Methods for Calculating the Population Size in Transport Modelling

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ABSTRACT

The article discusses the problem of choosing a method for calculating the population size for feasibility studies in transport modelling of the design road network of cities in the northern regions of the Russian Federation, using the example of the city of Novy Urengoy. The objective of the study is to determine the optimal method for forecasting the population size to obtain initial data for transport modelling. During development of feasibility studies for the city of Novy Urengoy, features of the demographic structure of the northern cities of the Russian Federation affecting the choice of the method for forecasting the population size were identified. Based on
the theoretical analysis of scientific literature, the article discusses various methods of calculating the population, analyses the relationship of the existing demographic structure and its influence on the methods of forecasting the population size for transport modelling. In the context of aggravation of demographic problems of the Russian Federation, it is important to assess the regional features of the prospects for changing the population size. The article suggests recommendations on the use of the method of forecasting the population size, considering regional features of cities founded in 20th century because of development of mineral deposits in the northern regions of the Russian Federation.

Keywords: methods for forecasting population size, transport modelling, feasibility study, demographic structure of the population.

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Background. The problem of choosing a method for calculating the population size for feasibility studies preceding transport modelling while developing design of road network of cities in the northern regions of the Russian Federation is described using the example of the city of Novy Urengoy.

The task of economic survey is associated with collection, processing, systematization, and analysis of initial data to substantiate the prerequisites for development of highways. Economic surveys for development of road network development schemes have the ultimate goal of outlining and substantiating development prospects of the network. Based on the prospects for development of the population and productive forces, the developers determine the need for a certain capacity of the transport network [1].

The population size, its structure, employment are the basic characteristics, and feasibility studies for development of the road system of cities start from the collection and analysis of the relevant information.

Development of a number of economic surveys revealed features of the demographic indicators of cities in the northern regions of the Russian Federation, which appeared in the second half of 20th century due to discovery of oil and gas fields. Using the example of the city of Novy Urengoy, let us consider the demographic characteristics of those cities,

since they should be considered in economic surveys preceding transport modelling.

1. Characteristics of the object of research

The city of Novy Urengoy is an urban district in the north of Russia in Yamalo-Nenets Autonomous District of the Russian Federation (Pic. 1).

More than 90 % of all natural gas and 12 % of oil from the total production in the Russian Federation are produced today in Yamalo-Nenets Autonomous District (YaNAD), [2]. The Yamalo-Nenets District, being the main hydrocarbons production region of the country, is also considered as a promising mining region in terms of the group of solid minerals. The main ones are iron ores, chromites, non-ferrous metals, etc. Besides, the fishing industry and reindeer husbandry are well developed in this Autonomous District.
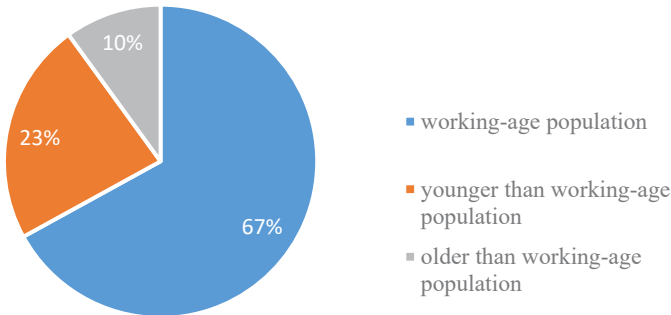

Pic. 1. Location of the city of Novy Urengoy.

Characteristics of the cities of YaNAD [3; 4]

City name	City status obtained in	Population as of 01.01.2020 (people)	Population density. people/km²
Gubkinsky	1996	29161	694,3
Labytnangi	1975	26295	1195,2
Muravlenko	1990	31561	346,8
Nadym	1972	44830	242,3
Novy Urengoy	1980	117482	531,6
Noyabrsk	1982	106911	551,7
Salekhard	1938	50976	603,3
Tarko-Sale	2004	21501	488,7
YaNAD in total		544444	0,7

- working-age population
- younger than working-age population
- older than working-age population

Pic. 2. Structure of population of Novy Urengoy.

The population as of January 1, 2020 was 544,0 thousand people. Compared to h the corresponding date of the previous year, the population of the district has increased by 2,5 thousand people [3].

