl (Paskhina, M.V., 2012). Besides, a comprehensive insight into the volumetric-spatial patterns of Krasnoyarsk's residential development done through mathematical modelling and geoinformation analysis has not previously been carried out, and therefore, it outlines the relevance of this research.

## **Methodology**

This work addresses the morphotopes of residential buildings' specific morphotypes in Krasnoyarsk; analyses the construction patterns of their structure regarding the geoinformation analysis and space syntax. This target sets the following research tasks: determination of morphological periods for the mass residential development in Krasnoyarsk; identification and comparison of residential planning units common morphotypes; revealing and carrying out an integrated open data-based measurement of morphotope indicators. To scope the research, to identify the development morphotypes, and to calculate the indicators, georeferenced data GIS-technologies are used; to analyse the functional density of morphotopes infilled with small and medium-sized businesses, geoanalytical visualization of "functional flows" is carried out; and to assess the pedestrian accessibility and visual coherence, the space syntax analysis is applied in the work. The calculation findings are obtained by the exploratory data analysis (Lipovka A.Yu., 2014)

## **Results and Discussions**

The extension of spontaneous processes in Krasnoyarsk's residential environment transforms the planning structure of its residential units – the buildings and open spaces are suffering morphological changes. There is a tendency towards internal structuring, and a fine-mesh patterning of micro-districts – all that leads to the development density increase. The evolving changes require a balanced assessment. The basic research tasks have divided the work into the following thematic sections:

### **Identifying the development morphological periods and typical morphotypes for the mass residential construction in Krasnoyarsk**

In this research, a morphotype is a structure of the micro-district's space, a set of quantitative geometric and topological indicators ratio for the development and open space (mass-gap relations). The distribution is carried out in the GIS by accumulating the construction time data in reference to the city planning structure units. The morphotype for each planning unit is assigned regarding the dominant buildings dated by certain historical era. Considering the analysis of the housing stock growth rates revealed by the Housing and Public Utilities Reform open data, conditional time slices are determined, i.e. the morphological periods of mass housing construction and their typical development morphotypes: I period – Formation of 5-floors, standard series housing stock (1960-1980), "Ribbon Development" morphotype: the largest number of buildings and picture of mainly line buildings with median number of floors – 4; population – 4 763 people; population density – 219 people/ha; characterized by typical housing construction with the lowest integration of public and business functions. II period – 9-floors panel building development (1980–1990), "Sporadic Development" morphotype: free planning, average number of floors is 7; population – 6 370 people; population density – 316 people/ha; characterized by elimination of discrete forms and move to increasing density. III period – Time of low rates in housing construction (1990 – 2010), "Mixed Development" morphotype – buildings of different geometry and layouts, average number of floors – 7; population – 8 250 people; population density – 412 people/ha; featured with infill and fragmentary development of different nature. IV period – modern processes of complex housing, "Combined Development" morphotypes:

combined buildings of 12 floors, in average; population – 9 658 people; population density – 589 people/ha; characterized by a fine-mesh planning structure, consisting of residential groups of different settings with the highest rates of non-residential integration into the residential buildings, and a wide architectural diversity. The configurational analysis of the structure is based on the most distinctive “representatives” of each morphotypes (Figure 1).

