Patterns of Local Human Activity: The Sociological Revision of Urban Spatial Structure

Nikolai Bulanin

Nikolai K. Bulanin, independent researcher.
E-mail: nbulanin@gmail.com

This article reveals and describes previously omitted elements of urban spatial structure—local subcenters within areas of uncertainty. Most contemporary works on the organization of urban space focus on identifying the main nuclei without considering the vast inter-nuclei spaces. To advocate for the existence and significance of such urban spaces, the Vysokovsky model is reworked and its sociological approach is revived in the form of a field survey within the research polygon. To describe the spatial behavior of local residents, a two-parameter conceptual frame is constructed which allows us to classify goods and services. The resulting representation of the polarization of local activity indicates the need for a closer look at peripheral zones previously viewed as homogeneous.

Keywords: urban spatial structure; polycentricity; multi-scale city; local human activity; area of uncertainty; Moscow

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Introduction

The impetus for establishing modern polycentric approaches to subcenter delimitation and urban frame distinction was provided by the Harris-Ullman model [Harris, Ullman, 1945], which was first to distinguish the development of an alternative outer CBD in addition to the main generally distinguished one. It could be argued that monocentric approaches derived from classic models of von Thünen [von Thünen, 1926], Burgess [Burgess, 1924] and Alonso [Alonso, 1964], although becoming archaic, could still appear useful when describing the general gradient from main city center to peripheral zones [Anas et al., 1998]. However, the tendency for decentralization, heterogenization and structural complication on all hierarchical levels of big cities is self-evident due to a fast population growth, transportation development, housing prices, drastic changes in lifestyle and demands of urban dwellers and a thousand more reasons – and now we see edge cities, new business districts or local places of gathering emerging and developing while historical centers have to search for new ways of functioning with the help of gentrification, car restrictions and green zones establishment.

Urban spatial structure must be viewed multidimensionally. It can be determined as the spatial distribution of morphological elements of the city and the links between them [Goncharov, Gudz, 2023]. Thus, the diversity of approaches to urban spatial structure studies is dictated by the complexity of cities themselves, and each group of models of urban spatial structure has a different goal which dictates the logic, mathematical apparatus and elements of urban organization at its core. When studying the concentrations, morphological approaches become essential as they allow us to highlight the heterogeneous and decentralized landscape of a city, emphasizing established and emerging nuclei. The level of polycentricity is defined not only by the size of each nucleus but also by their relative sizes, meaning the level of spatial inequality created by prevailing centers [Burger, Meijers, 2012]. To spot

the characteristics of the flows that feed urban centers every day, functional approaches are required. They prioritize network proximity over geographical proximity and state that polycentricity is defined by varying interconnectedness (intensity and functional diversity of interactions) of urban nuclei [Green, 2007].

The multi-scalar nature of cities complicates the studies of urban spatial organization. Spatial processes vary on different hierarchical levels of urban organization. Recent urban spatial studies tend to operate on city or metropolitan area scales – there is more data available, and it is easier to highlight general patterns of polarization. In order to detect local urban nuclei, however, we need to descend to a human scale, where every maintenance facility, every physical obstacle and every public transport stop matters. Some can argue that such level of detailing is unnecessary due to specific conditions of each urban territory, but one important factor needs to be kept in mind – most residential places are distanced from bigger urban subcenters due to a higher land value near them imposed by commercial competition. Such spatial organization leads to an emergence of areas of uncertainty characterized by a similarly low gravitational pull towards all surrounding subcenters. Thus, it can be assumed that the absence of strong links to the main urban frame potentially leads to a natural process of local centers of activity formation.

The polycentricity topic has an additional layer when it comes to post-Soviet cities. Domestic urban planning school of thought evolved independently and adapted models that focus on contemporary issues and disbalances of cities and aim to amend Soviet-time mistakes. The unevenly zoned model, created by architect and founder of HSE Graduate School of Urban Studies and Planning Aleksandr Vysokovsky, is considered the main instrument in that regard. Vysokovsky developed two approaches within the model – morphological and sociological, with the idea of depicting both the framework and the actual human activity patterns in tandem [Vysokovsky, 2005]. However, the initial dichotomic frame shifted towards the structural side of the city and sidelined the sociological approach which aims to divide the public and private territories and work with urban fabric rather than the carcass.

Consequently, this article seeks to provide a new perspective on the existing frame of urban spatial structure studies by returning the sociological agenda to the urban spatial organization field. We study the experimental polygon located within Moscow's Preobrazhenskoye and Bogorodskoye districts in order to distinguish spatial dependencies of local maintenance facilities' usage. We hypothesize the existence of nuclei within the area of uncertainty that are the result of local demand for day-to-day goods and services. Identifying these nuclei and describing the peculiarities of their functioning is thus the main goal of this research.

Diverging approaches for studying urban spatial organization

Post-Soviet cities have a specific space organization compared to European and American settlements, where most studies of urban spatial structure have taken place. Here, functional zoning is less regular and is often chaotic, and socio-spatial stratification is far less expressed – it is quite hard to distinguish population groups of similar revenue, interests or age, usually different buildings accommodate dwellers of contrasting lifestyles [Vysokovsky, 1997]. Post-Soviet cities, highly influenced by planned economy and command governance, often struggle to meet people's common needs due to uneven spatial distribution of goods and services: "...the typical pattern of distribution of retail trade and services in the socialist city basically corresponded to the administratively determined, hierarchically organized system of higher and lower order centers... The guiding principle of socialist urban planning was the minimizing of daily journey times for the city population" [Brade et al., 2007]. Although the concept of polycentricity was consistently used by the Soviet planners, the main motivation was not urban life convenience but the convenience of controlling the urban system itself: "Under socialist central planning (including local authority) institutions had clear priority, while economic necessity, geographical location and spatial structures within cities played only a subordinate role" [Brade et al., 2007]. Therefore, functional optimization of often inefficiently planned urban territories is needed to provide a higher comfort of living.

While European and American studies focus primarily on the industrial aspect of the city, placing economic activity in the center and taking spatial distribution of employment as a basis for determining polycentric structures, domestic researchers respond to local inquiry for a more comfortable and user-friendly urban environment by

developing a post-industrial approach.[1] Functional zones and human activities are put in the center of studies as they represent the behavior of urban dwellers better than job placement data which only reflects the most routine part of the daily cycle. For example, Filanova in her dissertation study of Samara [Filanova, 2008] distinguishes local socio-spatial formations (*rus.* «локальные социально-территориальные образования») as public spaces concentrating various functions which cover most of local dwellers' demands. The main idea behind such areas is to develop a more locally centered urban environment with elements of self-governance and autonomy. Similarly, Gaikova in Krasnoyarsk study [Gaikova, 2015] examines the aspect of a comfortable polycentric environment related to accessibility from both transport and functional points of view. She identifies cluster urban units as self-sufficient specific architectural and planning objects that provide a regular approach for creating a higher quality of life in the city. Another attempt to research urban framework anthropocentrically is a series of articles by Em [Em, 2017; 2018]. He tries to describe the dynamics of Moscow's spatial structure through central place theory and uses a number of socio-economic parameters to evaluate the level of centrality of distinguished nuclei.

The basis for these and many other contemporary studies was formed by the late Soviet and post-Soviet school of urban planning (*rus.* «градостроительство») through the development of a distinctive approach towards general understanding of city organization. Its logic of urban framework functioning is centered around the citizens' diurnal cycle, and the main goal was to smoothen the spatial inequalities of the Soviet urban planning heritage. The basis for modern urban spatial structure studies in Russia – the frame-fabric model (*rus.* «каркасно-тканевая модель») – was created by Soviet architect A. E. Gutnov in the 1970–80s [Gutnov, 1984; 1985] and became the basis for an innovative Moscow's perspective development concept [Gostev, 2023]. Gutnov's goal was to describe the process of evolution of urban systems with two simultaneous processes – the complication of the urban frame defined as "a stable structure-forming component of urban system with the high intensity of spatial development", and the expansion of urban fabric defined as "other components of urban system, its substrate". The dependence between usage intensity on the territory and its accessibility is fundamental and lies in the core of the model, providing the possibilities for further interpretations and creating the methodological superstructures [Gostev, 2018].