The current demographic situation in the Russian Federation is determined by a decrease in population, and by replacement of generations through departure from the age of 15−64 of a large post-war generation and influx of a less numerous generations of people born in the unstable 90s of 20th century. In addition, serious demographic problems are associated with high mortality rate regarding economically active ages and with decline in the birth rate.

In the cities of YaNAD the demographic situation is developing in a different way, almost all cities record an increase in population [3; 4].

Features of demographic indicators:
• high proportion of the working-age population;
• the city-forming group prevails in the structure of employment;
• high population density in cities and low-population density in the region.

These features influence the population size of the cities. YaNAD includes eight cities (Table 1).

Using the demographic indicators of the city of Novy Urengoy as an example, we will consider the main features of the structure of population of northern cities that have arisen following the start of deposits develpments.

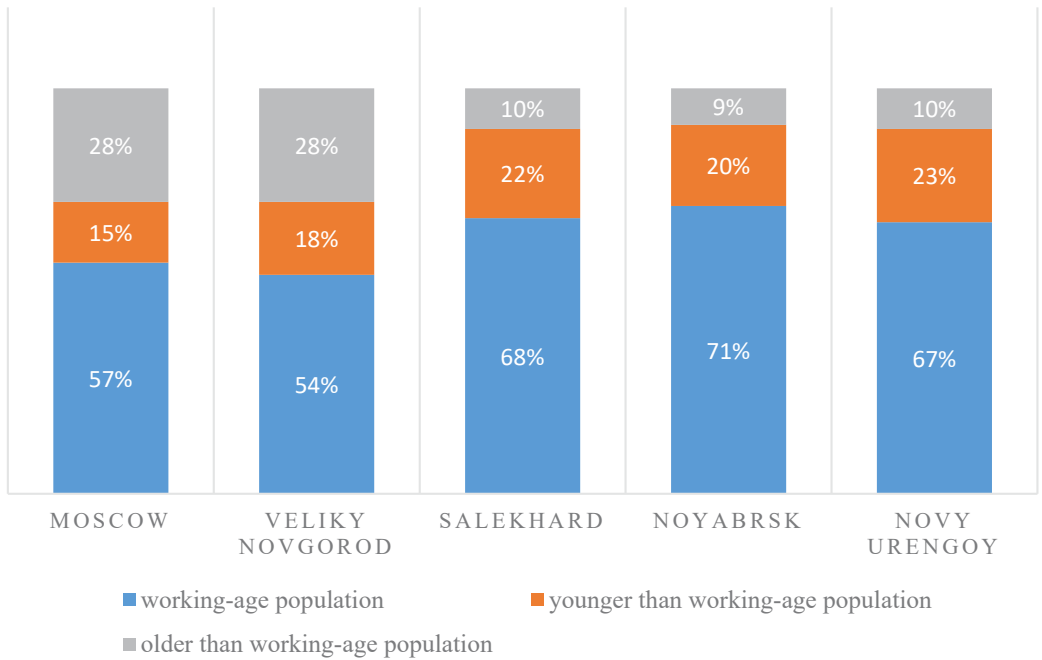**2. Demographic indicators of Novy Urengoy**

Novy Urengoy is the district's first city in terms of population. Its resident population constitutes 22 % of the total population of YaNAD. Unlike many Russian cities, where there is a steady and long-term natural population decline, Novy Urengoy maintains a positive natural population growth (in 2019 the birth rate was 13,3 people per 1000 inhabitants, the mortality rate was 3,3 people per 1000 inhabitants). The migration situation is characterized by population growth (in 2019: 948 people [2; 4]).

High proportion of the employable population. In the structure of the city's population, the proportion of people of working age is 67 %, the share of people under working age is 23 %, citizens older than working age constitute 10 % (Pic. 2) [2].

