

Spatial analysis of the territory of a megapolis city: environmental aspect

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Abstract: The purpose of this study is to conduct a spatial analysis of the territory of a city-millionaire using modern geoinformation methods and technologies. The focus of our analysis is the location of residential, industrial, public-business, and recreational zones, as well as the availability of education, health, culture, recreation, religion, service, and hotel industry facilities. For spatial analysis the geoinformation program QGIS was used, with the help of which the analysis of the actual use of the territory of a separate district of the city-millionaire was carried out, the analysis of provision of the territory of the district with the objects of socio-economic infrastructure, the assessment of transport accessibility of various objects on the territory of the district. The study also identified the directions of digital technology utilization, which can make a significant contribution to the modern geographical research and practice of sustainable development of territories. **Keywords:** spatial analysis, metropolitan area, digital technologies, geoinformation technologies, technological tools, educational objects, health care objects.

1 Introduction

The modern world is experiencing a rapid development of urban areas, associated with an intensive population and a variety of functions that cities perform for their inhabitants [1, 2]. Responsible planning and management of the development of urban areas requires a thorough understanding and analysis of their structure, distribution of functional zones, accessibility of social infrastructure facilities and provision of citizens with various services [3-5]. In this context, geoinformation technologies become an integral part of scientific and practical research, allowing to analyze spatial relationships more accurately and make informed decisions in urban planning [6-8]. The purpose of this study is to analyze the Vakhitovsky district of Kazan using modern geoinformation methods and technologies. The focus of our analysis is the location of residential, industrial, public-business and recreational zones, as well as the availability of education, health care, culture, recreation, religion, service and hotel industry facilities.

The key theoretical provisions underlying this study are related to the concept of spatial structure of urban areas, the influence of spatial location of objects on their accessibility for

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the population, as well as the importance of geoinformation tools for deeper analysis of spatial data [9-11]. The relevance of the topic is determined not only by the need for effective planning and development of urban areas, but also by the desire to create sustainable and comfortable urban environments for the life and activities of the population [13-15].

This study is based on the geographic information program QGIS, which has provided us with powerful tools for creating visualizations, analyzing data and identifying patterns on a geographic map. Further sections of the paper will present the materials and methods used to achieve the objectives, as well as a discussion of the results and possible directions for future research in geographic analysis of urban areas.

2 Materials and Methods

QGIS geoinformation program was used for the analysis of Vakhitovsky district of Kazan. This program provided the necessary technological tools for creating vector objects, grading and stylization of data fields, analysis of territory provision on the basis of regular network, construction of road network graphs and analysis of transport networks, as well as design of map layouts and their export.

The main stages of work with QGIS included the use of the following technological elements of the geoinformation program.

1) Creation of vector objects. During the study, polygonal, linear and point objects were created, which represented residential, industrial, public-business, recreational areas, as well as objects of education, health care, culture, recreation, religion, service and hospitality sectors.

2) Gradation and stylization of field objects. For visual presentation of the data, grading and stylization of field objects was performed using different color and style settings, which facilitated visual analysis of the spatial distribution of objects and their characteristics.

3) Analysis of area provisioning based on a regular grid. Using a regular grid, the provision of the territory with objects of different categories was analyzed. This analysis allowed to identify the density of objects and their uniformity across the territory.

4) Road network graph construction and transportation network analysis. The geographic data on the road network was used to construct a road infrastructure graph, which allowed to analyze the efficiency of transportation links and their impact on the accessibility of different zones of the area.

5) Map layout and export. The maps created were styled to meet the scientific standards and requirements and then exported into graphic files for inclusion in the research work.

The information base of the study was the works of scientists in the field of assessing the spatial structure of the urban area in terms of provision of the district territory with educational facilities [16-18], health care [19. 20], culture [21, 22] and other social infrastructure facilities [23-25], assessment of transport infrastructure [26-29].

