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# Assessment of Options for Logistics Objects in the Region Using Multi-Criteria Optimization (Case Study of the Republic of Tatarstan)

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**Abstract.** The article proposes a scientific and practical approach to solving the problem of optimizing the regional transport-logistics structure by creating a reference network of logistics facilities of different class and purpose on the basis of criterion assessment of logistics capacity of each district of the region. The methodologies used by most researchers help objectively assess the logistics potential of the region at the level of either macro-systems or micro-systems assessing logistics capacity at the level of transportation with a certain number of participants and stable freight turnover. The proposed method of multi-criteria optimization helps not only identify the opportunities of logistics resources of each administrative and territorial of the region, as well as promote its active integration as a constituent entity of the Russian Federation in domestic and international transportation corridors, creating new opportunities for the

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strategy of its economic development. The most frequently used mathematical methods of site selection for logistics centers (hierarchy analysis, "gravity center", theory of graphs and flows in networks and others) are certainly applicable when it is necessary to determine the location of objects with a certain number of customers and suppliers, stable inflows and outflows, but in the case of dynamic, unstable in time and volume of freight traffic, heterogeneous structures they do not give reliable results. The proposed calculation of comprehensive ranking assessment of each region is based on the implementation of multi-objectives taking into account both qualitative criteria and quantitative statistical and calculated values using the generated lists of alternatives (management decisions – districts of the Republic) of structured weighted criteria which are taken into account in calculating the comprehensive ranking of each management decision (of a particular area of the region). Determining the location of a logistics facility at the final stage of the project implies participation of subjects interested in its deployment: regional administration, representatives of business units. The proposed software package involves accelerated selection of deployment options through impacts on a number of criteria indicators. The project is at its final development stage; databases are being completed allowing to graphically show the proposed logistics facilities on the map considering their type.

**Key words:** logistics potential, logistics center, comprehensive ranking assessment, multi-criteria decision-making objective.

The results of scientific research we present are obtained in the framework of the development of a major research project which aims to improve the transportation and logistics framework in the Republic of Tatarstan (RT). In cases where it is necessary to place logistics centers in major economic zones, one faces many comparable options, the number of which increases, not only due to a large number of potential locations for logistics facilities, but also due to the possibility of multiple streamlining the management of material flows which in turn depend on the level of economic activity of the territories; therefore, integrated criteria-based assessment is based on logistics capacity of each the municipal districts of the Republic.

The research set the following objectives:

– to identify the main indicators for assessing logistics capacity of the region's administrative divisions, collect objective quantitative statistical data and justify the choice and evaluation of quality indicators;

– to compile a comprehensive ranking of the region with highest logistics capacity based on the collected data, using author's and software packages, through the implementation of multi-criteria objective of decision-making;

– to develop a software package and adapt it to Windows. The package helps quickly make design decisions with the participation of regional administration (at all levels) and interested business structures, and interactively shows the objects for placement on the map.

When choosing the methodological approach to solving the specified problems we revealed that the existing numerous methods objectively assess the region's logistics capacity either at the level of macro-systems, defining its role in national and international transport and logistics system (TLS), or systems evaluating logistics capacity at the industrial level [16; 8; 10] or at the level of unimodal transportations [21; 22]; a very small number of publications present methods taking into account the integrated approach to the organization of transport and logistics systems within Russia's constituent entity [7; 9]. A detailed analysis of existing methodological approaches to the assessment of the region's logistics capacity is presented in [12]. To make the assessment of logistics capacity of the region's administrative division (AD) more objective we applied combinatorial mathematical modeling according to which statistical data were collected and necessary calculations performed relative to the entire set of criteria for each of the 43 districts of the region among which were:

1. Quality binary linguistic criteria (348 indicators) which were expertly assessed according to the principle of advantageous / disadvantageous; presence/absence, including:

– central position relative to the regional center;

– position relative to international transport corridors;

– position relative to the intersection of federal highways;

– position relative to major regional highways;

– deficit of storage platforms;

– proximity to river ports;

– proximity to airports;

– proximity to railway stations and terminals.

2. Statistics and quantitative design criteria (645 values) expressed in relevant units of measurement including:

– district's area;

– district's production potential;

– total length and density of land communication lines;

– length of railway lines;

– length of highways and paved roads;

– availability of built logistics centers including corporate ones;

– turnover of transshipment cargo through the territory of districts;

– cargo carriage volume and freight turnover by all means of transport;

– cargo carriage volume and road freight turnover;

– cargo carriage volume and rail freight turnover;

– cargo carriage volume and seaborne freight turnover;

– amount of existing storage space;

– index of cargo flow density;

– index of freight activity.

