Analysis of urban territory in terms of accessibility to social objects

T I Baltyzhakova, E S Bryzhataya

1St. Petersburg Mining University, 2, 21st line of Vasilyevsky Island, Saint Petersburg, 199106, Russia

E-mail: tatiyana.baltyzhakova@gmail.com, Brigik97@mail.ru

Abstract. The paper presents data on the influence of road infrastructure on the accessibility of social objects. The studies have shown that the current method of calculating the accessibility of social objects does not reflect the factual situation. Isochrone maps allow calculating the accessibility of objects more accurately. This method takes into account not just the shortest distance to objects but the state of the road network. The spatial analysis of the accessibility of social objects in Kalininsky district of Saint Petersburg has shown that the actual number of people provided with it is far less than it should be.

1. Introduction
For developing territories, one of the most important town-planning tasks is to find out the suitable sites for social objects and to make the environment accessible for everyone. The availability of various socially significant objects directly affects the quality of life of the population and the social situation in the area. The residents will feel more socially protected when they are provided with easy access to kindergartens, schools and medical facilities. It should also be noted the importance of easy access to facilities such as clinics, as their visitors may be people with limited mobility. As for children, the actual distance to kindergartens should be less than designed, because their mobility is limited too. The term “accessibility” isn’t new. It first was created in XIX century by Johann Heinrich von Thunen in his model for spatial analysis.

It is a well-known fact that definition “territory accessibility” appeared in the science articles in the 19th century. It is generally agreed today that territory accessibility is the territory characteristic showing the degree of possibility to get to somewhere by selected transport types. This specification of locality is applied in spatial planning and geomarketing.

In this paper, accessibility is defined as an opportunity for simple and quick access to certain objects. This parameter is closely related to the social and economic factors. It is widely used in urban planning, and geomarketing, when looking for places to locate business objects (shops, shopping centers, etc.).

In the Russian regulatory practice, the availability of objects is described by the requirements for radial distance [1]. When placing new kindergartens and schools, planners draw buffer zones which are circles with given center and radius. It is important to emphasize that this results will be very approximate, because buffer zones do not take in account any obstacles on the way.
2. Materials and methods

One of the ways to analyze walking accessibility is using isochrone maps. Isochrone is isoline showing the places that can be reached within the selected time. The isochrone configuration is closed polyline while the “accessibility radius” is a circle. The isochrone coverage (isochrone area) is a polygon within this polyline. For example, you can build a five-minute isochrone around an apartment house and count the number of social facilities that the residents of this house have direct access to.

An investigation of the accessibility of objects within isochrone maps dates back to 1880’s [2], when Francis Galton began to think about the ideal trip from London to different countries and parts of the world. The result of this work was colorful isochrone maps, which highlighted areas that can be reached within the same period of time with a certain color. In 1903, a study of isochrone maps of the Prussian province Brandenburg was published. It compared the traveling time for transport systems for different years since 1819 [3]. Nowadays, isochrone construction technology has been extended to different spheres of human activity. For example, isochrone maps are used in medicine to predict ventricular arrhythmias in patients with previous myocardial infarction [4].

As was stated earlier buffer zones give the approximate estimation of accessibility. Figure 1 shows the comparison between the buffer zones (Figure 1a) and the isochrone map (Figure 1b). Figure 1b shows the actual accessibility for schools of the Kalininsky district of St. Petersburg into account various obstacles (green zones and highways).

The main goal of our research is to compare two ways of assessing the accessibility of social objects: “accessibility radiuses” and “isochrones”. This research is aimed at calculating the number of houses and the population covered by these zone types.

Building an effective, powerful and economically feasible access area that meets the needs of society requires the use of special tools for working with spatial data - the geographic information system (GIS).

The main goal of GIS application is to ensure sustainable development and functioning of the transport system and social infrastructure. Municipalities that control a large territory cannot effectively manage them without a GIS. Also an important aspect for solving such problems is determining the time and distance to the nearest object, since such objects can be vital destinations (hospitals, clinics, firefighters, etc.).

In this article Kalininsky district of St. Petersburg is chosen as the subject for analysis in terms of accessibility to social objects. In this area there are many objects of social infrastructure and factors affecting the access zone (for example, linear and areal obstacles). These obstacles make it difficult to
build straight-line routes from residential areas to destinations. Figure 2 shows the boundaries of the district, social facilities and main area obstacles (industrial zones near the Finland Station, Novorossiysk Street and Kalininsky Vegetable Base).

In this study QGIS 3.4 was used as GIS application because of its diversity in spatial analysis tools and easy use. The steps in analyzing the accessibility of the territory of the Kalinin district are the loading and processing data from OpenStreetMap, building two models “accessibility radiuses” and “isochrones”. The last step of analysis is counting the number of houses and the population covered by these zone types by summation of intersections of residential complexes with these zones.

Figure 2. Map of Kalininsky district using OSM data about social objects (kindergartens, schools and polyclinics)

To perform the calculations, a set of vector geodata is taken, containing information about the road and transport network and objects of social infrastructure. This information can be gathered in various ways: purchased from specialized suppliers, found one of the open data sources (Yandex.Maps.API) [5], by digitizing aerial photographs of the territory, etc. In this case, data from www.openstreetmap.com was used.