3 Results

One of the objectives of the study is to conduct a spatial analysis of the territory of Vakhitovsky district of Kazan. For this purpose, using the QGIS service (Quantum GIS - free cross-platform geographic information system) was analyzed the actual use of the territory of Vakhitovsky district, the analysis of the provision of the territory of the district with social and economic infrastructure, assessment of transport accessibility of various objects on the territory of Vakhitovsky district of Kazan.

Let us analyze the actual use of the territory of Vakhitovsky district. (Fig. 1).

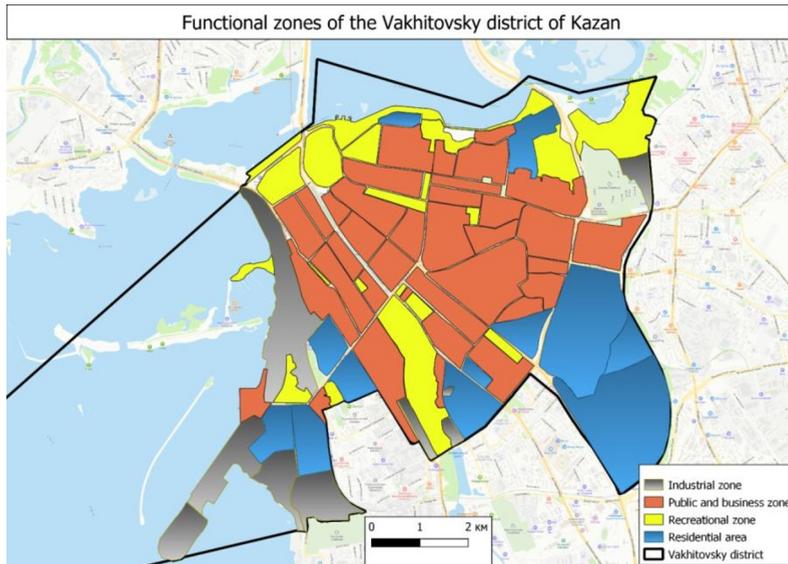


Fig. 1. Distribution of functional zones on the territory of Vakhitovsky district of Kazan.

The modern Vakhitovsky district occupies the central part of the city of Kazan and borders with other districts such as Sovetsky, Privolzhsky and Kirovsky. Its territory is washed by the waters of the Kuibyshev Reservoir and the Kazanka River, which act as natural boundaries with the Kirovsky and Novo-Savinovsky districts respectively. The Nizhny Kaban Lake and the Bulak channel can be found inside the district. The total area of Vakhitovsky District is 2582.0 hectares, of which 1867.7 hectares are on land and 714.3 hectares are occupied by water surfaces.

As of January 1, 2021, the population of Vakhitovsky District was about 85.9 thousand people. The district is divided into different zones with different functional purposes. The total area of residential zones in the district is 4.5 square kilometers, the total area of public-business zones is 12.5 square kilometers, the total area of recreational zones is 5.5 square kilometers, and the total area of industrial zones is 2.3 square kilometers. In total, there are 12 residential zones, 35 public-business zones, 21 recreational zones and 9 industrial zones in the district. Such characteristics of the territory of Vakhitovsky district testify to its diversity and development in various spheres, providing residents with a comfortable place to live, work and rest.

Let's analyze the location of educational facilities in the Vakhitovsky district of Kazan (Fig. 2).