The next phase of the project was the identification of areas in RT with highest logistics capacity according to the requirements in the form of a list of R criteria. To achieve this we developed a unique technique for calculating ranking evaluation of each district based on the implementation of a multi-criteria decision-making objective (MC DMO) underlying the following calculations and their interpretations.

The relevance of applying the author's approach to solving the multi-criteria problem of this type is based on the fact that the existing mathematical methods and models of choosing the location of logistics capacities such as the method of "gravity center", simplest models of linear programming [2], models of queueing systems, methods of the theory of graphs and network flows [5] helps obtain optimal reliable results when it is necessary to determine the location of logistics centers (LC) for a single object with a limited number of known customers and suppliers with known static incoming and outgoing material flows. These methods are traditionally implemented when creating a corporate centralized supply network of industrial enterprises and trading companies.

When selecting locations of logistics objects with a large number of participants in extensive logistics chains with connections difficult to track, these methods become ineffective due to the large dimension of the issue and a large number of objective economic, geographical, occupational and other factors influencing the adoption of optimal decisions. In this case, it is advisable to use the methods of multi-criteria selection which traditionally include: methods based on quantitative measurements (multi-criteria theory of utility); methods based on qualitative measurements the results of which are converted into a quantitative form (methods of hierarchy analysis (MHA), and methods based on the fuzzy set theory); methods based on quantitative measurements using several indicators when comparing alternatives (group of ELECTRE methods); methods based directly on qualitative measurements without moving to quantitative variables at the time of measurement and registration (verbal decision analysis).

Among all these methods the mostly used when selecting locations of logistics centers are MHA [8, 10, 16], when the level of region's attractiveness is evaluated by comparing the rating of competitiveness of the studied area with the assessment of competitiveness of the reference region (actual or notional) with best performance. The disadvantage of this method is that it requires the presence of a standard for assessment and working only with quality indicators for integrated assessment provided by the expert, which is rather subjective. To convert qualitative information to an interval scale in MHA we use the verbal-numerical ratio scale which puts in line certain numbers with the degree of preference of one indicator over another. However, the conversion of verbal measurements into numbers has no sufficient justification since pair-wise comparisons of factors are made in terms of the dominance of one parameter over the other, the significance of one of the other is determined in the solution process by an expert by results of processing of its antisymmetric expert matrices with mandatory verification of their contents to the requirements of transitivity.

The proposed methodological approach works both with qualitative and qualitative objective measurements, estimating realistic quality indicators at the same time (on a binary linguistic scale convenient to the expert), and with objective quantitative statistical data given on the traditional interval scale. Since the vast majority of MC DMO are designed to consider a variety of purposes (indicators, criteria) we use a "detailed" MC DMO model which can be represented as the following data tuple [3; 19]:

$$< t, X, R, A, F, G, D > . \qquad (1)$$

where t – statement (type) of an objective; X – a set of acceptable alternatives (management decisions, variants of actions); R – a set of criteria for assessing the degree of achieving established goals; A – a set of criteria scales (nominal, ordinal, interval, ratio scales); F – mapping of a set of acceptable alternatives in multiple criteria evaluations of their effects (outcomes); G – a system of preferences of a decision maker (DM); D – decisive rule reflecting the system of preferences of a DM. We also note that in the case of group decision-making (G system type – reflects the preferences of one or a group of experts) model (1) must be supplemented by the following elements: E(f) – group preferences function and L – principle of individual preferences consistency, the most natural form of which can be the method of expert estimation followed by verification of initial estimates by known non-parametric statistical methods which consist in calculating the relevant parameters and comparing them with known boundary values.

Specification of the "detailed" (1) type MC DMO model can help obtain the models for real problem situations and by moving it into a fuzzy environment where X, R, F and G are fuzzy. The preparation involves the selection of statistical indicators according to the research objectives according to certain criteria indicators, R (according to the list of criteria). It is also necessary to compile a list of management decisions (researched alternatives) X – region's districts as administrative divisions (AD). To create the parent matrix it is only necessary to construct a mapping of a set of R criteria on the set of X alternatives. The work array $C = \{c_{ij}\}$ is a consequence of creating the mapping $\tau_1$:

$$\tau_1 : R \to X. \qquad (2)$$

where $X = \{x_i\}$, $i = 1, m = 43$ – the cardinality of the set of AD in the Republic of Tatarstan, which is presented as a list in the nominal scale of its constituent districts, $R = \{r_j\}$, $j = 1, n = 24$ – the cardinality of the set of values (criteria) considered in the list (list on the nominal scale). Then the mapping of the (2) type can be represented as a two-dimensional set measured in linguistic and physical units in the interval matrix $C = \{c_{ij}\}$, $i = 1, n = 43$; $j = 1, m = 24$ sized $m \times n = 24 \times 43$, which represents the formalization of available statistical information of initial data at the time of the study.