The city of Novy Urengoy, which emerged in the course of deposit development, has been characterized by a high proportion of people
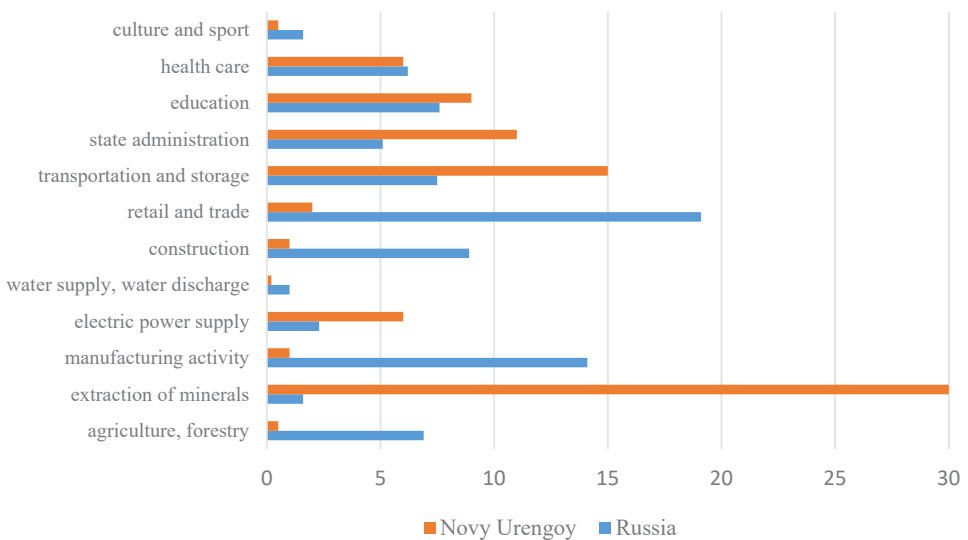
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Pic. 3. Structure of population of the cities of the Russian Federation [3].

of working age throughout the entire period of its development. The age structure of the population was strongly influenced by migration.

At present, in many cities of the Russian Federation, the number of persons of retirement age is increasing, the birth rate is decreasing, and the working-age population is decreasing. This results in cities' «aging». In rapidly developing cities, on the contrary, due to migration of young able-bodied citizens, the share of the employable population is increasing, and a high birth rate is observed. The specificity of the age structure of the population forms special requirements for transport development of the territory.

Pic. 3 shows data on the structure of the population of several cities of the Russian

Pic. 4. Number of employed by main types of economic activity, percentage.

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Federation, which if we compare all the examples with the examples of Salekhard, Noyabrsk and Novy Urengoy, illustrates the shift in the demographic indicators of northern cities [3].

A high proportion of employable population invariably leads to an increase in trips for job purposes. In Novy Urengoy, the peculiarities of industrial development and the territorial disunity of residential and industrial areas lead to a significant residential and labour imbalance, and the population is forced to make daily trips from residential areas to industrial zones and to other areas of concentration of places of employment.

The city-forming group prevails in the structure of employment of the population. When analysing the structure of employment of the population of the city of Novy Urengoy and the Russian Federation as a whole, the features of the city-forming group of the city's population are clearly visible. The mining industry accounts for 30 % of the employed population of the city, while in the Russian Federation as a whole, the mining industry employs only 1,6 % of the population. There is also a large share of those employed in transportation and storage (15 %); while in the Russian Federation this share is 7,5 %. The number of employed by the main types of economic activity as a percentage is shown in Pic. 4 [5].

In the northern regions of the country, extractive industry enterprises determine emergence of new and development of existing cities. The size of the city-forming group making the main trips is determined based on the prospects for development of the industry. In general, since the beginning of development of industrial territories, migration has been a natural process of the district's development.

High urban density and low population density in the region. The settlement of the population in YaNAD is characterized by high urbanization. The population density of cities is significantly higher than the density in the district as a whole. On average, in cities it is 581 people/km², and in the district as a whole it is only 0,7 people/km² [2]. The demand and supply of the labour market in urban and rural areas have a structural imbalance. There are many jobs in the cities, and there is a shortage of labour resources, which is compensated by migration of the population of working age. The opposite situation is observed in rural areas. An additional feature of the regional labour market is that over 15 % [6] of those employed in YaNAD economy work on a rotational basis and live outside Yamal.

The population of cities in Yamalo-Nenets Autonomous District has a positive trend. In Novy Urengoy, over the past five years, there have been positive indicators of natural increase and mechanical population growth.

The low population density of the region, together with considerable territorial remoteness of small settlements, create special requirements for development of transport infrastructure and form serious tasks for socio-economic development of the region.

Revealing true trends of demographic processes is not at all an easy task, as it might seem. It is necessary to assess reliability of statistical information and select the appropriate indicators for each case (or design them). Different indicators, depending on their individual properties, can characterize the direction and intensity of the same process in completely different way.