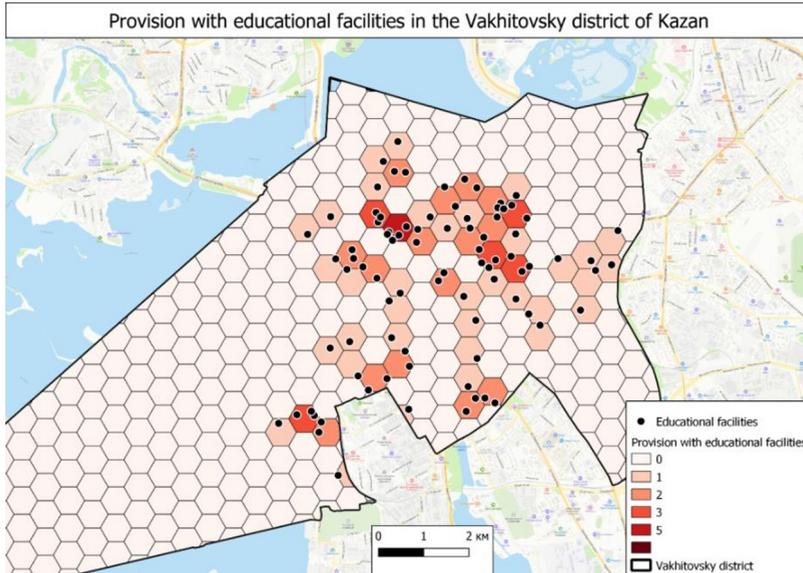


Fig. 2. Provision with educational facilities in the Vakhitovsky District of Kazan.

Vakhitovsky District of Kazan has an extensive network of educational institutions, which includes 21 schools (including lyceums and gymnasiums), 24 preschool educational institutions and 27 institutions of higher and secondary vocational education. Most of the district's general education institutions are innovative and offer students programs of increased complexity, contributing to their development and success. A data bank of talented and gifted children has been established in the district, which makes it possible to effectively identify and support their talents.

One of the priority tasks in the area of national education in the district is the preservation of the native language and cultural heritage. The Vakhitovsky district is also a center of science and study. Almost all higher educational institutions of the city are concentrated here, including Kazan Federal University, Kazan National Research Technological University, Kazan National Research Technical University named after A.N. Tupolev-KAI, Kazan State Medical University, Kazan State University of Architecture and Civil Engineering, Kazan State Agrarian University, Kazan State Conservatory and many others. This makes Vakhitovsky district a significant educational and scientific center attracting students and scientists from all over the country and even beyond.

Vakhitovsky District as a whole has a high number of universities (18) and colleges / colleges (20) and an average number of schools (26) and kindergartens (21). The total number of educational facilities is 85.

Let's analyze the location of healthcare facilities in Vakhitovsky district of Kazan. (Fig. 3).

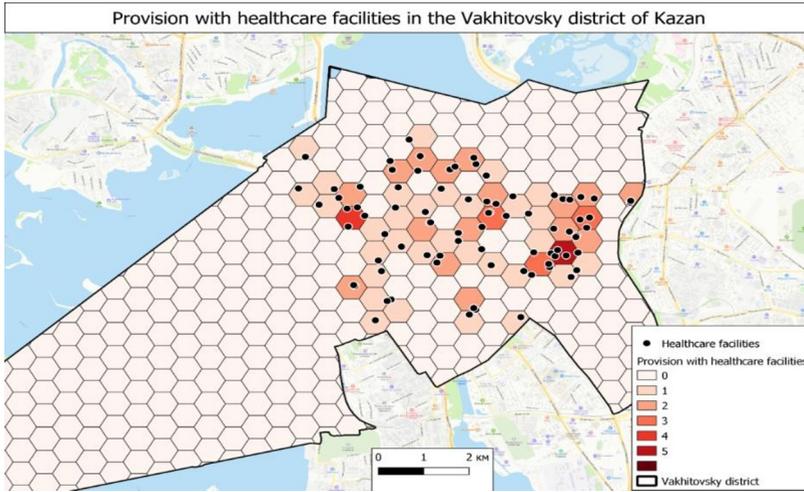


Fig. 3. Provision with healthcare facilities in the Vakhitovsky district of Kazan.

In Vakhitovsky district there are 5 polyclinics, 4 specialized hospitals, 57 private multidisciplinary medical clinics and 25 dental clinics, the total number of health care facilities reaches 81. This area of the city provides a high level of accessibility and diversity of medical services for the local population.