The technique of addressing MC DMO includes the following steps:

1. Structuring the list of criteria indicators with obtaining a hierarchical "tree of objectives" (TO) in the form of fishbone diagrams by Professor Ishikawa [18].

2. Successive weighting of TO branches at each hierarchy level with calculating the weight of terminal branches of the tree $\omega_j$, $j = 1, mw$ (where mw – the number of branches at each hierarchy level, which from the position of weights as a unit fraction represent a complete group of events) to implement unweighted model and weighted model.

3. Calculating two-dimensional vector of local priorities $U = \{u_{ij}\}$ as the mapping to the method $\tau_2$, AK&M [4; 18] taking into account the semantics of criteria of the two types (with the increasing criterion values the quality increases; with the increasing criterion value the quality is reduced):

$$\tau_1 : C \to U \cdot \qquad (3)$$

The mapping (3) is carried out by means of two ratios (4) and (5):

$$u_{ij} = \frac{c_{ij} - c_{ij}^{min}}{c_{ij}^{max} - c_{ij}^{min}} \cdot 100\%, \qquad (4)$$

$$u_{ij}=\frac{c_{ij}^{max}-c_{ij}}{c_{ij}^{max}-c_{ij}^{min}}\cdot 100\% . \qquad (5)$$

Moreover, formula (4) is used when increasing the value of a particular criterion the quality increases, formula (5) – when increasing the criterion value reduces the quality.

4. The calculation of the vector of global priorities $V = \{v_i\}$, $i = 1, n$ for additive convolution:

$$v_i=\sum_{j=1}^{m} u_{ij}\cdot w_j . \qquad (6)$$

5. Finding the best element of the vector of global priorities and the numbers of an optimal alternative:

$$v^{opt}=\max\{v_i\}\rightarrow i^{opt}\rightarrow x^{opt}. \qquad (7)$$

6. Finding the set of quasi-optimal alternatives by forming a cluster (based on the formation of equivalence relations) in the Republic of Tatarstan objectively close to the area of LC location as the most optimal (here $x^{opt}$ – Tukayevsky district in the Republic of Tatarstan as the leading one by production potential as a result of the research).

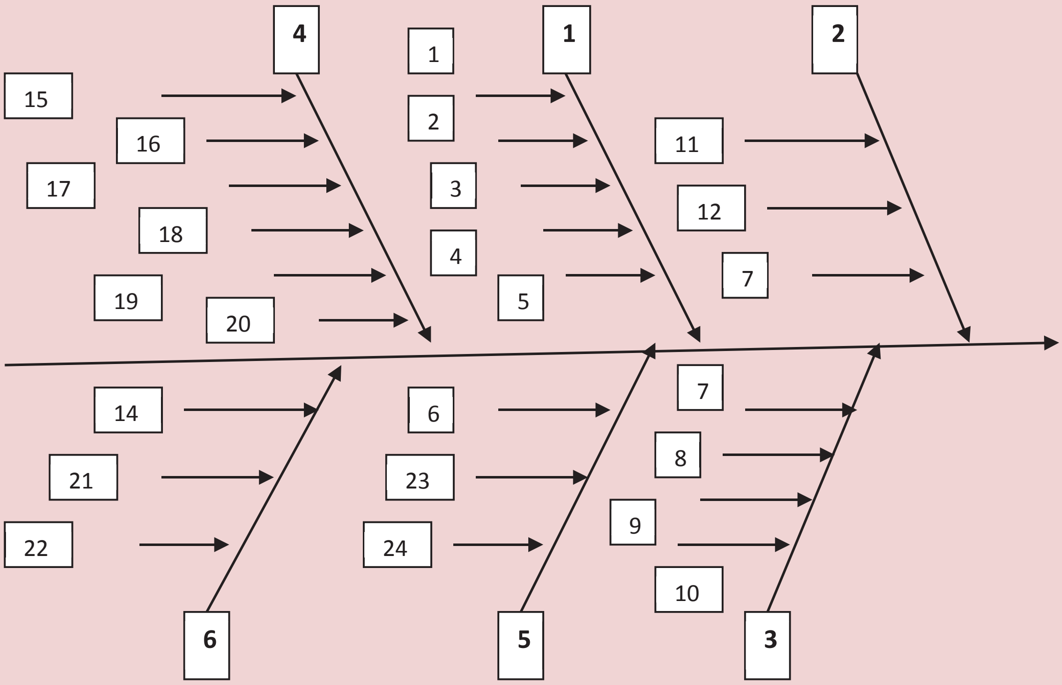
The structuring of the list of criteria indicators may be performed using formal (one of the possible methods used in the research is the author's approach by A.M. Shikhaleva [20] based on fuzzy frames) and phenomenological methods. The latter is of particular interest because it gives an opportunity for particular interested representatives of the district (investors, administration) to participate in operational simulation together with the working group of researchers. Then the first approximation is presented to the interested representatives of the district by the following structure of the "tree of objectives" (TO) in *Figure 1.*