Gutnov's works were succeeded by the unevenly zoned model (*rus.* «неравномерно-районированная модель»), created in the 1980s by A. A. Vysokovsky. The model is a complex view of city functioning based on the polycentricity principle, aimed at solving the problem of the "absence of the most important environments inherent to every comfortable city in general plans – streets with multifunctional activity, various types of residential environment, green squares, parks, logistic complexes and territories with multifunctional industrial activity" [Vysokovsky, 2015]. To solve another problem of Soviet planning – improper choice of local foci on urban periphery – a more user-friendly way of organizing the urban frame is proposed, with its subcenters leaning towards the CBD instead of creating a nucleus in the geometric center of a district. The model-approved nuclei are proposed as the basis for choosing proper construction sites, adjusting functional zoning and creating a more comfortable city where multifunctional public and monofunctional private spaces coexist [Gostev, 2022]. Due to the breadth of coverage of various aspects of urban life, the Vysokovsky model is often used as a verification instrument in recent studies of urban spatial structure such as evaluation of level of activity in subcenters during the day to expose its rhythm and pulsations [Alyapkina, 2019], or detection and clusterization of centers of night life [Parfyonova, 2020]. In practical terms, identification of urban framework helps to depict both physical and socio-spatial layers of organization and is used to forecast different scenarios of territorial development and make long-term decisions [Vysokovsky, 1997].

In order to demarcate the nodal districts of the model, Vysokovsky developed two autonomous but interconnected approaches – morphological and sociological [Vysokovsky, 2005]. They reflect the dichotomous nature of the city with infrastructure and activity attractors on one hand and spatial behavior of urban dwellers on the other. This dualistic system, however, was reduced to the morphological approach in recent years as sociological approach in Vysokovsky's interpretation appears to be too laborious. There were attempts to revive it by comparing objective and cognitive data for several districts of Moscow [Goncharov, Nikogosian, 2017]. Respondents were asked to describe their areas of activity near certain nuclei as well as the alleged boundaries and central locations of each spatial unit. However, the results of two datasets diverged significantly as respondents do not usually think in specific terminology, and each person's individual area of activity is not limited by the model-constrained units. Our research, among other goals, aims to enhance and supplement the existing methodology and provide practically substantial findings by theoretically justifying the approach and specifying the questionnaire.

1. The distinction between industrial and post-industrial approaches in urban space modeling is highlighted by E. A. Kotov [Kotov, 2017] based on the types of data available for Russian cities compared to U. S. census tracts' datasets.

Morphological approach

On modeling polycentricity

First, it should be noted that the general morphological approach towards polycentricity contains the morphological approach of the Vysokovsky model among many others. The first categorization was provided by McMillen [McMillen, 2001b], where he singled out four main approaches to urban nuclei identification. A decade later Jaume [Jaume, 2012] offered a classification of polycentric models based on criteria applied to delimitate the nuclei, with four methodological groups representing the morphological approach (thresholds, density peaks, residues of a locally weighted regression and spatial econometrics) and the functional approach (commuting flows).

Spatial econometrics stands out as it is the most universal tool applied for different problems in geospatial analytics. Two main indexes – Getis-Ord Hotspot Analysis [Getis, Ord, 1992] and Local Moran's Spatial Autocorrelation (LISA) [Anselin, 1995] – allow researchers to determine the territories standing out from their vicinities and the levels of significance of that divergence.

Models using positive residues of local weighted regressions were introduced in the basic form of a standard negative exponential function of employment density by McMillen and Prather [McMillen, Prather, 1994]. Later, the approach was developed by McMillen [McMillen, 2001a; McMillen, Smith, 2003] by introducing a two-stage approach – a nonparametric smoothing of values which captures the effect of distance from the CBD using a flexible Fourier form where significant positive residues of weighted least squares are an indicator of potential subcenters, and a validation of obtained nuclei effects on employment density using a semi-parametric regression.

The threshold approach was first applied by Giuliano and Small [Giuliano, Small, 1991] as peer-reviewed (regarding their overall number of nuclei and the peculiarities of specific territory) population and employment parameter values that determine the existence of significant economic activity. This cutoff method is well suited for city comparison [McMillen, Lester, 2003] or an evolutionary tracking, due to the evidence of nuclei configuration shifting without model adaptation to a present state [Anderson, Bogart, 2001; Shearmur, Coffey, 2002].

The method of density peaks is defined by the usage of various center-periphery estimation functions and refers to tracts that present a local maximum with respect to neighboring territories. The works of McDonald [McDonald, 1987], McDonald and McMillen [McDonald, McMillen, 1990], Craig and Ng [Craig, Ng 2001] and Redfearn [Redfearn, 2007] demonstrate different techniques and interpretations of a parameter gradient in search of the most precise configuration of urban spatial structure. Some studies combine density and cutoff approaches for population and employment data [Garcia-López, 2010].

When compared to existing industrial methods of modeling urban spatial structure, the morphological approach of the Vysokovsky model is closer to the density peaks group. Density peaks models use similar definitions of subcenters – for example, McDonald [McDonald, 1987] defines the nucleus as being a census tract where the center-periphery gradient of parameter values is broken and neighboring tracts of the same ring from the CBD have significantly smaller values. Nevertheless, there is a difference between Vysokovsky's approach and other models – it works better in allocating nuclei in the central part of the city while the others are more precise on the periphery due to differing mathematical apparatus.

According to Vysokovsky, the morphological approach is based on studying the spatial distribution of the objects that characterize the human diurnal cycle and distinguishing the places of highest local concentration as an urban framework. To model the smoothed surface of an indicator Vysokovsky suggests applying the trend-analysis, or a spatially-modified version of the method of the moving average [Vysokovsky, 1986]. It allows to allocate subcenters by comparing the value of a standard cell to the weighted average of its neighbors using the formula

$$\overline{T = \frac{2X + \sum_{i=1}^{n-1} Y}{n+1}},$$

where T is a trend value of a parameter, X is an actual value in a standard cell, Y represents the values in the contiguous cells, and n is a number of cells including the one for which the trend is calculated. Trend value is required to identify the significance level of each cell on the city scale using the standard deviation value (σ) of a fact-trend difference as a threshold

$$\sigma = \sqrt{\frac{\Sigma(X-T)^2}{n}} = \sqrt{\frac{\varepsilon^2}{n}}.$$

The subtracts' distribution highlights the outliers – the cells with a relatively high human activity compared to their surroundings (see Fig. 1). The 2σ, 1σ and 0.5σ thresholds determine a three-level hierarchy of the nuclei. Generalizing, 2σ-threshold highlights city-wide subcenters, which attract the audience from different districts; 1σ-threshold stands for the nuclei where people come from the contiguous territories; finally, 0.5σ-threshold represents more locally bound, situational or emerging urban nuclei.

The main challenge of Vysokovsky's morphological approach is to find a sufficiently comprehensive dataset to represent the potential generated activity in every part of a city [Vysokovsky, 1986]. Modern researchers tend to allocate subcenters applying the maintenance facility areas as the most accessible and

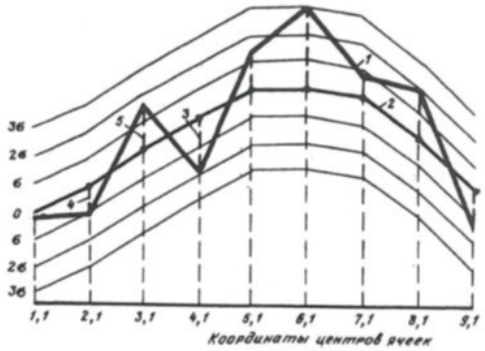


Fig. 1. Trend-analysis used for development units' placement prediction
Source: [Vysokovsky, 1986].

convenient data providing adequate structure with supply-demand logic – the enterprise should be able to have enough customers to exist in a certain place at a certain time in a certain premise area. Moreover, these datasets provide information on economic specialization of the territory, as the objects could be aggregated into functional categories [Kotov et al., 2016].

