Assessment of urban territories transport accessibility conditions in Arctic cities

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Abstract. The article deals with the issue of organization of transport services in the territories of cities located in the harsh conditions of the cold climate in the Arctic zone. The hypothesis of the study is that uncomfortable weather conditions affect the mobility of the population and form a special behavior of the population with minimal time spent in the open air. Also, people's transport behaviour will depend on the level of development of transport infrastructure that provides access to urban areas. As an evaluation criterion, the time of accessibility to the city centre as the focus of the population's labour trips was chosen. Using the example of three cities located in the Arctic zone, isochrones of accessibility of the urban centre by road and passenger transport, as well as on foot using GIS were shown. As a result of the study it is highlighted that the current transport system of the cities does not meet the transport demand of the population, taking into account the characteristics of climate and stay in open space: there is a problem of excessive use of personal transport, lack of development of passenger transport, low quality pedestrian traffic. Based on the results of the study, the main directions for the sustainable development of cities and their transport systems for the Arctic conditions have been formulated.

1 Introduction

Ensuring due quality of urban life is the main objective of the city-planning policy in all worldwide cities. One of the challenges is to achieve the possibility of free relocation of people and their access to urban facilities and services. This issue is particularly relevant for the cities of the Arctic zone where the climate plays a significant role in shaping people's living conditions and their relocation round the city.

The climate impact issue is widely discussed in contemporary scientific research. People's being outdoors for most of the year is a problem for cities located in harsh cold climate, affecting the population mobility. In this case, cities should be designed in a way to secure

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due preconditions for comfortable access of the population to the urban infrastructure at the level of land use and development of urban street-and-road network.

This is a problem relevant for most cities in Russia located in the Arctic zone. They are specific in being compact in terms of urban layout, but the density of the entire settlement system is very low. This creates preconditions for low level of external inter-city and regional mobility, focusing attention on intra-city mobility. It should be noted that the problem of consistency of the Arctic region's settlement system has received considerable attention in the Russian scholarly research. However, the problem of organisation of transport mobility within the city is rooted in its insufficient research. The purpose of the study is assessment of conditions for the organisation of population mobility in the cities of the Arctic zone of the Russian Federation, with a view to understand the scope of the problem of their sustainable development and formation of comfortable urban environment.

The analysis of the global experience shows that the level of motorisation in the countries located in the northern regions is high per 1,000 residents, which is indicative of intensive use of automobiles in everyday life. Russia is characterised by the lowest indicator which is expected to grow in the long term. This fact evidences the car-oriented development trend of the urban transport system (Figure 1).

Table 1. Average motorization per 100 habitants (2020 year Eurostat statistics data).

Country	Average motorization per 100 habitants
Norway	546
Sweden	477
Finland	653
Russia	317

The current development trends in sustainable cities dictate a need for transition to other transport concepts focusing on passenger transport modes or pedestrian traffic, as presented in Figure 2. One of the research challenges is to assess the feasibility of urban policy shift towards the modern urban mobility patterns.

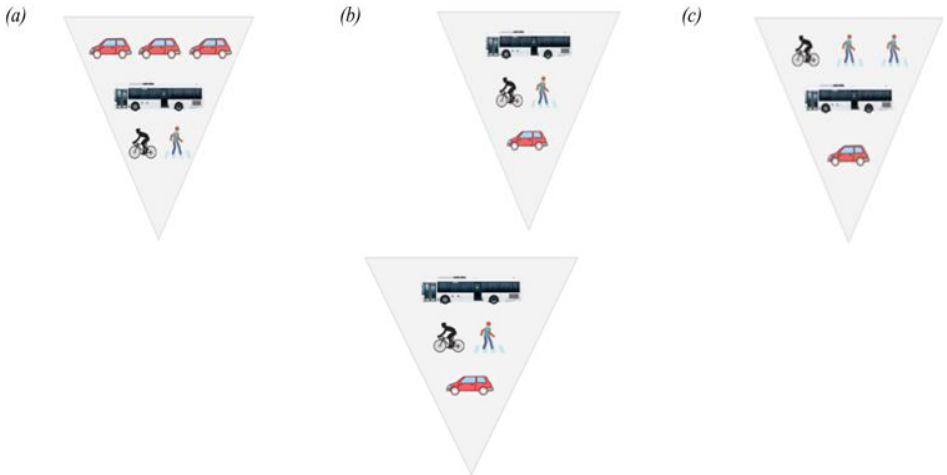


Fig. 1. City mobility patterns: (a) car-oriented city, (b) public transport oriented city, (c) transit oriented city.

