MODERN APPROACHES TO SITING OF TRANSPORT AND LOGISTICS INFRASTRUCTURE FACILITIES

Baginov, Andrey V.*, CJSC PromtransNIIproekt, Moscow, Russia.*

ABSTRACT

The article considers the issue of the feasibility of application of modern mathematical tools in solving the problems of location of objects of the transport and logistics infrastructure. The analysis of existing approaches to assessment and significance of the methods used, in particular of coordinate, gravitational and combined methods, is carried out. The example of the transport and logistics complex of the Republic of Buryatia shows the applicability of the proposed methods and management tools, including software simulation tools.

Key words: transport and logistics infrastructure, location of objects, transport complex of the region, software-simulation modeling, criteria, methods.

Background. *All that is connected with the location of the transport and logistics infrastructure belongs to the fundamental tasks of the organization of production. This is mainly due to two reasons: firstly, mistakes made in solving problems of this kind lead to additional operational costs; secondly, the leveling of negative consequences associated with unsatisfactory location of the facility is often not possible.*

Objective. *The objective of the author is to consider modern approaches to location of transport infrastructure facilities.*

Methods. *The author uses general scientific and engineering methods, mathematical apparatus, evaluation approach.*

Results.

1.

Studies of domestic scientists [1–11], dealing with the problems of placing transport objects, reveal in sufficient detail the range of mathematical and software-simulation tools. However, often the use of the proposed methods in practice is not well-founded, and the results do not allow to make a correct administrative decision.

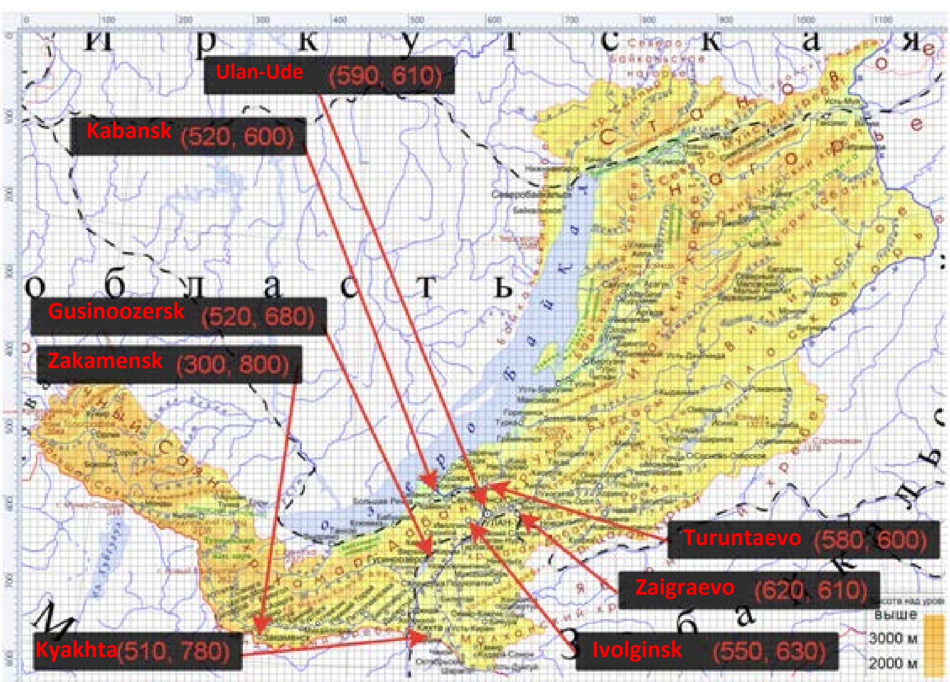
Conditionally modern approaches to location problems can be divided into two groups:

– choice of the most preferable variant is carried out among a pre-formed set of alternatives, the solution is reduced to multicriteria analysis and calculation of ranking of the considered variants;

– choice of the best option is carried out without focus on specific options, the object is placed with respect to location of the participants in the transport and logistics process (suppliers, consumers, trade enterprises, industries, stations, etc.) or traffic flows, and the decision maker actually operates with the arguments of the geometric character which are coordinates.