Among the medical institutions located in the Vakhitovsky district, worth mentioning are the Ophthalmological Hospital, which specializes in the treatment of eye diseases, the University Clinic of KFU, where students and professors of the leading university of the city provide medical care, as well as the Republican Clinical Skin and Venereal Dispensary, the Republican Clinical Psychiatric Hospital named after Academician V. M. Bekhterev and the V. P. Krupin Clinic, specializing in specific areas of medicine. In addition to public institutions, there are many private medical centers in the district, providing a wide range of services. Vakhitovsky District has an extensive healthcare infrastructure, offering residents a variety of options for receiving quality medical care.

Let's analyze the location of cultural facilities in the Vakhitovsky district of Kazan. (Fig. 4).

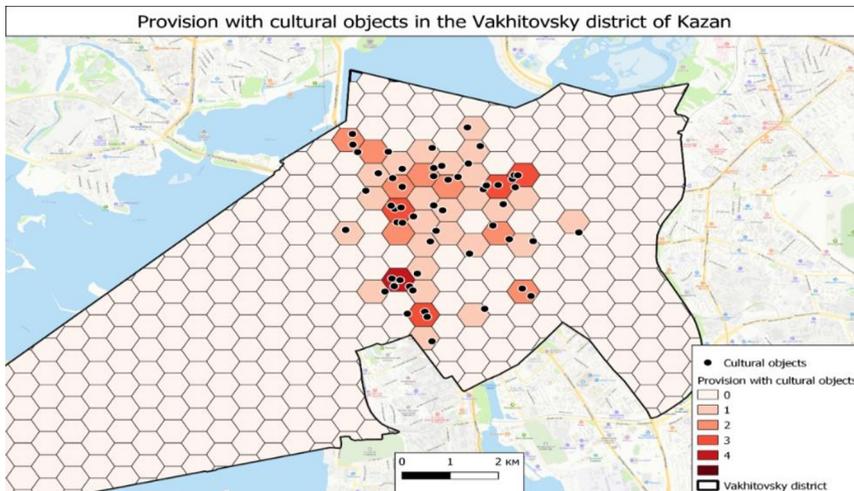


Fig. 4. Provision with cultural objects in the Vakhitovsky district of Kazan.

In the culturally saturated Vakhitovsky district one can find a rich variety of cultural facilities. There are 30 museums, 10 theaters, 7 public libraries, 4 cinemas and 5 concert complexes, the total number of which is 57. The district is famous for its significant contribution to the cultural life of the city, attracting talented artists.

On the territory of Vakhitovsky district there are theaters and museums known outside Russia. Here one can find such landmark institutions as the National Library, the State Circus, the Song and Dance Ensemble, the House of Friendship of National Cultural Societies of the Republic of Tatarstan, and the S. Saydashev State Library and Concert Hall. In addition, the district pays great attention to the issues of moral and aesthetic education, actively developing cultural and leisure institutions.

In Vakhitovsky district 612 buildings and structures of cultural significance can be found. Of these, 122 are of federal significance, 339 are of republican significance, 62 are of local significance, and 89 have been recently discovered. More than 50 monuments and busts of monumental art beautifully decorate the space of Vakhitovsky district.

Such a variety of cultural objects testifies to the importance of Vakhitovsky district as a cultural center, where every resident and visitor can enjoy the richness and diversity of art and culture.

Let's analyze the placement of recreation facilities in the territory of Vakhitovsky district. (Fig. 5).