2 Methods

The research methodology supposed applying the systems analysis methods and modern

digital technologies for assessment of urban territories transport accessibility conditions in Arctic cities. It included the three stages presented in Figure 3.

Fig. 2. Research methodology.

Since it was cities in the Arctic zone that were chosen for the research, the first step was exploring the climatic characteristics and the topography that would influence the population mobility.

The research methods used to obtain the baseline data included in-situ observations of the selected cities with the use of open sources of information: public maps, official websites of cities, social networks – communities of city residents, in order to obtain data on mobility of the population and transport preferences. Further, spatial analysis methods were used to describe the connection between the transport network and the land use map, to identify city centres, population attraction trends, labour application places.

Based on the research results, index maps showing accessibility of city areas from city centres were designed, since the latter are focal points of labour concentration and cultural attractiveness for the population. All graphical survey was carried out on the basis of the geographical information system, which ensures due accuracy of the obtained results.

3 Materials

Twenty-five cities located in the Arctic zone of Russia were chosen as the study material. The article presents the results for 3 cities that were selected to demonstrate the findings of the study. They are presented in Figure 4.

Fig. 3. City location and view. Foto source: Yandex map.

The criterion for selecting due cities was climatic conditions and topography, that were analysed at the first step of the research. The cities have flat topography and severe climatic conditions as features in common – cold long winters and short summers. The differences lie in average winter temperatures – from mild winters influenced by the sea in Severomorsk to harsher winters in Onega and to very severe conditions in Novy Urengoy. Let us consider the main climatic characteristics of the cities:

- The city of Severomorsk is located in Murmansk region. The climate here is moderately cold for the most part. Winters are mild and long, the coldest month being January with the average temperature of -8 degrees Celsius.
- Summers are cool and short, with July being the warmest month having the average temperature of +12 degrees.
- The city of Onega is located in Arkhangelsk region. The city has a temperate climate.
- Winters are long but moderately cold, the coldest month is January with the average temperature of -11 degrees. Summers are cool and short, the warmest month being July with the average temperature of +17 degrees.
- The city of Novy Urengoy is located in Yamal-Nenets Autonomous Area. The city has a markedly continental climate. Winters are very frosty and long, the coldest month is January with the average temperature of -20.7 degrees. Summers are cool and short, with the average temperature of +17.1 degrees in July.

The diversity of climatic conditions makes it possible to identify common and differing features in transport behaviour of the population and urban areas accessibility conditions.

4 Results

The research results are formulated on the basis of the second and third stages of the applied methodology.

The second stage of the research involved spatial analysis of the cities, which included:

- the analysis of land use plans (Figure 4) and
- the analysis of the transport network chart and types of population mobility.

Fig. 4. City layouts: (a) Novy Urengoy, (b) Severomorsk, (c) Onega. Sources: Official sites of cities.

The main characteristics of the cities derived from the spatial analysis are presented in Table 2.

Table 2. Cities` spatial description.

City	Square, sq.km	Population	Population density, habit. per sq.km	City street length, km	City street density, km per sq.km	Cimate & relief			
						Average winter tempr., ^{0}C	Average summer tempr., ^{0}C	Sea level	Relief
Severomorsk	60	55.0	917	47.5	0.79	-8.0	+17	31 m	plain
Onega	164	18.15	110	101.8	0.62	-11.0	+17.1	6 m	plain
Novy Urengoy	226.5	118.1	520	117.5	0.51	-20.7	+12	40 m	plain

The results of the given stage include the following general characteristics of all the cities:
1. the actual urbanised area of the cities does not occupy the entire area within the established boundaries; there exists a considerable territorial reserve for urban sprawl;

2. the cities are compact in terms of their built-up area within the radius of no more than 3 km from the city centre, but the population density is low even within the city boundaries; the built-up area is represented by low and medium-rise buildings;
3. the main points of attraction of the population are the city centre, as a concentration of urban functions, and the industrial enterprises, as the main places of employment;
4. the street-and-road network density is low, indicating at insufficiently developed access to different urban areas;
5. there is a problem of poorly defined structure of the street-and-road network by category;
6. there is a problem of poor quality or absence of road pavements as well as a poorly developed system of pedestrian sidewalks;
7. the population mobility pattern is characteristic of all of these cities – predominant use of the automobile for travel within the city limits, the use of passenger transport for user groups having no cars, short walking distances for casual purposes, no active use of bicycles and e-scooters.