In the first case, the solution can be divided into several stages:

1. Editing a list of the criteria considered and determining their criterial indicators. It should be noted that the number of criteria can be arbitrary, but for a small range, the results cannot provide high



Pic. 1. The objects (settlements) in question and their coordinates.

Table 1

Population of cities of national importance and municipal districts

No.	Name	Population, people	Territory, thous. km	Administrative centre
1	Ulan-Ude city	431922	0,348	Ulan-Ude city
2	Kabansky district	57094	13,5	Kabansk village
3	Ivolginsky district	52227	2,7	Ivolginsk village
4	Zaigraevsky district	51251	6,6	Zaigraevo urban-type settlement
5	Selenginsky district	42605	8,3	Gusinoozersk city
6	Kyakhtinsky district	37465	4,7	Kyakhta city
7	Pribaikalsky district	26756	15,5	Turuntaevo village
8	Zakamensky district	26091	15,3	Zakamensk city
9	Dzhidinsky district	24611	8,6	Petropavlovka city
10	Severobaikalsk city	23673	0,119	Severobaikalsk city
11	Mukhorshibirsky district	23413	4,5	Mukhorshibir village
12	Bichuisky district	23233	6,2	Bichura village
13	Barguzinsky district	22294	18,5	Barguzin village
14	Tunkinsky district	20795	11,8	Kyren village
15	Tarbagataisky district	20509	3,3	Tarbagatay village
16	Khorinsky district	17281	13,4	Khorinsk village
17	Eravninsky district	17211	30,7	Sosnovo-Ozerskoe village
18	Kizhinginsky district	15112	7,9	Kizhinga village
19	Kurumkansky district	13852	12,5	Kurumkan village
20	North-Baikal district	12262	54	Nizhneangarsk urban-type settlement
21	Muisky district	10264	25,2	Taksimo urban-type settlement
22	Bauntovky evenki district	8743	66,8	Bagdarin village
23	Okinsky district	5470	26	Orlik village

Table 2

Initial data

No.	Name	Population, people	X	Y
1	Ulan-Ude city	431922	590	610
2	Kabansk village	57094	520	600
3	Ivolginsk village	52227	550	630
4	Zaigraevo urban-type settlement	51251	620	610
5	Gusinoozersk city	42605	520	680
6	Kyakhta city	37465	510	780
7	Turuntaevo village	26756	580	600
8	Zakamensk city	26091	300	800

accuracy, and a wide range of criteria will significantly complicate the solution of the problem. However, some of the criteria considered will have little effect on the final result.

2. Determining the significance of the criteria in question:

$$\alpha_i = \frac{\beta_i}{\sum_{i=1}^{n}\beta};$$

$$\beta = \sqrt[n]{\gamma_1\gamma_2\gamma_3\cdots\gamma_n},$$

where α – significance of the criterion, β – average geometric coefficients of relative importance, γ – coefficients of relative importance of the criteria.

3. Normalization of the values of the criteria indicators Z with the aim of reducing them to dimensionless quantities. In this case, if the best option is the smallest value of the criterion, the search for the normalized value is $Z = \frac{x_{min}}{x_p}$*, where* x_p *– criterion value,* x_{min} *– the best (minimum) value. Otherwise, the procedure is inverse:* $Z = \frac{x_p}{x_{max}}$*, where* x_{max} *– the best (maximum) value.*

4. Determination of the ratings of the criteria in question $R_k = \sum_{i=1}^{n} Z_{ik}\alpha_i$ *and choosing the best option, where* R_k *– rating of the, e.g., k-th carrier,* Z_{ik} *– value of the i-th criteria indicator for the k-th carrier.*