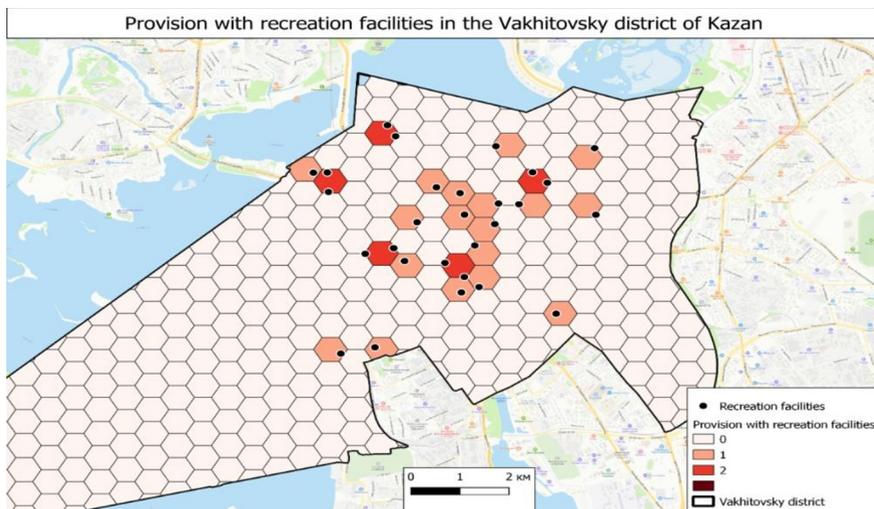


Fig. 5. Provision with recreation facilities in the Vakhitovsky district of Kazan.

In Vakhitovsky district you can find a variety of opportunities for sports and recreation. There are 16 sports facilities and 18 public spaces, the total number of recreational facilities is 34. This district is the greenest in the city, with a total area of 393.0 hectares of green space. In the neighborhood you can find such famous public spaces as the Kremlin Embankment, the Zemlyadelsky Park, the pedestrian streets Bauman and Peterburgskaya, the Black Lake Park, the Hermitage Garden, the Lyadsky Garden and others. These places offer excellent opportunities for walking, sports and outdoor recreation.

In Vakhitovsky district residents of the city are provided with all the necessary conditions for physical training and sports. There are 9 children's and youth sports schools, Central Stadium, Dynamo Stadium, Ice Palace of Sports, Basket Hall, Sports and Recreation Complex "Labor Reserves" and other sports facilities. The variety of these places allows the residents of the district to engage in various sports and maintain an active lifestyle, taking care of their physical condition.

Let's analyze the placement of religious facilities on the territory of Vakhitovsky district. (Fig. 6).



Fig. 6. Provision with objects of religion in the Vakhitovsky district of Kazan.

In Vakhitovsky district of Kazan you can find a variety of religious objects. There are 23 churches and 14 mosques, the total number of religious sites is 37. These places are an important part of the spiritual life of the district and the whole city. One of the symbols of Vakhitovsky district and Kazan as a whole is the Kazan Kremlin. On its territory are located the Cathedral of the Annunciation, the Syuyumbike Tower and the beautiful Kul-Sharif Cathedral Mosque. These architectural masterpieces attract tourists and believers from all over the world. Also on the territory of Vakhitovsky district there are other significant religious objects, such as Al-Marjani Mosque, Galejev Mosque, Zakaban Mosque, Burnayev Mosque, Azimov Mosque, Peter and Paul Cathedral, Cathedral of the Kazan Icon of the Mother of God, Kazan Cathedral, St. Nicholas Cathedral, Chabad Lubavitch Synagogue, St. Catherine Evangelical Lutheran Church, Catholic Church of the Exaltation of the Holy Cross and many other churches. These places are centers of faith and places where believers gather for prayers and religious rituals. This diversity of religious sites in Vakhitovsky district reflects the cultural and spiritual diversity of Kazan, creating an atmosphere of tolerance and mutual respect.

Let's analyze the location of service facilities in the Vakhitovsky district. (Fig. 7).