Several methods are known to determine the prospective population size of cities:
• statistical extrapolation;
• limiting demographic carrying capacity of the territories;
• age shifting;
• labour balance.

The method of *statistical extrapolation* involves extrapolation of population growth based on its size over the past years; it proceeds from a permanent set of economic conditions. Since invariability of economic conditions is a rare phenomenon, this method has not found wide application [7; 8].

The method of limiting demographic carrying capacity of territories provides for determination of the prospective population size, based on the possibilities of settlement in the conditions of stability of the urban area. The size of population, calculated considering planning features of the city, is consistent with the number of people employed at the facilities operating and located in the city. This method is suitable for cities with strictly limited territorial resources. Most often, obstacles to further growth of these cities are natural barriers (mountains, reservoirs, etc.) [7; 8].

The age shifting method is based on census data. The prospective population size is

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Table 2

An example of the population size by transport districts and by main indicators [data of LLC NIPI TRTI]

Transport district (area)	Population, people	Employed, people	Job places, units	Places of study, units	Number of students, people
1	0	0	1365	0	0
2	0	0	0	0	0
3	569	353	158	0	23
4	0	0	2290	0	0
5	3895	2415	840	0	156
6	540	335	203	0	22
7	50	31	551	0	2
8	0	0	763	0	0
9	0	0	1389	0	0
10	394	244	818	0	16

determined by predicting the transition of the population from one age group to another, considering the survival rate and age-specific fertility factors. This method is appropriate for long existing cities [7; 8].

The labour [market] balance method is suitable for most urban planning conditions. The essence of this method lies in determining the ratio between different groups of the population: city-forming, employed in service sector, and inactive population. The entire population is distributed among those groups depending on the nature of labour activity [7; 8, pp. 94–96].

The prospective population size, according to this method, is set depending on the planned scale of the city's development and the size of the labour resources. The calculation is made according to the formula:

$H = A \cdot 100 / (T - B - a - b - n + m)$,

where H is prospective population of the city, people;

A — absolute number of the city-forming group, people;

T — share of the population of working age, %;

B — share of the population employed in service sector, %;

a — number of household employed at working age, %;

b — number of students at working age, %;

n — number of disabled people who are not working, %;

m — number of working pensioners, %.

Following the survey done, the main demographic indicators of the city of Novy Urengoy were considered. Based on their dynamics the labour balance method was chosen to forecast the population of the city.

The need for labour resources is calculated based on the planned growth rate of GRP by years and the growth rate of labour productivity, which is defined as an indicator of GRP per employee. To determine the need for labour resources, the indexed value of GRP by years is divided by the indexed indicator of labour productivity. From the obtained indicator of the average annual demand for labour resources, the projected number of the employed population is subtracted, considering natural increase, and thus the indicator of demand for labour resources is calculated. To determine the total number of migration growth, the indicator of the need for labour resources is increased by the ratio of employed and unemployed population. The number of children within migration growth is determined based on the structure of natural population growth. The main provisions of the calculation are suggested in the sources included in the list of references [9–20].

Having analysed all the methods for predicting the population size, we can conclude that for the northern cities and for the city of Novy Urengoy, in particular, it is necessary to use the method of labour balance, since the working population and the city-forming group prevail in the city within a highly urbanized region.

The structure of the population forms the demand for mobility. Knowledge of the demand for mobility is the basis for transport planning. The predicted results of the population size are

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used as initial data in the transport modelling of the city of Novy Urengoy to determine development of the city's transport system, and then tables of the population size by transport districts are compiled according to the main indicators (Table 2).

The formed databases with forecast information on the number of the inhabitants, including those employed, on the number of students who lives in the city, the number of places of employment and study are used for development of a transport model and for forecasting future traffic flows.

Conclusion. Following the study, the main demographic methods for forecasting the population size were considered. Considering the regional features, the choice of the method for forecasting the population size for transport modelling is justified on the example of the city of Novy Urengoy. The reproduction of the population, demographic processes, the nature, and tendencies of changes in the demographic situation have an impact on all other spheres of social life, largely determining the course of economic, transport, social and other processes. The use of the labour balance method in economic surveys of the northern cities of the Russian Federation will make it possible to use the capacity of the territory more accurately. With further transport and economic surveys intended for projects of development of the northern cities of the Russian Federation, it is recommended to apply the same labour balance method to calculate the population size.

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