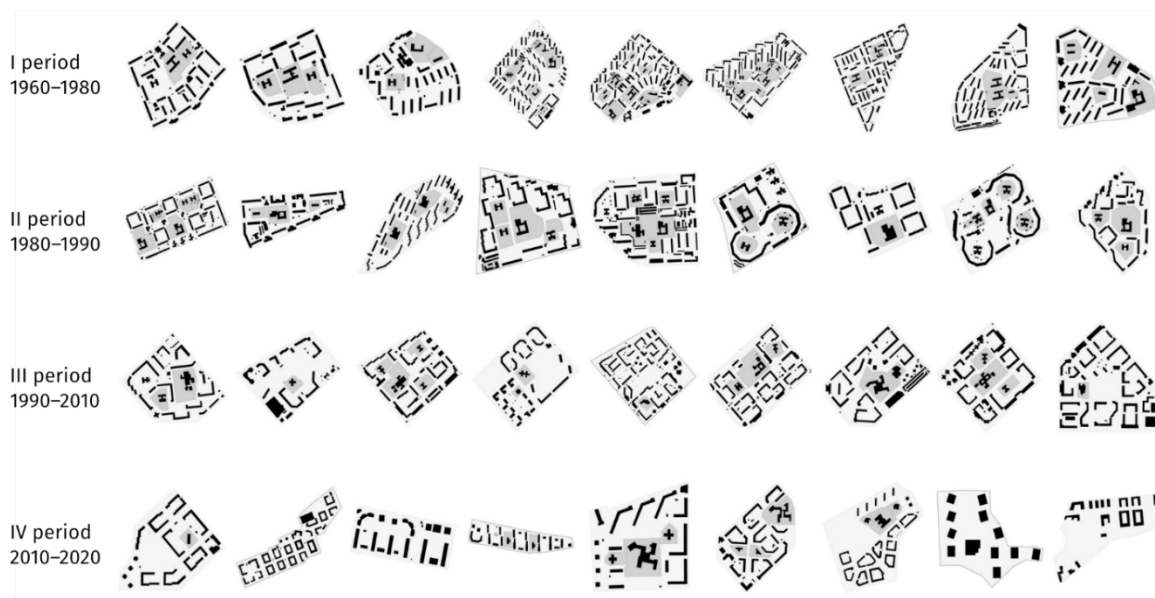


Figure 1. Systematizing typical morphotypes of residential planning units (micro-districts), Krasnoyarsk: “Ribbon development” describes the 1st period (1960 – 1980); “Sporadic Development” characterizes the II period (1980 – 1990); “Mixed Development” is typical for the III period (1990 – 2010); “Combined Development” marks the IV period (2010 – 2020)

The first period of mass housing construction in Krasnoyarsk correlates with the 1960 – 1980 standard housing construction with 5-floors buildings near large industrial enterprises. By the end of the 1960s, multi-floors buildings were entering the micro-districts, i.e. 9 – 16-floors houses; this can be explained by a willingness to use effectively the urban territory. In 1971 – 1972, “Kultbytstroj” (originally, ZhBI-2 (Concrete Products Factory)) began mastering the 111 – 97 series for the residential buildings’ construction, setting a new principle of “free” layouts for the micro-districts with bigger number of floors. There is a tendency to move the city’s general layout from a relatively compact form to a discrete one, characterized by a system of self-sufficient industrial and residential complexes (Fedchenko, I.G., 2019). During the economic transition of the country, the residential development was being formed fragmentarily, in an infilled way, by different construction archetypes. In the early 21st century, there is a relative growth in complex housing, mainly performed by standard buildings of a new, hybrid type.

### Identifying residential development morphotopes in Krasnoyarsk

This research also introduces the idea of development morphotope following the definition proposed by Conzen: “The smallest urban localities obtaining a distinctive character among their neighbours from their particular combination of constituent morphological elements” (Conzen, 1988). Thus, these elements consist of the characteristics of plan type, building type and land use. A morphotope is essentially the smallest type of morphological zone.

This study represents an attempt to analyse the most common morphotypes of Krasnoyarsk residential development and to identify the dominant morphotopes, which represent combination of plan geometry and building height scope, as illustrated in Figure 2.

geometry	line	dot	spline	L-shape	U-shape	Block
number of floors	A	B	C	D	E	F
<b>1</b> 1-5 floors	A1	B1	C1	D1	E1	F1
<b>2</b> 6-9 floors	A2	B2	C2	D2	E2	F2
<b>3</b> 10-16 floors	A3	B3	C3	D3	E3	F3
<b>4</b> 17-25 floors	A4	B4	C4	D4	E4	F4

Figure 2. Matrix of residential development morphotopes, Krasnoyarsk

Not all of 24 morphotopes were found within Krasnoyarsk. The following regularities are found: “line” is presented for all floor numbers; all the plan geometries are represented in the range of 10 – 16 floors; “U-shape” is presented only once — in 10 – 16 floors range; high-rise construction is presented only in “line” and “dot” (Table 1).

Table 1. Residential development morphotopes of Krasnoyarsk

	A	B	C	D	E	F
<b>1</b>	A1 +	B1	C1+	D1+	E1	F1
<b>2</b>	A2 +	B2+	C2+	D2+	E2	F2+
<b>3</b>	A3 +	B3+	C3+	D3+	E3+	F3+
<b>4</b>	A4 +	B4+	C4	D4	E4	F4

Further, the balance of morphotopes within residential planning units was calculated and morphotypes were defined (Figure 3,4). As the analysis shows, the I period of housing construction is mainly characterized by one morphotope – “line”, while in the II period the role of “spline” is more vivid; there is a large variety of morphotopes in the III period – a result of developers monopoly liquidation, and a search for combining discrete and perimetral forms; in the modern period, there is an increase in new standard construction, development densification, and formation of fine-mesh planning structure, consisting of residential groups with a closed building perimeter.