To estimate functional variety within a selected polygon of research, the Herfindahl-Hirschman index (HHI) is applied as an add-on to the Vysokovsky model. The index value is obtained with the formula

$$HHI = S_1^2 + S_2^2 + \ldots + S_n^2,$$

where S is the share of facilities with a certain functional category and n is the number of functional categories. Used in economics as a measure of either market concentration, economic diversity or macroeconomic specialization [Palan, 2010], in this research it reflects functional diversity inside each standard cell. There are several variations of threshold values division, the most popular being the economic approach which is based on the level of competition within a certain market (from monopoly to fierce competition) [Djolov, 2013]. For our purposes, economic application can be transferred to a spatial dimension regardless of the thresholds applied as they may differ depending on dataset structure – each cell is arbitrarily regarded as a separate market, and the lower the index is in a cell, the higher is the diversity of functions. Additionally, the share of the most widespread functional categories is added to analysis to characterize the territory in more detail.

Data

The dataset used for spatial modeling contains calculated floor areas of over 280 thousand maintenance facilities in Moscow,[2] in 2019 (see Table 1). Data represent the expected consumer flow according to Vysokovsky Graduate School of Urbanism research of Moscow's polycentricity [Kotov et al., 2016]. The authors state that economic agents tend to maximize their income by using the room space as efficiently as possible, which creates a general correlation between floor area and human activity. Similarly to that study, the functional diversity is represented via 18 categories covering all main aspects of urban life needs. The objects not available for urban dwellers (not located on closed territories) were excluded from the dataset as they do not represent a general human activity pattern. Trade enterprises, as well as business and public services and household services prevail in the overall structure, so the values of these categories play a crucial role in determining the functional diversity of territories.

Functional category	№ of facilities	% from total
Trade Enterprises (shopping malls, markets, shops)	98 341	34.95%
Business and Public Services	50 294	17.88%
Household Services	28 950	10.29%
Financial Institutions	19 992	7.11%
Catering Enterprises	15 882	5.64%
Healthcare Institutions	15 323	5.45%
Organizations, Institutions of Municipal and Federal Governance	13 939	4.95%
Educational Institutions	7 774	2.76%
Cultural and Arts Institutions	7 189	2.56%
Pharmacies	4 827	1.72%
Sports and Entertainment Facilities	4 233	1.50%
Communications Enterprises	4 055	1.44%
Transport Hub Facilities	3 282	1.17%
Physical Training and Leisure Facilities	3 249	1.15%
Tourist, Sanatorium-resort and Recreational Institutions	2 385	0.85%
Social Services Institutions	907	0.32%
Religious Sights	680	0.24%
Ritual Services	59	0.00%
Total	281 361	100.0%

Table 1. Functional categorization of maintenance facilities
Source: HSE Faculty of Urban and Regional Development.

The dataset is spatially generalized with the help of a standard 750-m-hexagon grid. Spatial distribution of floor areas of maintenance facilities reveals a strong monocentric pattern, created by the dense historical center and radial-circular planning structure of the city (see Fig. 2). Center-periphery gradient of the parameter, however, does not follow a perfect pattern, and a distinctive ring of peaks rises in the sub-peripheral zone. The spatial distribution on the periphery is more chaotic, and most peaks are located around large shopping centers or metro stations. Another noticeable feature of Moscow is sectorality, as natural and man-made barriers divide urban fabric into separate zones. This creates the corridors of higher parameter values, to one of which the research polygon belongs.

2. Territories attached to Moscow in 2011 were not considered as its integral part.

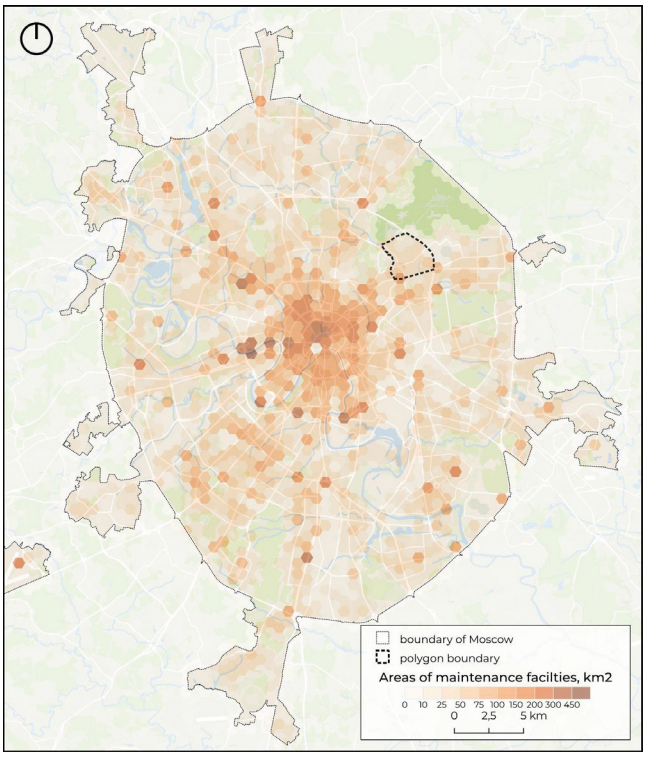


Fig. 2. Spatial distribution of areas of maintenance facilities in Moscow
Source: made by author; data by HSE Faculty of Urban and Regional Development.

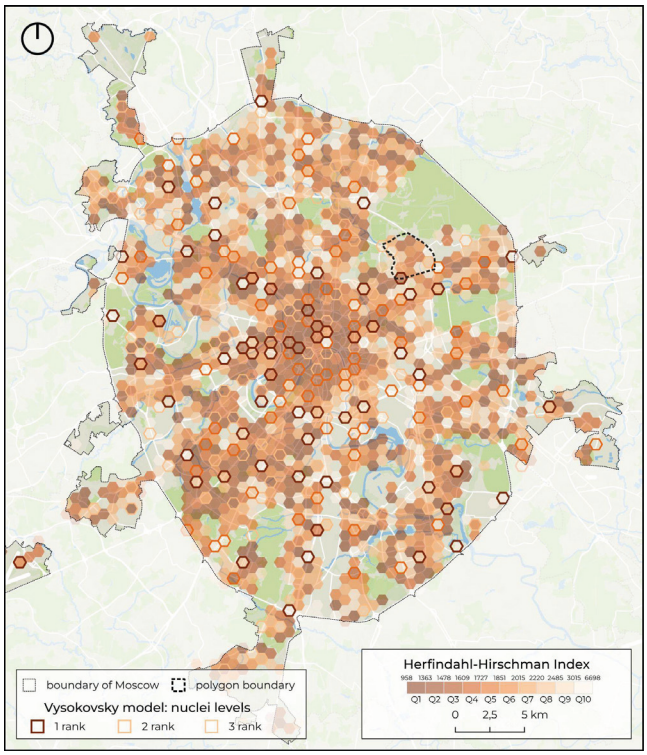


Fig. 3. Spatial structure and level of functional diversity in Moscow
Source: made by author; data by HSE Faculty of Urban and Regional Development.

Moscow's spatial structure

The city as a system should be viewed inseparably, so there is no way to single out its structural elements without defining the general picture of urban space organization in the first place. To distinguish subcenters within the research polygon, we need to model human activity based on floor areas of the maintenance facilities (see Fig. 3). It must be noted that the standard 750-meter hexagon grid reflects not the exact nuclei locations but rather the trend values, which are often split between multiple cells. If the vicinity of a cell is too deserted, a phantom subcenter may emerge, distorting the overall frame. In addition, in case the subcenter is divided between several cells it might not be identified as high neighboring values would diminish each other.