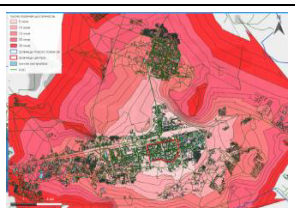
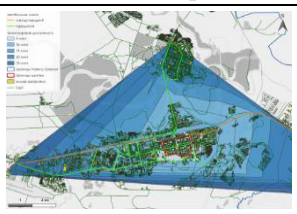
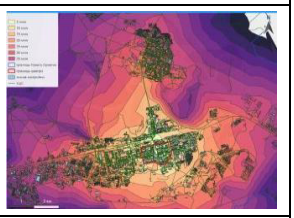
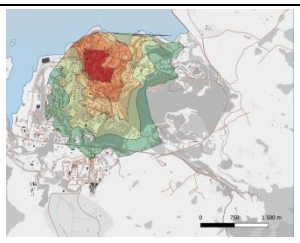
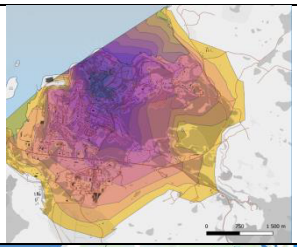
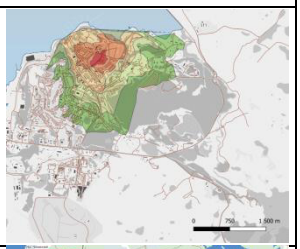
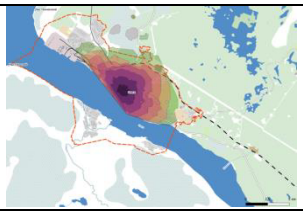
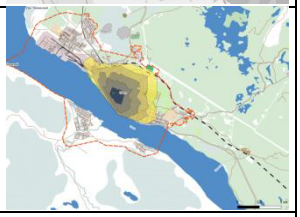
The recorded differences between the cities concern the state of city streets and some absolute numerical characteristics depending on city size.

The next stage was the assessment of accessibility of urban areas with the method of isochrones – equal distance lines. The city centre was chosen as a reference point for all of the cities.

The isochrones were plotted in 5-minute increments for the following mobility types (Table 3):

- Motor transportation;
- Passenger transportation;
- Pedestrian travel.

Table 3. City transport access conditions.

City	Isochrones, min		
	Cars	**Public transport**	**Pedestrians**
Novy Urengoy			
Severomorsk			
Onega			

* – color gradation is 5 minute isochrones offset from a city center to suburbs.

The research shows the following results:
1. The motor transport covers the entire built-up area of the cities within their official administrative boundaries, with the exception of areas occupied or separated by water bodies, like in Onega or Novy Urengoy;
2. Severomorsk and Onega face the problem of connectivity of the urban areas because of the factual absence of the street-and-road network, or the absence of bridge crossings over the river;
3. The passenger transport is developed only within the built-up area and has a limited radius of accessibility, which is well illustrated by Novy Urengoy chart. The situation of people's no access to passenger transport in residential development areas is not uncommon;
4. The pedestrian accessibility is quite high in the urban areas owing to the small size and compactness of the cities.

In general, the level of accessibility of the explored urban areas should be assessed as unfavourable. The low street-and-road network density, the poor quality of transport routes, the insufficient coverage of built-up areas by passenger transport networks as well as the poor quality of pedestrian and cycle transport infrastructure hamper the mobility of the population. The time loss connected with intra-city travel, the dependence on private cars, along with the harsh climate, dictate the need for improvement of the transport infrastructure.

The following main directions for spatial development of the cities can be proposed:
1. Increasing the density of the street-and-road network in order to ensure better connectivity of the areas, which will contribute to their development;
2. Revision of the passenger transport systems with regard for the existing and prospective development, as well as revision of the passenger traffic – for the transition to sustainable transport policy;
3. Designing comfortable streets with well-developed network of sidewalks for due encouragement of pedestrian, cyclist and e-scooter traffic.

5 Conclusions

Assessing the urban areas accessibility conditions is an important mission addressing a whole complex of both transport-related and spatial challenges of the city. Following the assessment of the situation in some cities located in the Arctic zone of Russia and a survey of territories in terms of transport accessibility, a number of problems were revealed. It is not possible to suppose a high quality of urban environment and high living standards without ensuring comfortable and safe conditions of population mobility. The active use of road transport for daily travel is not good for urban environment and contributes to carbon and other pollutant emission. The harsh, cold climate factually exacerbates the problem requiring careful urban planning and design. The present study requires further investigation, as concerns detailed traffic and passenger flow mapping, flow distribution between the focal attraction points – with the view to proceed to the next stage involving formulation of concrete proposals for the development of urban environment. The research process on these lines is a necessary step for sustainable city development.

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