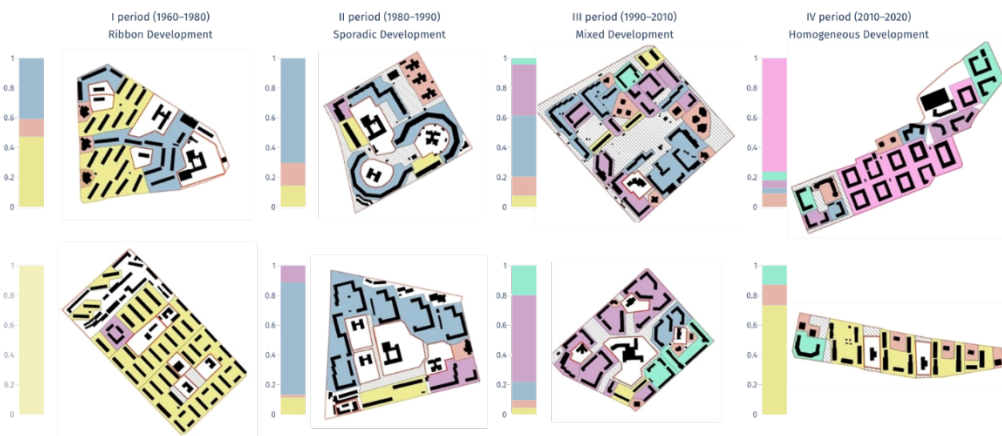




Figure 3. Comparing the balance of morphotopes in residential planning units' morphotypes, defining morphotypes of different morphological periods

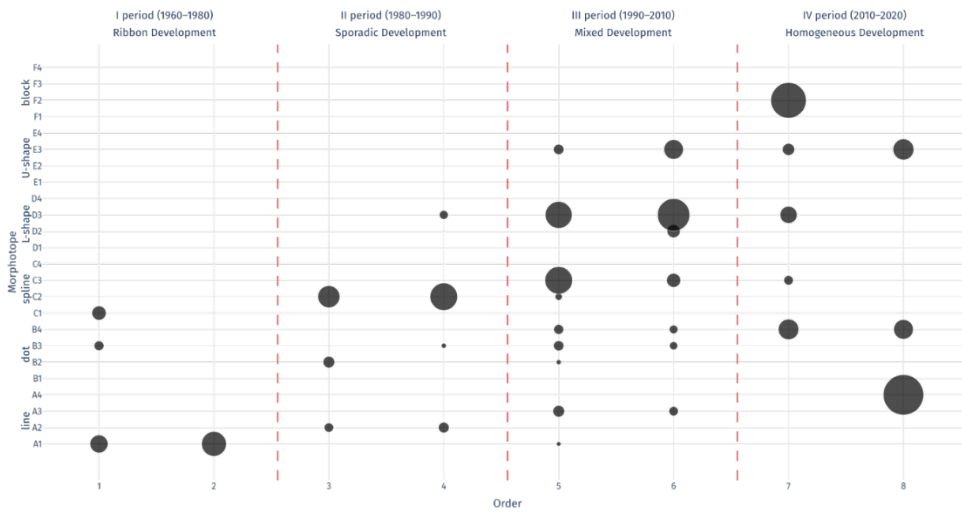


Figure 4. Statistical spread of morphotopes in residential planning units' morphotypes of different morphological periods. Defined morphotypes were assigned to other residential planning units, and distribution in time was obtained (Figure 5).

**Exploratory analysis of morphotopes – morphotypes indicators**

This part is carried out through the special Python libraries, designed for data processing and visualization, which allow to visually represent the dependencies matrix of residential development indicators: FAR, OSI, Space mobility, visual coherence, and functional density (Figure 6). The calculation has concluded that the density indicator in Krasnoyarsk correlates mostly to building height; family of “line” morphotopes correlates to highest range of OSI and functional density.