In the second case, the use of a conditional grid of coordinates is necessary to determine the coordinate location of objects or transport flows with respect to which the optimal location will be searched. For example, in [10], the author proposes to search for coordinates of the location of the container terminal relative to the density of container flows based on the search for the coordinates of the center of mass, imposing a conventional coordinate grid on the polygon in question:

$$x_0 = \frac{1}{M}\iint_D xr(x,y)\,dxdy;$$

$$y_0 = \frac{1}{M}\iint_D yr(x,y)\,dxdy,$$

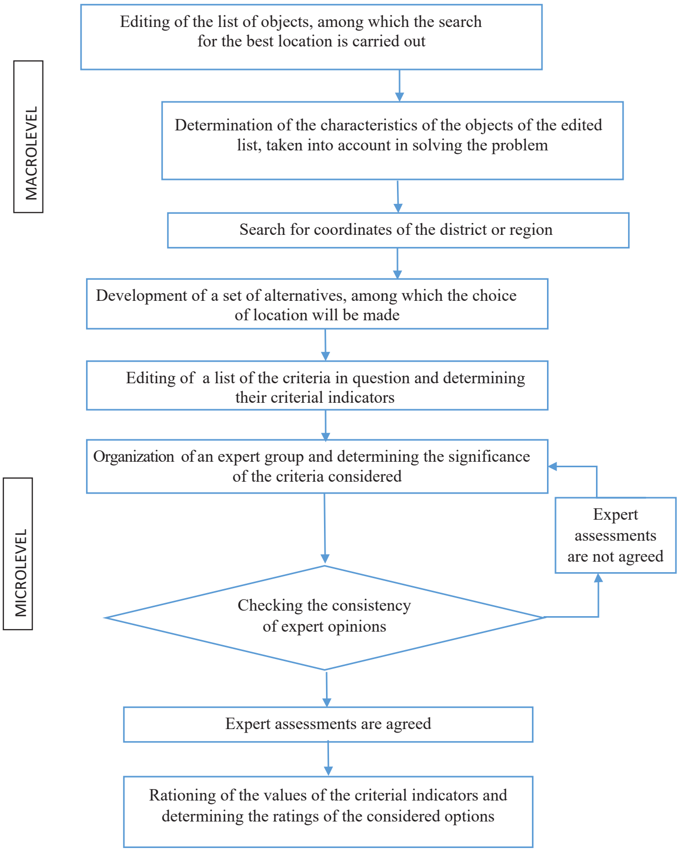


Fig. 2. Algorithm for combining methods for solving allocation problems.

where D – search area; x, y – density of container transportation.

In [11], to locate a single transport infrastructure object with respect to consumers, it is proposed to search for the coordinate solution by the gravitational method:

$$C_x = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i};$$

$$C_y = \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i},$$

where w – volume of work (deliveries) performed; x, y – coordinates of objects (consumers).

Despite the availability of operational results, it is worth noting the impracticality of coordinate methods. To a greater extent, it consists in abstractness and loss of many objectively important criteria – such as the area and configuration of the building site, the cost of alienating land, the degree of development of transport infrastructure at the location, etc. Moreover, the result obtained in the conditions of large transport and logistics systems will gravitate to locations that have a high level of work performed, i. e. are not free for allocation of the transport and logistics sites. Note that this tool does not allow to determine the location of several objects when forming a network of transport and logistics infrastructure.

As an example, let us consider its applicability in the conditions of the transport and logistics complex of the Republic of Buryatia.

2.