The primary processing of data involves checking the geometry of objects: the closure of polygons and the continuity of the transport and pedestrian network.

Isochrone maps are built with the service “Galton by Urbica” that takes into account pedestrian paths using OpenStreetMap (OSM) data [6]. When constructing the isochrones, not only topology of the road network (length of its parts) is taken into account, but also the speed of movement depending on the coverage of the tracks and sidewalks. The factors include transport costs, pauses at pedestrian crossings, time for descending into underground passages are not taken into account in the analysis of territory accessibility. The spatial separation methods used by Allen, Liu, Signer [7] and Ingram [8] take into account the above factors, but their solution is more difficult to use.
Vector layers with polygonal isochrones were created by performing the query with the coordinates of social objects (latitude and longitude), zone size and construction accuracy [6]. Each social object has its own value of the radius of accessibility: for children’s gardens it is 350 meters, for schools - 500 meters, for hospitals – 1000 meters [1]. Areas for accessibility radius were created as buffer zones. It should be noted that the radius of accessibility does not reflect the actual distance to the point of achievement, because the movement of population is on the pedestrian network, but not in a straight line.

Building isochrones with service [6] revealed some drawbacks. The first one is insufficient OSM data in the small cities. For Saint-Petersburg, this map includes almost all pedestrian paths. The second drawback is that OSM data does not consider the behavioral specificity of pedestrian traffic, which can result in forming of paths which are often not shown on maps [9].

3. Results and discussion

The results show that the difference between the areas of the isochrone and in the accessibility radius can increase to 85%. It is discovered that 89%, 85% and 54% of the population are provided with access to hospitals, schools and kindergartens respectively according to results of creating isochrones map. When using the buffer method, this value reached 94-96% (Figure 3).

The difference between the number of houses and the number of population is explained by the difference in number of people living in different houses. The territory of the district is diverse in terms of the type of development and the number of people in the houses. From the figures 3a and 3b it is apparent that actual social accessibility can be represented only with isochrones because the problem of getting a child to school or kindergarten is very relevant in Russia.

The results of the present study demonstrate that the residuals between the buffer zone area and isochrone area of schools are distributed normally (Figure 4b). This fact allows us to construct a buffer zone with an equivalent radius when it is impossible to construct an isochrone. The equivalent radius is radius at the highest frequency of occurrence of isochron area. This method is an alternative analysis of urban territory in terms of accessibility to social objects. You can build buffer zones with reduced radius and see actual walking accessibility.
Figure 4. Analysis of residuals between the buffer zone area and isochrone area in Kalininsky district of St. Petersburg: a – for kindergartens; b - for schools

Territory accessibility depends on the development of the road network and its “pattern”, the number of infrastructure facilities and the number of obstacles. Than the road and pedestrian networks are more developed (its density is higher), the isochrones transforms into a circle.

In a comparative analysis of the old and new districts of St. Petersburg, it is important to note that the planning of hospitals and other social facilities is in a state of delay. The results of the present study demonstrate that the new quarter in the intersection of Marshal Blucher Ave. and Kushelevskaya Road of St. Petersburg is located in the “social shadow” zone of hospitals (Figure 5b). In the district mostly constructed in 60-70s of the XX century the density of social objects is sufficient to provide the population almost completely(Figure 5a). The reason for the “social shadow” is the lack of social infrastructure and a large distance between pedestrian crossings across the Kushelevskaya Road.

Figure 5. Analysis of territory accessibility to polyclinics: a – in old districts of buildings of the 60-70s of the XX century; b – in new districts of St. Petersburg
4. Conclusion
The development of transport infrastructure gives an impetus to the development of social infrastructure, because the street-road network has the greatest influence on the territory accessibility of healthcare, education, etc. The accessibility of these social facilities determines the quality of life of the population.

In territorial planning, the forecast of actual social accessibility means not only the location of social facilities, but also the configuration of accessibility zones. The loss of part of these zones is due to the presence of various types of obstacles: industrial zones, highways, not equipped with pedestrian crossings, or hydrographic object. The main ways to solve the problem of accessibility to social objects: an increase in the number of social facilities or the development of transport and pedestrian networks.

In the Russian-language literature, estimation methods for transport and walking accessibility are poorly covered and little used in economic and geographical research[10]. “Accessibility radius” is the most used and inaccurate method. The isochrone method is one of the most reliable isoline methods. The disadvantage of this method is the subjectivity of the choice of the isoline sizes and the lack of differentiation of the territory located on the border of the isochrones [11].

When planning the location of social facilities, the following factors should be taken into account: the density of the road network, the presence of impassible obstacles (rivers, lakes and buildings) and passible obstacles (roads, green areas and low fences). We can build actual accessibility zones for social objects using isochrone maps with a comprehensive assessment of the above factors.

The biggest problem with building the isochrone maps that objects to which we need to calculate the accessibility can be not only point, but also polygons (urban forests, parks, boulevards and squares). But the solution for areal social facilities may be to coordinate not their center, but the entrance to the facility’s territory [5].

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