The most distinctive characteristic of the achieved spatial structure is the existence of several radial axes of first-level subcenters which follow major transport corridors and form the structural carcass of Moscow. They are divided by vast gaps in sub-peripheral and peripheral areas – as the cells with less than 20 objects are sorted out, the industrial and recreational zones splitting Moscow's urban fabric are revealed. HHI adds to the overall picture of urban spatial structure, showing a drastic reduction in functional diversity from the historical center to Moscow's periphery, where the pattern is rather heterogeneous (see Fig. 4). Central zone is surrounded by the Sadovoye ring highway, after which the gradient breaks. High diversity reappears in the Krasnoprudnaya, Rusakovskaya, Stromynka and Bolshaya Cherkizovskaya Streets, duplicated by the metro line – most first- or second-level subcenters are identified around the stations of that line. The relative position of the polygon allows us to evaluate the actual importance of the highlighted subcenters as well as to consider the possibility of existence of local activity manifestations.

The research polygon has four distinct borders – two natural ones (Losiny Ostrov national park and Yauza river) and two highways (Northeastern chord and Bolshaya Cherkizovskaya Street). Such isolation from neighboring territories is beneficial as primarily self-contained urban fabric has fewer external effects which simplifies the evaluation of local patterns of spatial behavior. Main points of entry into the territory are three metro stations and a transportation hub, all positioned on the edges of the polygon. Access-wise this creates a buffer zone which is regarded as the area of uncertainty. The polygon was mostly built up in the 1960s–80s as a residential district, with several zones of contemporary residential (which consists mostly of closed residential complexes) and commercial development. The microdistrict approach to planning resulted in a high saturation with educational and healthcare institutions that generally satisfy local demand. The demand for public transportation within the polygon is met by a circular tram line as well as several bus routes operating along the arterial roads. The role of green carcass is played by a wide boulevard Rokossovskogo, which stretches

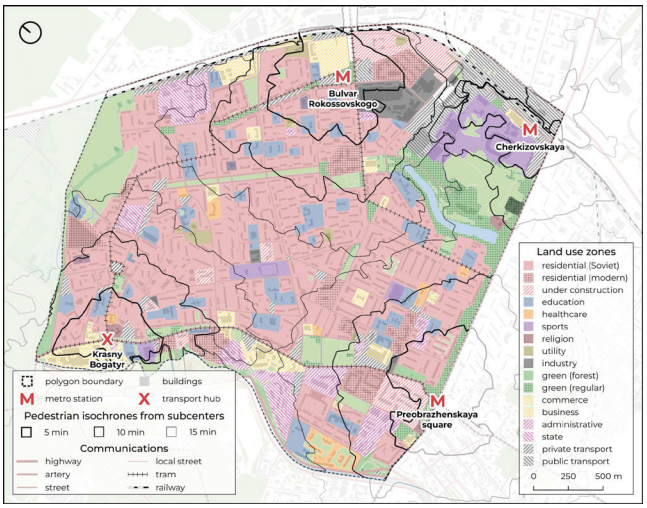


Fig. 4. Land use and road system of research polygon
Source: made by author; data from Yandex Maps and gisogd.mos.ru.

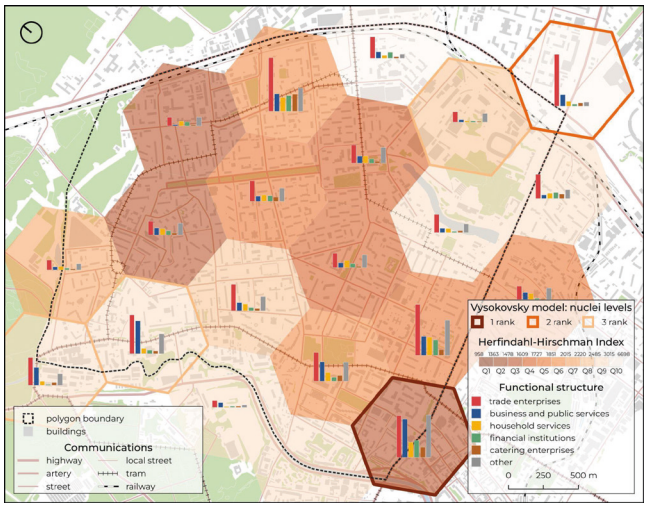


Fig. 5. Spatial structure and functional diversity of research polygon
Source: made by author; data by HSE Faculty of Urban and Regional Development.

through the northern areas, as well as many parks around the area of study. The Yauza River bank and areas adjacent to the railway are the most diverse functionally and surround a calmer central residential zone (see Fig. 4).

According to the Vysokovsky model, three nuclei are located around the perimeter of the polygon (see Fig. 5). The first-level subcenter around "Preobrazhenskaya Square" metro station is distinguished due to a 115-meter "Preo-8" business center as well as first-floor commercial facilities surrounding the square. The territory has the closest location to Moscow's historical center, serving as a transit hub to local dwellers as well as incomers from other districts and forming the biggest and most diverse activity spot (25% – trade enterprises, 23% – business and public activities, 10% – financial institutions). The second-level nucleus surrounding "Cherkizovskaya" metro station serves as a major transit hub (with Vostochny Railway Station, Moscow Central Circle and North-Eastern Chord intercepting) and a situational place of attraction with a 27,000-seat "RZD Arena" football stadium. However, the subcenter is cut off from the rest of the polygon by Cherkizovsky Park and metro depot, and its functionality is primarily limited to trade enterprises (over 61%). Finally, the third-level subcenter is on the junction of Krasnobogatyrskaya and Millionnaya streets, where most maintenance facilities are concentrated within "Krasny Bogatyr'" business center. One more potential subcenter not allocated by the model is the area of "Bulvar Rokossovskogo" metro station, but due to redistribution of commercial areas between several cells the subcenter was not highlighted.

According to the Vysokovsky model, the area of uncertainty, although containing fewer maintenance facilities, has a high functional diversity. People living in the residential zone do not require many outlets of one type within walking distance, but their demand for various facilities must be met. However, the question remains – is this vast inter-nuclear area evenly filled with different facilities, or are there concentrations that serve as local centers of activity.

Sociological approach

Prerequisites for on-site activity research

When speaking of the sociological approach in determining urban spatial units, Vysokovsky put mental maps of city dwellers in the center, calling them vernaculars. According to a common definition by L.V. Smirnyagin, a vernacular region is a place where people feel collective interconnectedness through either history, activities or identity and are able to distinguish themselves from inhabitants of neighboring territories [Sotsial'no-ekonomicheskaya geografiya..., 2013]. Vysokovsky, however, had a different perspective – through vernaculars he represents every urban dweller's naturally formed and stable area of daily activity [Vysokovsky, 2005]. Consequently, overlaid individual vernaculars highlight public and private spaces and construct a realistic picture of activity polarization in the territory. They create a basis for understanding the usage of locations and are a result of mass perception, extracting the main characteristics according to the majority of local dwellers. [Vysokovsky, 2015]

The main distinction between morphological and sociological approaches is the essence we are working with. People regard urban space not as a strictly demarcated framework but as a continuous tissue, focusing on certain facilities and functions rather than zones or territories. Spatial behavior of urban dwellers is usually highly structured temporally, centered around a daily cycle with three general destinations – place of residence, workplace and public locations of social interaction and leisure time spending (according to Oldenburg's concept of first, second and third places [Oldenburg, 1989]). Activity

spaces tend to form so that the venues are located within the vicinity of these routine routes. The densest intersections of vernaculars form loci zones. According to Vysokovsky, they have to correspond to morphological structure of territory and concentrate commerce, thus forming focal (or nodal[3]) districts that are considered central spatial units. The main problem of these spatial units is an ambiguity of boundaries – the influence of a focal point diffuses gradually, meaning the existence of a vague buffer between two spatial units [Rodoman, 1999]. In center-periphery theory these buffers are the periphery, but on a large scale the name "areas of uncertainty" fits them better due to the remoteness of centralities, where both scenarios of balanced usage of closest nuclei and emergence of new ones through local demand are possible[4].