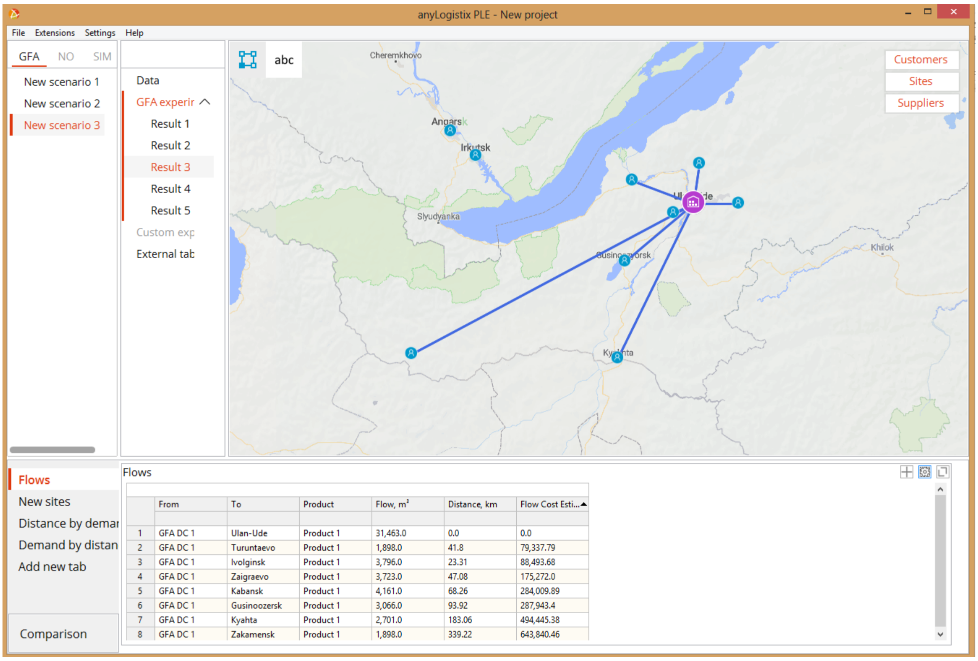
According to the adopted program [12], the transport complex of the Republic of Buryatia totals 1675 enterprises. The number of employees of transport organizations is about 10,4 thousand people. The share of employed in the transport sector from the total number of employees in the economy of the republic is 4,1 %. At the same time, the share of transport in the structure of the gross regional product is 23 %. And this arrangement allows to classify transport as one of the priority sectors of the economy.

The composition of the transport complex of the republic includes the infrastructure of rail, inland water, air and road transport. In a greater degree, the demand for intraregional freight transport is met by road (in some places up to 98 % of cargo), transit – mainly by rail transport.

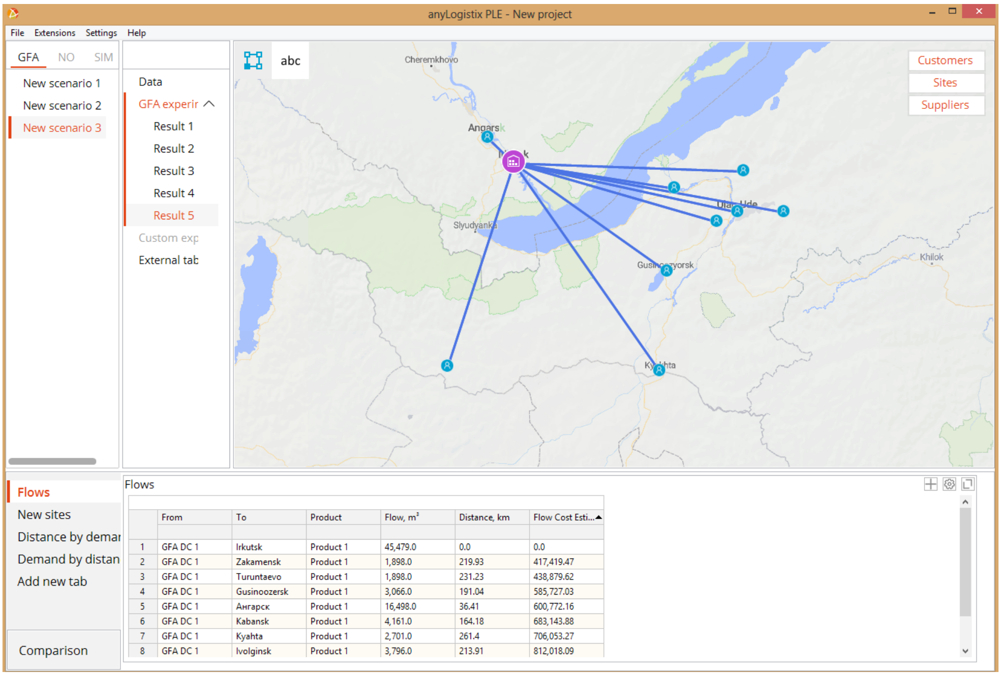
Volumes of consumption of transport products in Buryatia can be indirectly characterized by the number of population of cities of republican significance and municipal districts (Table 1).