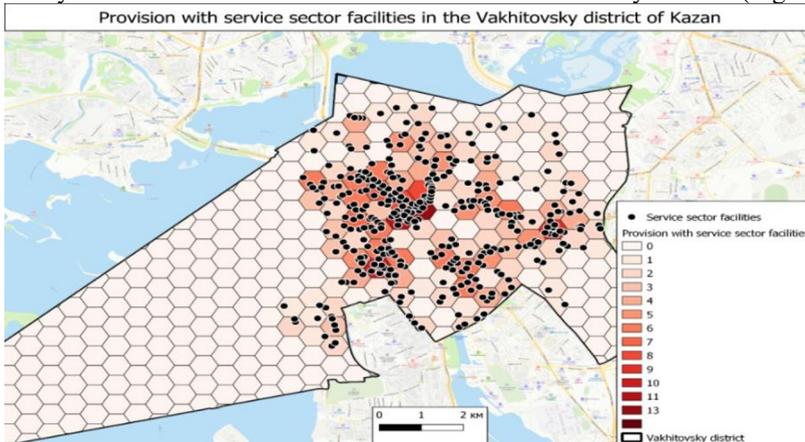


Fig. 7. Provision with service service facilities in the Vakhitovsky district of Kazan.

In Vakhitovsky district of Kazan can be found a large number of service service facilities. There are 235 cafes and restaurants, 61 stores, 5 shopping centers and 48 hairdressing salons. The total number of objects in the service sector is 300. This means that residents and visitors of the district have a wide choice of places where you can relax, eat, shop or visit a hairdresser. Special attention should be paid to Profsoyuznaya and Pushkin streets, which are the centers of Kazan's "night life". Here there is a high concentration of bars, cafes and restaurants offering a variety of options for spending the evening.

The public and business center of Vakhitovsky district also offers a large number of shopping centers and entertainment venues. Among them are the shopping mall "Koltso" and shopping center "Respulika", which offer a wide range of goods and entertainment. Also located in the district are Shopping central Universal Shopping Center, Korston Shopping Mall, Suvar Plaza Shopping Center, GUM Shopping Center, Kolkhozny and Chekhovskiy markets, Torgovaya Sloboda Shopping Center and Muraveynik Shopping Center.

In the public and business center of Vakhitovsky District, as well as in its "elite" neighborhoods, one can observe a certain lack of consumer service facilities such as hairdressers, dry cleaners, ateliers, pharmacies and supermarkets. However, outside the central part of the district, commercial infrastructure is usually sufficient, although there may be a shortage of catering and entertainment establishments.

Vakhitovsky district provides a variety of public service facilities, taking into account the different needs of residents and guests of Kazan.

Let's analyze the location of hotels in Vakhitovsky district (Fig. 8).

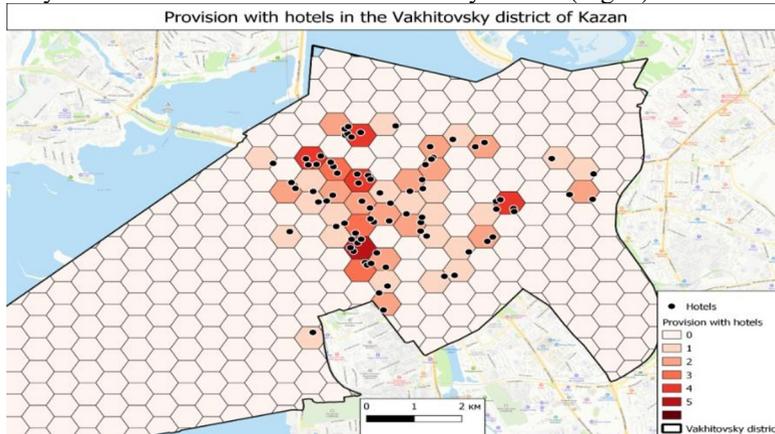


Fig. 8. Provision with hotels in the Vakhitovsky district of Kazan.

Vakhitovsky district of Kazan is known for its rich choice of luxury hotels that will satisfy the most refined tastes of tourists. Here you can find hotels with different number of stars, offering a high level of comfort and quality service.