Besides centrality, there are other factors influencing specific location choices. Maintenance facilities such as shops, cafés, salons, etc. are operating as goods or services on the city market, with each functional category establishing a niche and each urban dweller behaving as a consumer who has to constantly make economic decisions depending on individual preferences, lifestyle, wellbeing. Each market can be described as a two-dimensional system of product usage, applied as the functional utilization approach in marketing studies [Zaichkowsky, 1985; Ram, Jung, 1990]. We take two parameters of this system – depth and breadth of consumption – to describe the general behavioral pattern. Depth of usage stands for a number of times any consumer usually has a demand for a certain facility usage. Breadth of usage, on the other hand, represents the number of potential scenarios possible within every venue, or simply the level of necessity of offered goods and services in day-to-day life and current requirements of people. For our purposes, we have generalized this characteristic by combining two parameters into a broader frequency of usage parameter.

To divide outlets spatially, another dimension of functional utilization is required – uniqueness of a product. It represents the level of saturation of a city market with a particular functional type of facility and corresponds with Walter Christaller's central place theory, where the rank of an urban settlement defines the level of uniqueness of goods and services they contain [Christaller, 1933]. We can say that similarly to settlements of different size containing goods and services of different order and levels of diversity, nuclei tend to concentrate outlets based on their significance within urban space, and to represent varying patterns of behavior we need to include the outlets of varying levels of uniqueness in this study.

Regularly visited maintenance facilities together with residential and employment locations form individual activity spaces – geometrically, surfaces of intense spatial behavior [Horton, Reynolds, 1971]. In a wider sense, activity spaces can be viewed as knowledge spaces which contain not only the locations of personal experience but also places of second-hand experiences from various sources [Schönfelder, Axhausen, 2004a]. Although spatiotemporal changes in activity fields are revealed [Timmermans et al., 1982], generally areas of activity stabilize as users of urban space adapt to an environment and slow down the exploration process after the initial phase of learning. The concept of activity spaces matches the vernaculars defined by Vysokovsky, having more practical application examples at the same time, where researchers mostly implement commuting data like Mobidrive dataset [Schönfelder, Axhausen, 2004b] or actively tracked cellphone location data [Xu et al., 2016]. In this study activity spaces are collected as preferred locations of consuming products of varying uniqueness and frequency of usage via the field survey due to lack of other types of data and the smaller scale of the research polygon.

Methodology and constraints of field survey

The street survey was conducted on two non-holiday weekends with good weather conditions. Overall, 112 maps were collected, with 107 respondents residing within the research polygon and 5 who resided in its immediate vicinity. The estimated population residing within the territory is approximately 150,000 people, meaning the sample has a 92% confidence interval with a 90% coverage probability. The rejection rate fluctuates between 2 and 5 refusals per answer collected depending on the survey day.

The correct choice of strategy on response collection was the central issue of survey methodology. The initial idea of surveying along main streets failed due to a high average walking speed of pedestrians. Consequently, the strategy shifted to a more sporadic surveying within recreational zones as the most effective non-target data collection locations due to a lower speed of pedestrians and a more relaxed atmosphere. Another successful strategy was moving inside residential blocks in peripheral zones, where it was possible to fill the gaps in spatial distribution of residential locations and to canvass some underrepresented groups of respondents.

3. The difference between focal and nodal is in the presence of transport hubs in the latter [Rodoman, 1999]; similar narrative could be traced back to Kevin Lynch's description of a node as one of five core elements of any city: "Nodes are the strategic foci … typically either junctions of paths, or concentrations of some characteristic" [Lynch, 1960].

4. The logic here is similar to that of the Huff model [Huff, 1963] which postulates the existence of zones of influence of certain objects (from shops to cities) decaying with a function of distance. When overlapping, they form a vague border where consumers do not have any advantage of going to a particular object, called the area of uncertainty.

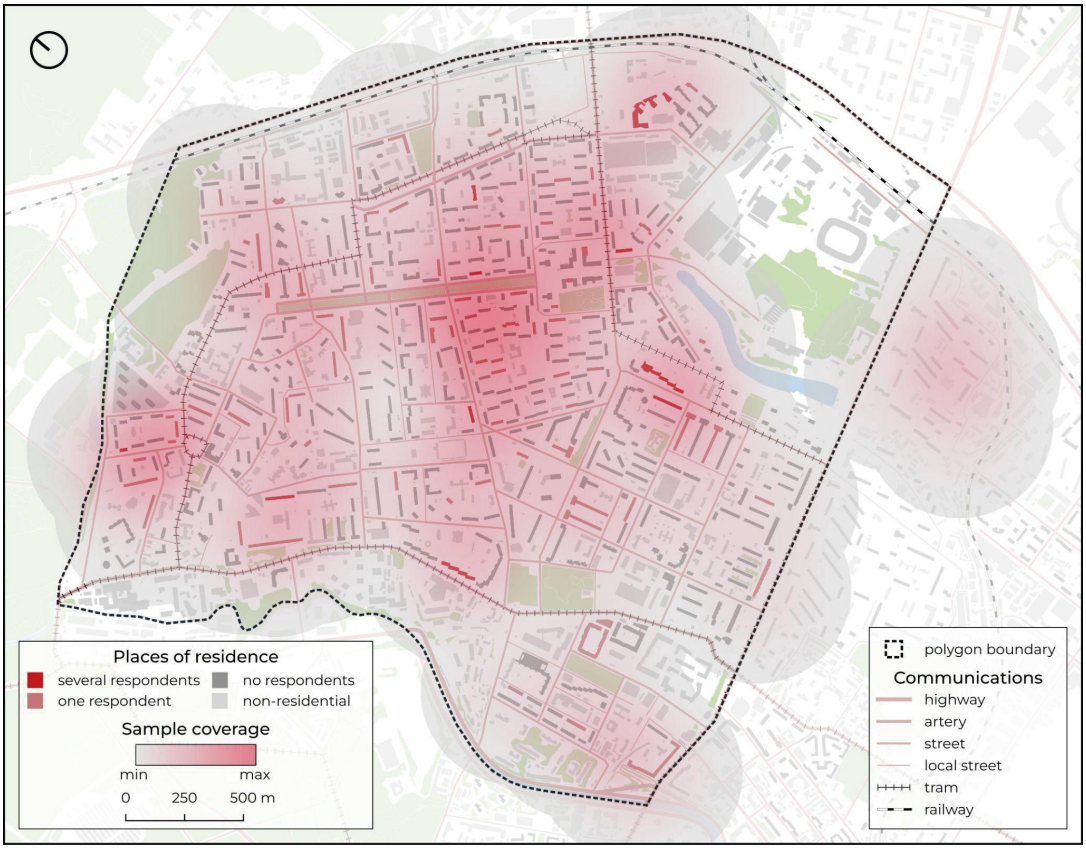


Fig. 6. Places of residence named by respondents
Source: field survey.

The survey focused on local dwellers as regular users of the polygon[5] and did not take into account incomers who are less familiar with the territory. To avoid potential concerns of privacy violation, the question on place of residence was asked in a vague form, allowing respondents to map one of the neighboring houses instead of one's own. This resulted in receiving the answer almost every time as respondents felt much less exposed.

For the sample to be representative, two criteria were articulated – spatial homogeneity of places of residence and age-sex structure of respondents. The first criterion provides a better representation of local patterns of activity across the polygon, especially considering more self-oriented zones like modern residential complexes (see Fig. 6). Several respondents residing in immediate vicinity to the polygon predominantly utilize the venues within it.

The second criterion allows us to achieve a sample close to the general population pyramid of the territory with 10-year intervals[6] (see Fig. 7). During the survey some age-sex groups were more difficult to meet and interview than others which slightly affects the sample. For instance, interviewing middle-aged women was complicated because many of them were accompanied by children. Also, the interviewer's gender likely hindered the response collection from potential female respondents as they generally feel less safe talking to male strangers on the streets. For older men the rejection rate was much higher than on average, and it was generally harder to find them on the streets.

To describe consumer behavior of respondents from the functional utilization point of view, 9 categories of goods and services were identified (see Fig. 8). Their choice was the summary of two key factors. First, there had to be a sufficient presence of relevant outlets on the territory. Second, they had to differ in frequency of usage and uniqueness. Some products match the parameters due to pairing with similar types of products of different characteristics (types of food with differing frequency of usage or types of catering with different uniqueness). During the survey, respondents were asked to map preferred facilities where they usually go for the specified products (if used within the polygon).