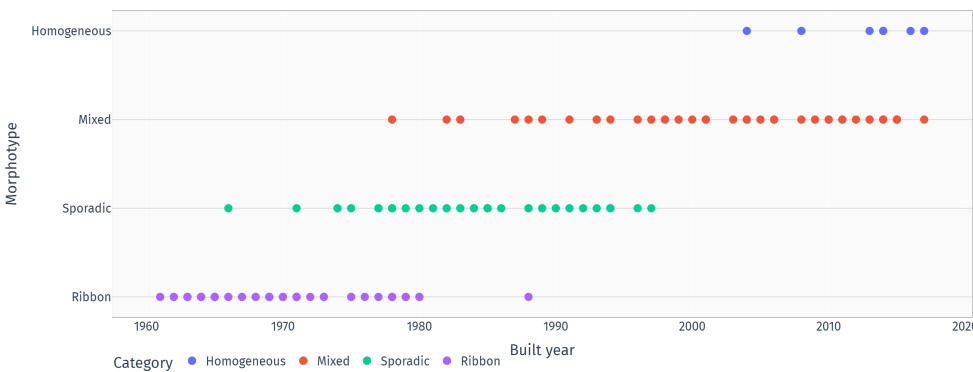


Figure 5. Timeline of residential planning units' morphotypes in Krasnoyarsk

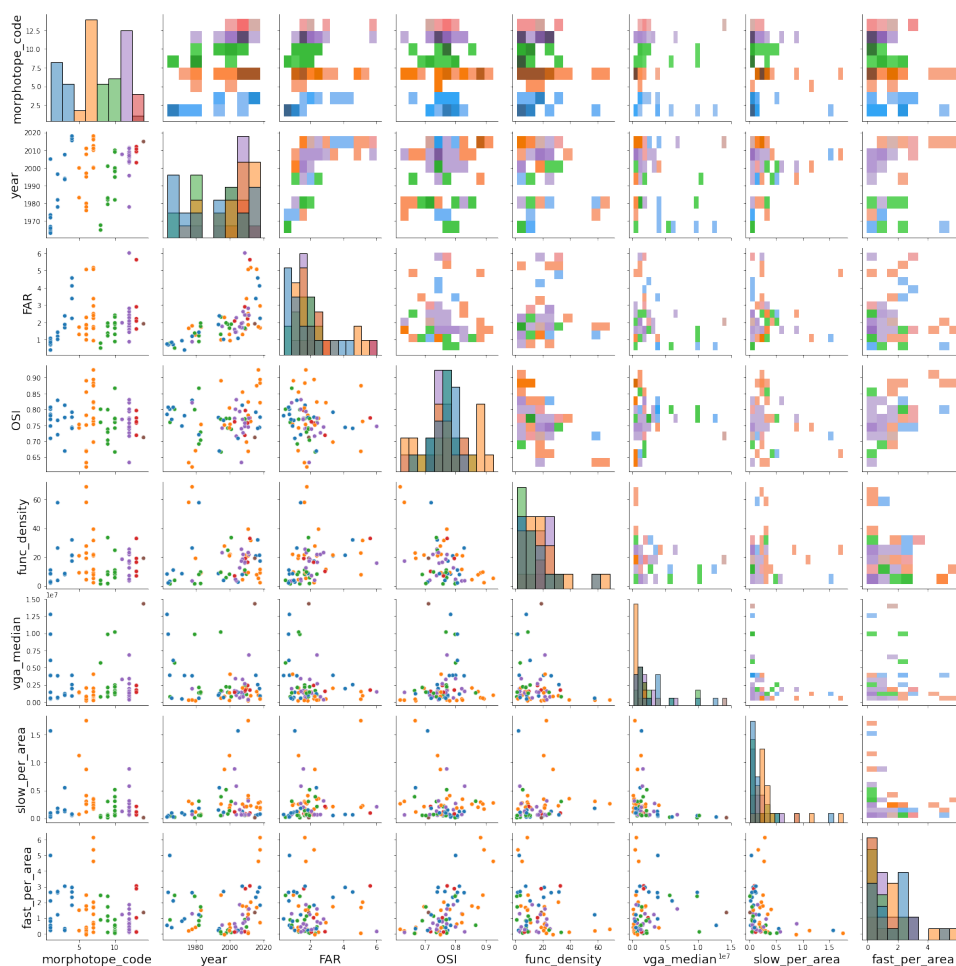


Figure 6. Exploratory analysis of morphotopes – morphotypes indicators correlation dependence

## Conclusions

Extrapolating the values of each calculated morphotope enables evaluating the intensity of residential development. Comparative analysis of Krasnoyarsk's typical residential planning units morphotypes by the key volumetric-spatial indicators has identified the trends to morphological transformations: a move from discrete forms to compact high-rise buildings; there is also a return of layout's homogeneous structure.

Today, the study of socio-cultural characteristics of the city contributes to the analysis of urban morphotypes formation. In Russia, at the contemporary stage of urban planning, there is an acute issue of development densification in large cities given the preserved comfort and favourable microclimate.

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