There are 79 hotels in the area, of which 3 hotels have five stars, 22 hotels have four stars and the remaining 54 hotels offer less than three stars. This is the total number of hotels in Vakhitovsky district. Among the luxury hotels in Vakhitovsky district, a few particularly attractive options should be highlighted. In the category of five-star hotels we can mention Luciano and Mirage. Four-star hotels such as Maxim Gorky Hotel, Karl House, Bilyar Palace, Grand Hotel Kazan, Korston Royal and Courtyard by Marriott Kazan Kremlin offer comfortable rooms and a wide range of services for their guests. Among three-star hotels it is worth mentioning Hotel Tatarstan, Kaganat, Shalyapin Palace, Nogai, Europa, Regina, TatarInn, Giuseppe, Hayal and Kazan Sultan.

Just some of the many hotels available in Vakhitovsky district. Thanks to the variety of offers, every tourist will be able to find a suitable option for a comfortable stay and enjoy their stay in Kazan.

Let us analyze the transport accessibility of the territory of Vakhitovsky district in the area of tram traffic (Fig. 9).

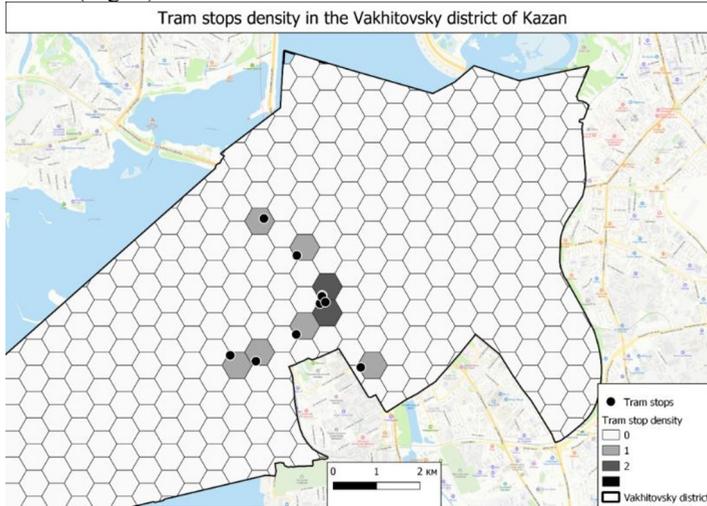


Fig. 9. Tram stops density in the territory of Vakhitovsky District of Kazan.

Vakhitovsky District has a developed transportation infrastructure, which includes a streetcar system and road network. Although the number of streetcar stops is small, the district provides convenient public transportation.

There are only 10 streetcar stops located in the neighborhood, through which various routes pass. Although the number of stops is small, they provide residents and visitors with the opportunity to travel to various destinations within Vakhitovsky District and connect with other parts of the city.

the area of the street and road network in the district is significant 2537.0 thousand square meters. The carriageway and paved sidewalks occupy the same area. This provides comfortable movement of transport and pedestrians in the district.

Bridges are an important element of the transportation infrastructure of Vakhitovsky District. There are 12 bridges in the district, which provide crossing of various water obstacles and connection with other parts of the city. These bridges play an important role in facilitating traffic and providing convenience for residents and visitors to the district.

In general, the transportation and road infrastructure of Vakhitovsky district provides convenient conditions for movement and facilitates connection with other parts of the city, contributing to comfortable and efficient transport accessibility.

Let's analyze the transport accessibility of the territory of Vakhitovsky District in the area of bus traffic (Fig. 10).