The structure of responses demonstrates a significant shift of usage towards more common and densely located outlets inside the polygon. More common goods and services (food and banking) were marked by more than 80% of respondents, while the share for more occasional ones (delivery pick-up points, places of rest and entertainment, self-care services) drops to just over 60%. Cafés and fast-food

5. The main concern here is the term "local dweller" which was sometimes misinterpreted (for instance, some people who migrated to the research polygon a long time ago were still associating themselves not with it but with their previous place of residence). Here, we include only those respondents who have lived within the polygon for some time.
6. For this study the population pyramid of Moscow is used as a reference.

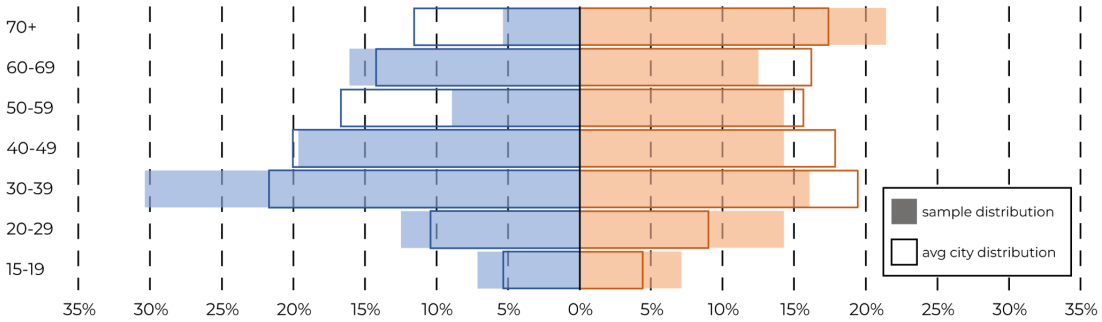


Fig. 7. Sample population pyramid compared to Moscow's average sex-age distribution
Source: field survey.

establishments, pointed out in slightly less than a half of the cases, were mostly left out due to three main reasons: insufficient quality of available facilities, high prices, and respondents' preference for cooking at home. Restaurants, clothes and footwear outlets are predominantly used outside of the polygon (most popular answers being the city center or the nearest big shopping mall near "Semyonovskaya" metro station) due to low quality and lack of variety, although there are several objects nearby.

Local patterns of human activity

To describe spatial patterns of local dwellers' consumer behavior, the chosen product groups are categorized by uniqueness and evaluated by the distance from places of residence. To identify concentrations, heatmap contours are obtained; additionally, the vectors from places of residence to selected locations within concentrations are added. The isochrones from hubs within the polygon are built considering an average walking speed of 5 km/h; they emphasize the area of uncertainty in the center of the territory.

Locations of the least unique products – perishable and storable food and delivery – tend to form concentrations within the area of uncertainty due to a higher daily necessity, although general spatial distribution is quite even and dense (see Fig. 9). Three local areas can be distinguished within the polygon based on perishable food locations – they are formed either around local shopping malls or in places of high concentration of different functions in close vicinity, meaning the user can potentially satisfy several demands at once. The first concentration, formed around the "Slavich" (1) mall which contains many small maintenance facilities, has a radial distribution of users who mostly dwell up to 800 meters from it. The second (2) and the third (3) nuclei, on the other hand, attract people living both nearby and far off as they are situated closer to the major roads, tram lines and model-approved nuclei.

Besides spatial accessibility, respondents point out the quality-price ratio as one of the main factors for choosing a specific food shop. This explains the difference in locations for purchasing perishable and storable food – many respondents do not trust chain stores in terms of meat and fish quality and freshness and prefer more distant but more trustworthy outlets like Preobrazhensky market (4) as the frequency of usage of that category is lower. Similarly, specialized fish or meat stores are preferred if they are located within a walking distance from places of residence.

The general usage pattern of pick-up points is slightly different. Spatial accessibility of pickup points that are characterized by an occasional usage allows local dwellers not to choose the exact location but rather select the service as the average distance from places of residence is the shortest out of all maintenance facilities. Their concentrations, thus, are predominantly the result of convenience of using several outlets with different functions in one place.

Spatial behavior of users diverges for different unevenly spread products (see Fig. 10). Question on entertainment and rest locations, introduced to respondents without specifying the details, appeared to be much more outdoors-centered than expected. People do not see many opportunities like going to the cinema or theater within the polygon that meet their recreational needs, and thus prefer visiting other districts for it, especially the area surrounding the nearby "Semenovskaya" metro station or the historical center. Instead, green zones stand out as the primary places of rest, as plenty of them are within or surrounding the polygon, the most popular being "Sokolniki" (1) and "Cherkizovsky" (2) parks and boulevard

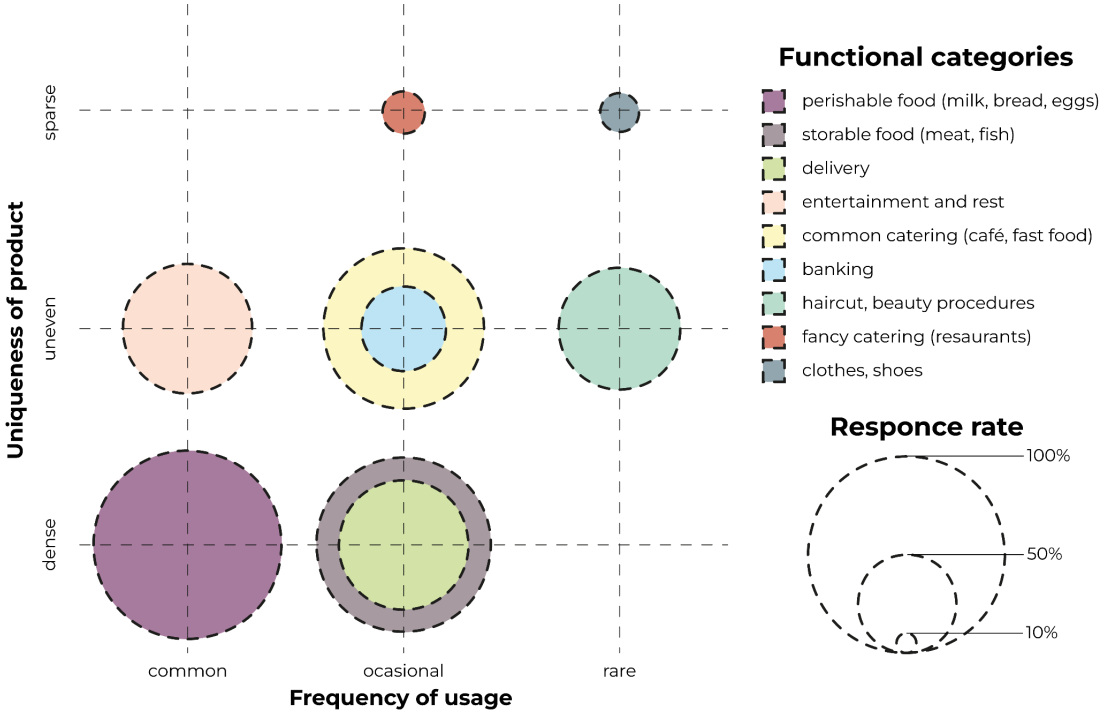


Fig. 8. Functional categorization of maintenance facilities
Source: sociological survey.

Rokossovskoro (3). Overall, this characterizes the territory as more peripheral and monofunctional as no unique locations for recreation were identified.

For other product categories higher object-oriented concentrations were identified, which approves the initial hypothesis about their level of uniqueness. Cafés are mostly decentralized and are not very popular within the polygon – a large proportion of respondents mentioned their expensiveness and low quality of service. The only place of attraction in terms of common catering is the "Yantar'" community center (4) which was named by younger respondents. Besides cafés, it resides several other outlets and serves as a venue for a diverse leisure time.