To facilitate the calculations, it is advisable to consider objects with a population of more than 25 thousand people. The coordinates of such objects are shown in Pic. 1. The initial data for the solution of the problem is summarized in Table 2.

Using the gravitational method, we obtain the coordinates of the location of the transport infrastructure object (523,75; 663,75). Proceeding from the received results, it is most expedient to place the object on the border of Kabansky and Ivolginsky



Pic. 3. Interface and results of the first experiment.



Pic. 4. Interface and results of the second experiment.

districts of the republic, 50–60 kilometers to the west of the main consumer of transport products which is Ulan-Ude city.

Despite the high transport availability, and particularly the availability of railway communication with Ulan-Ude and the availability of the federal highway A340 Ulan–Ude-Kyakhta, the result cannot be considered correct for a number of reasons. Firstly, with the increase in the number of cities of republican significance and municipal districts, the coordinates will inevitably be adjusted towards the northern regions and Severobaikalsk city. Secondly, the conducted calculations do not allow taking into account such objectively important criteria as the area and configuration of the site, the cost of alienating land, the degree of development of transport infrastructure, etc.

With this in mind, we can conclude that the gravitational methods for determining the optimal location of objects of the transport and logistics infrastructure are correct only at the macro level of the solution of the problem, in the aspect of *determining the district or region of location. Combination of methods seems appropriate. In general, the combining algorithm is shown in Pic. 2.*

It is worth mentioning that, given the volume and complexity of the combined use of placement methods, it is worthwhile, in the framework of this article, to focus attention on the macrolevel of the solution of the problem, on coordinate methods. In this connection, the elements of the microlevel of the algorithm associated with the criterial analysis are not considered.

Modern tools of software-simulation provide quality of the results obtained by the gravitational method. The environment allows solving gravitational problems, taking into account the geographical location of objects (customers, suppliers, etc.), products and units of their measurement, transportation tariffs, distances, volume of demand and supply, etc. In this case, when the experiment is set up, the medium is equivalent for both the single object sought and for the group.

We will carry out experiments with the gravitational method in the environment of anyLogistix. In the first case (Pic. 3), data similar to the problem solved above appears: the amount of population will indirectly characterize the volume of work performed. We shall present periodicity of deliveries as identical in all settlements.

As can be seen from the results of the experiment, the environment suggests placing the desired object directly within the city of Ulan-Ude. The difference between an independent solution and the solution offered by the environment of anyLogistix is explained by the presence of an unavoidable error in determining the coordinates of settlements when the problem is solved independently.

In the framework of the second experiment (Pic. 4), we will complicate the task by adding two large settlements of Irkutsk region – Irkutsk (population 624 thousand people) and Angarsk (226 thousand people). Changing the data is necessary to evaluate the correctness of the results proposed by the environment.

From the results of the second experiment, it can be seen that the solution proposed by the environment is location of the sought object within the boundaries of Irkutsk. At the same time if we search for the location coordinates on our own, the result will be significantly different, since the coordinates found will be in the lake Baikal, which, of course, is absolutely incorrect. It is also worth noting that the result proposed by anyLogistix is logical also because it corresponds to the location with a developed transport infrastructure – this is the city of Irkutsk.

Conclusion. *The expediency of using the proposed algorithms, as well as the quality of the results obtained, depend significantly on the level of detail (the number of criteria, the composition of the expert group, etc.). When making managerial decisions, it is, of course, important to approbate the final results using software simulation tools.*

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Information about the author:
Baginov, Andrey V. – engineer of CJSC PromtransNIIproekt, Moscow, Russia, baginov93@mail.ru.

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