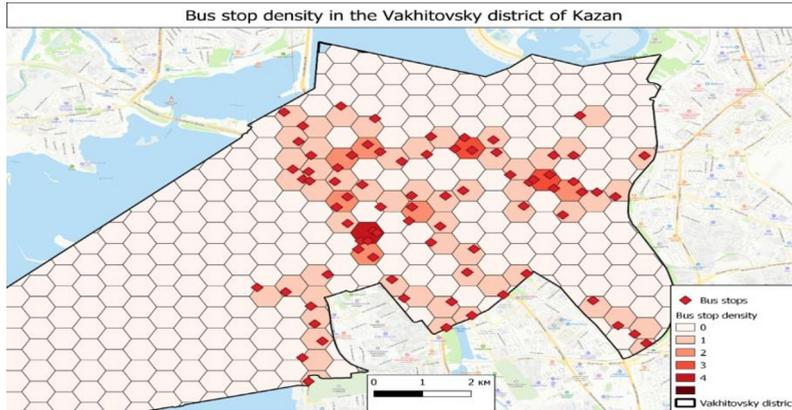


Fig. 10. Bus stops density in the Vakhitovsky District of Kazan.

Vakhitovsky District has a well-developed transportation infrastructure that provides convenience of movement for residents and visitors of the district.

Despite the fact that no route passes through 6 bus stops in the district, the total number of bus stops is 75. These stops are important pick-up and drop-off points for passengers, providing accessibility to public transportation within Vakhitovsky District.

There are also three metro stations in the district, which complements the transportation infrastructure and provides convenient transfer options and connections to other parts of the city.

Bus routes cover the central area of Vakhitovsky District in all directions, providing convenient transportation links to other parts of the city. Bus stops are located at a small distance from each other, which facilitates access to public transportation and reduces waiting time

Especially in the central area of Vakhitovsky district there is always a high concentration of cab cars. Residents and visitors can count on getting a cab quickly, as the waiting time rarely exceeds two minutes.

In general, the transportation infrastructure of Vakhitovsky District provides convenience and accessibility for moving around. Bus routes and the metro make it easy to travel both within the district and to other parts of the city, and the high concentration of cabs provides a fast and convenient transportation service.

4 Discussion

The results of this study, based on the analysis of Vakhitovsky district using QGIS geographic information program, emphasize the importance of digital technologies in modern science and practice of geographic analysis. The introduction of QGIS allowed a more accurate and comprehensive assessment of the structure and provision of the district with various types of objects.

Given the rapid development of digital technologies [30-34], future research in this topic can explore the following directions.

1) Application of artificial intelligence. The integration of artificial intelligence into geographic information systems like QGIS can greatly improve the analysis of spatial data by enriching its interpretation and providing new ways to identify patterns and trends.

2) Spatial analysis of big data. Given the accumulation of huge amounts of geographic data, it becomes urgent to develop methods and tools for efficient big data analysis, which will allow for a deeper exploration of the interaction of various parameters at the spatial level.

3) Interactive research. The development of interactive mapping tools will allow users to conduct their own spatial analyses, interacting with data in real time and creating customized conclusions.

4) Forecasting urban development. The use of geodata-based forecasting and simulation models will help anticipate changes in the location of facilities and infrastructure, which is valuable for planning sustainable development of urban areas. These strands will demonstrate how the integration of digital technologies and geographic information tools can make a significant contribution to contemporary geographic research and the practice of sustainable development of territories.

5 Conclusions

Thus, within the framework of the study we have carried out a spatial analysis of Vakhitovsky district of Kazan. With the help of QGIS service a series of maps were made: a general map of residential, industrial, public-business and recreational zones in Vakhitovsky district; a series of maps of the location of facilities and provision of education, health care, culture, recreation, religion, service and hotel facilities in Vakhitovsky district; maps of public transportation stops by the number of passing routes. The following conclusions were made. In Vakhitovsky district public-business zones significantly prevail, further, with a serious lag, followed by residential and recreational zones, approximately different in number and area, at the end with a significant lag are industrial zones. Vakhitovsky district is characterized by optimal provision with all the main socio-economic and socio-cultural facilities. In addition, the Vakhitovsky district has a well-developed transport infrastructure, as it is located in the central part of the city, borders with most of the other districts, having a convenient connection with them through transport dams and bridges, as well as on the territory of the generally compact area a large number of public transport stops and a high intensity of passenger and road transport traffic.

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