Locations of beauty services are also highly dispersed throughout the territory. People tend to choose a beauty salon or a hairdresser based on individual preferences rather than location. Moreover, some respondents do not have a specific location and regularly switch between different salons. The only detected concentration (5) allows us to identify places of more communal and closed usage like residential complex "Preobrazheniye" meaning its dwellers rarely interact with the rest of the polygon.

Three major ATM and bank locations emerge depending on each respondent's specific bank preference and general proximity to places of residence (6, 7, 8). A high share of respondents selected several points as their usage depends on the routes they take within the polygon to get to other locations, primarily the hubs. The pattern on exclusive territories is similar to that of beauty procedures.

Finally, maintenance facilities with the most unique products – upscale dining and clothes and shoes – are not represented sufficiently to identify local activity centers which is another indicator of the polygon's more private and peripheral nature. The responses tend to approve that conclusion, with most respondents preferring to go outside the territory for these products.

Nevertheless, those rare respondents who use unique products on the territory allow us to distinguish some patterns and confirm previous hypotheses. For instance, the restaurants used by respondents partially concentrate in the same community center "Yantar" as cafés. This happens due to differing understanding of what a café and a restaurant are based on individual lifestyles and habits. If the respondent is a regular visitor of catering facilities, they might downgrade most of them to cafés, while those who rarely eat outside places of residence tend to elevate the status of facilities they visit. Clothes and shoes outlets named by respondents concentrate near "Bulvar Rokossovskogo" metro station in large shopping malls. Even though the nucleus is not detected in that place by the model, the pattern to gravitate towards locations of higher importance on the city scale is evident.

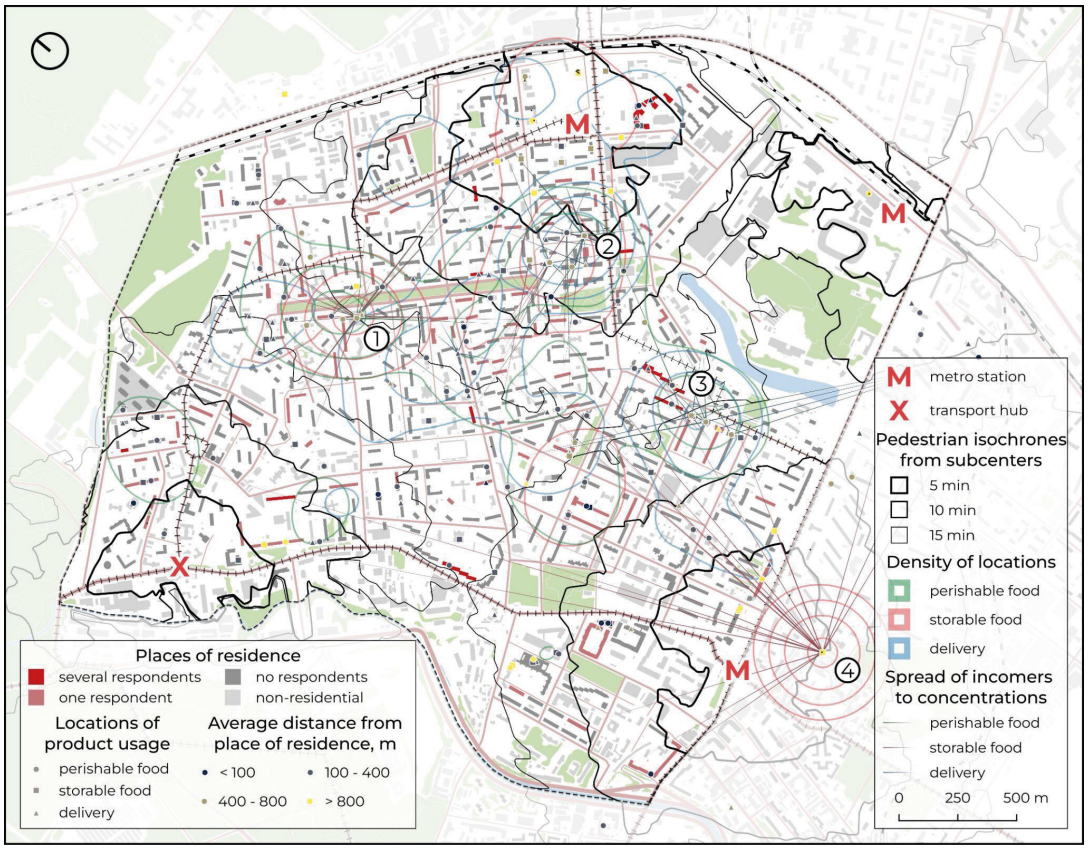


Fig. 9. Distribution of common product locations
Source: sociological survey.

With the peculiarities of each product category reviewed, the general picture can be drawn. The trend for polarization in the areas of uncertainty based on consumption of non-unique products looms with "Slavich" mall as well as two locations of high transport accessibility and population flows. "Yantar" community center is focused on providing more unique and occasional products and serves as a meeting point for certain groups of users. The principal similarity of these locations is the possibility to meet multiple needs without the necessity to travel away from the immediate proximity of a place of residence. This logic weakens with the levels of uniqueness and frequency of usage – if some unique and rarely used product is required, more effort may be invested to achieve it.

This belt of local concentrations of different product usage indicates the existence of a distinct type of structural element that has not been considered properly in urban spatial organization studies before. It does not function on the city scale as the nuclei highlighted by different models represent the nodes where people commute from other areas. Nuclei framework hence plays the role of a "skeleton" of an urban organism that defines the general connections. Local concentrations that maintain the quality of life for all urban dwellers can be regarded as "ligaments" in that metaphor, bonding the parts of flesh representing urban fabric. Thus, when describing and analyzing the functioning of the city structure, from now on they must be considered as well.

Conclusion

The results of the survey do not match the spatial structure highlighted by the Vysokovsky model and bring a contrasting layer of an actual local human activity. The nature of the model's nuclei and collected locations' concentrations differ fundamentally in understanding human activity on city and local scales. Model-allocated nuclei attract local dwellers primarily for unique and rarely used products. Local concentrations, on the other hand, include facilities with mass products that must be more accessible. They may not provide a lot of options (in fact, the number of actual outlets may be quite small), but their most important feature is the diversity of functions. Apart from the products included in the survey there are many small businesses that provide basic essential goods and services like all kinds of repairs, pet products or medications. They may exist

Fig. 10. Distribution of uneven product locations
Source: sociological survey.

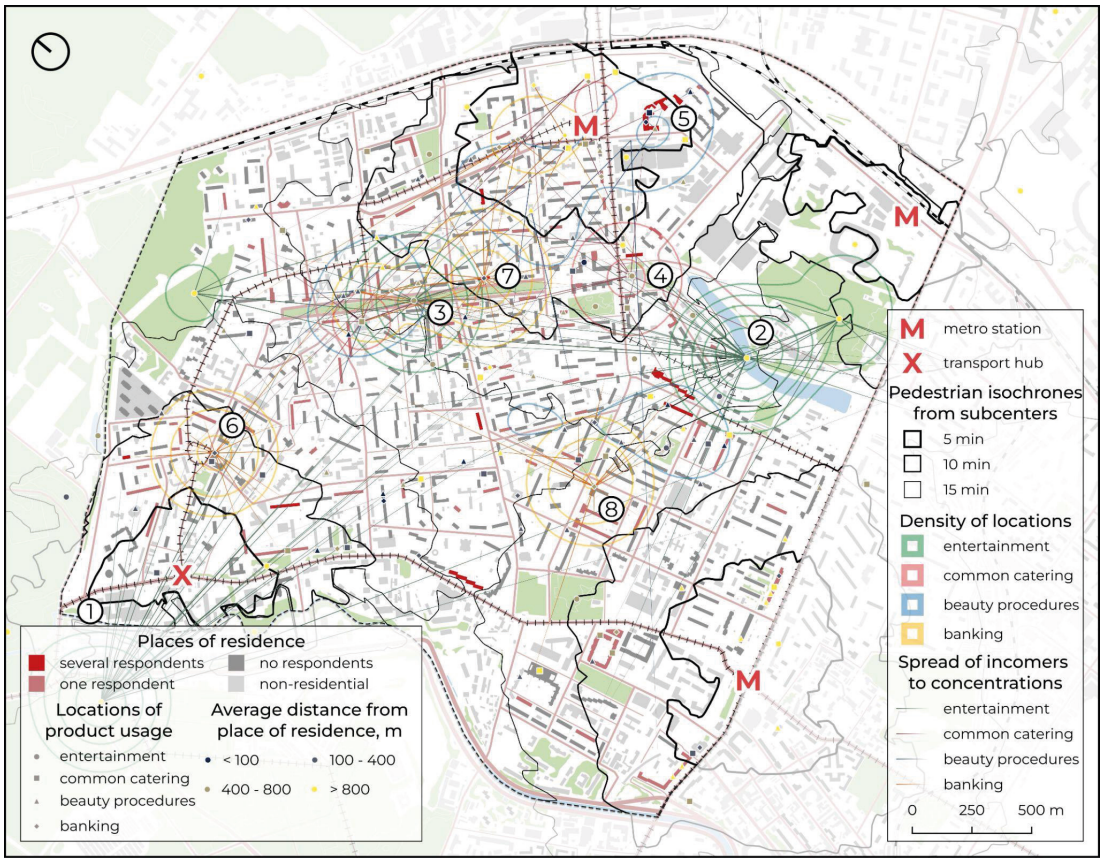
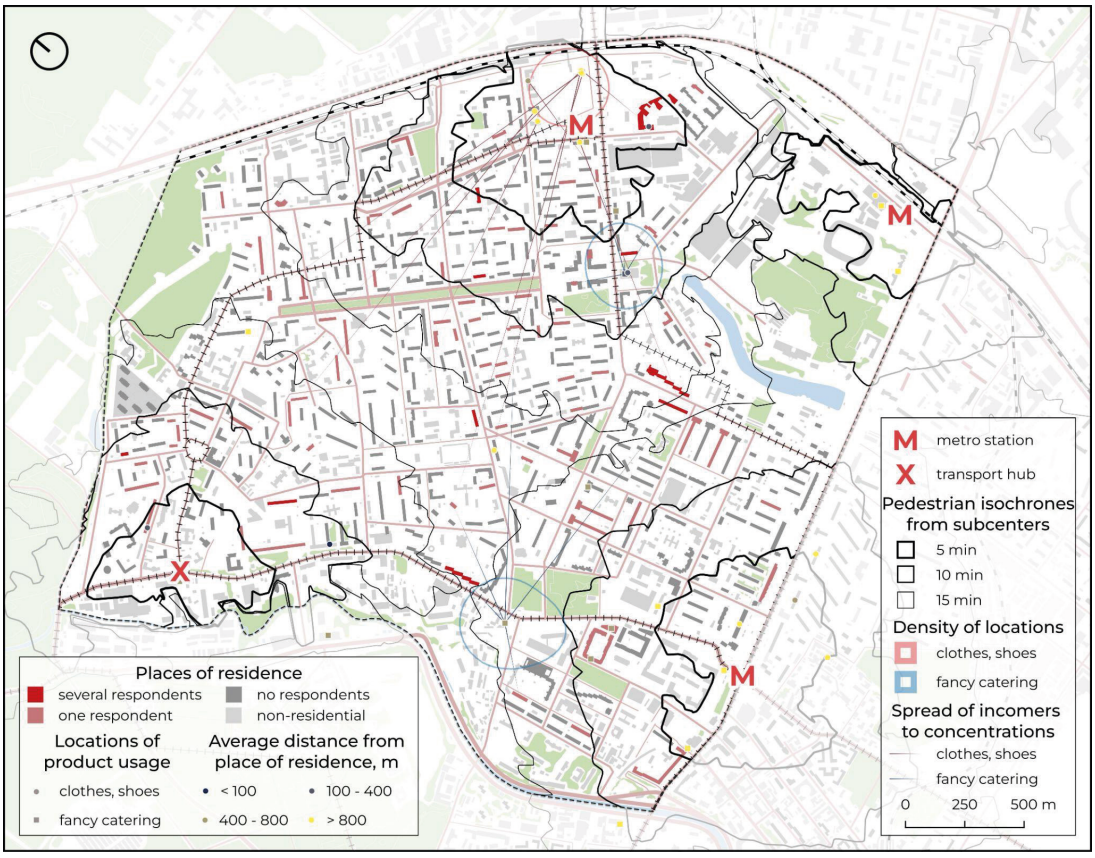


Fig. 11. Distribution of sparse product locations
Source: sociological survey.



within a larger facility – mall or community center – or gravitate naturally if first floors of the buildings are available for businesses or they are able to find alternative accommodation without any commercial premises.

Another type of space organization is a closed residential complex which includes essential facilities and excludes its dwellers from the surrounding territory's life. The example of "Preobrazheniye" demonstrates that it is not necessary to leave the complex boundary of both common and eneven products, and the proximity of a metro station is more important than the availability of facilities on the rest of the polygon territory. Thus, the development of such self-centered type of built-up environment is harmful for urban tissue functioning as it hinders the socio-behavioral coherency of territories.

This research has several limitations that should be taken into account when citing or replicating the methodology. First, the applied version of the morphological approach of the Vysokovsky model is simplified compared to the original and identifies the nuclei less precisely. Second, the research shows only generalized patterns of local activity and does not specify them for different groups of population, based on either age-sex or social division. Third, the survey does not fully capture each respondent's full activity area but rather its most noticeable and distinctive parts that allow us to single out the general pattern of local spatial behavior. And finally, the study was conducted in a geographically isolated polygon with a distinctive area of uncertainty and hubs forming it. This territory is a perfect location to highlight a clearly defined phenomenon, but depending on spatial configurations of other territories such features may not always occur.

Our findings have implications for understanding the connection between the established urban frame and actual behavioral patterns on a local scale. One of the possible next steps in describing local human activity from the spatial organization point of view is adding behavioral scenarios into the research. Such an approach can help to create a transition from regarding separate products to modeling sequences of actions that are possible within certain areas. Consumer logic works great when applied to separate products, but urban dwellers never act like homo economicus, making irrational decisions and switching behavior based on different factors. They are always subjects to new trends in all spheres of life as well as countless external sources of influence. Moreover, the recent paper on urban economic resilience of businesses and communities from changes in spatial behavior in a response to various shocks reveals a cascading effect which is itself a result of a complex set of factors shaping spatial organization [Yabe et. al., 2024]. Thus, the understanding of decision-making process on location choice and route selection is crucial when studying urban spatial structure.

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ЗАКОНОМЕРНОСТИ ЛОКАЛЬНОЙ АКТИВНОСТИ НАСЕЛЕНИЯ: СОЦИОЛОГИЧЕСКИЙ ПЕРЕСМОТР ГОРОДСКОЙ ПРОСТРАНСТВЕННОЙ СТРУКТУРЫ

Буланин Николай Кириллович, независимый исследователь.
E-mail: nbulanin@gmail.com

Статья нацелена на раскрытие и описание ранее опускаемых элементов городской пространственной структуры — локальных субцентров в ареалах безразличия. Большинство современных работ, посвященных изучению организации городского пространства, фокусируются на выявлении крупных ядер без учета межъядерных пространств. Для обоснования существования и значимости таких форм городского пространства применяется видоизмененная модель Высоковского, в том числе социологический подход как полевой опрос в границах полигона исследования. Для описания пространственного поведения местных жителей конструируется двухпараметрическая концептуальная рамка, позволяющая классифицировать товары и сервисы. Полученная репрезентация поляризации локальной активности демонстрирует необходимость большего внимания к периферийных зонам, ранее рассматриваемым в качестве гомогенных.

Ключевые слова: городская пространственная структура; полицентричность; мультимасштабный город; локальная активность населения; ареал безразличия; Москва
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