The criteria were combined at the first hierarchical level into groups, their constituent criteria – separate branches represented the second level of hierarchy for each group. The process of building a TO is based on the content of criteria indicators themselves, giving them equally or non-equally significant weights at each level of the hierarchy is the subsequent stage. Since groups are formed by researchers, they are given summarizing name criteria. The process of building a TO is demonstrated with equally significant criteria at every level of the hierarchy, where all branches of the TO are of equal importance. Along the way, we phenomenologically create respective groups of structured criteria-based indicators.

In the first approximation, we take the equal significance of groups and equal significance of criteria inside each group and we receive the following weight indices $w_{ij}$ (given in parentheses), where i = 1.6; j – number of criterion indicator from the general list of criteria ($r_j$):

*Group 1* (hereinafter, groups in Figure 1 are highlighted in the squares in bold) "Region's geographical position" ($v_1$ = 0.1667; here and below: all 6 groups of criteria have the weight = 1 / 6 = 0.1667); we assigned 5 criteria to this group, therefore, the weight of each of them will be in relative units of 1 / 5 = 0.2: $r_1$ = "Size of region's territory", square kilometers ($w_{1.1}$ = 0.2); $r_2$ = "Central position relative to the regional center (Kazan)", close/far ($w_{1.2}$ = 0.2); $r_3$ = "Position in relation to the

Figure 1. Hierarchical tree of objectives




intersection of international transport corridors (ITC)”, favorable/unfavorable ($w_{1.3}$ = 0.2); $r_4$ = “Position relative to the intersection of federal highways”, favorable/unfavorable ($w_{1.4}$ = 0.2); $r_5$ = “Position relative to the intersection of major regional highways”, favorable/unfavorable ($w_{1.5}$ = 0.2);

*Group 2* “Proximity to ports and stations” ($v_2$ = 0.1667): $r_{11}$ = “Proximity to river ports”, yes/no ($w_{2.11}$ = 0.3333); $r_{12}$ = “Proximity of airports:, yes/no ($w_{2.12}$ = 0.3333); $r_{13}$ = “Proximity to railway stations and terminals”, yes/no ($w_{2.13}$ = 0.3333);

*Group 3* “Length of communication lines” ($v_3$ = 0.1667): $r_7$ = “Length of land communication lines”, kilometers ($w_{3.7}$ = 0.25); $r_8$ = “Length of railway lines”, kilometers ($w_{3.8}$ = 0.25); $r_9$ = “Length of roads”, kilometers ($w_{3.9}$ = 0.25); $r_{10}$ = “Length of paved roads”, kilometers ($w_{3.10}$ = 0.25);

*Group 4* “Through transportation” ($v_4$ = 0.1667): $r_{15}$ = “Cargo carriage volume by all means of transport”, million tons ($w_{4.15}$ = 0.1667); $r_{16}$ = “Road cargo carriage volume”, thousand tons ($w_{4.16}$ = 0.1667); $r_{17}$ = “Rail cargo carriage volume”, thousand tons ($w_{4.17}$ = 0.1667); $r_{18}$ = “Seaborne cargo carriage volume”, thousand tons ($w_{4.18}$ = 0.1667); $r_{19}$ = “Rail freight turnover”, million tons per kilometer ($w_{4.19}$ = 0.1667); $r_{20}$ = “Road freight turnover”, million tons per kilometer ($w_{4.20}$ = 0.1667);

*Group 5* “Production potential and generalized communication parameters” ($v_5$ = 0.1667): $r_6$ = “Region’s production potential (volume of industrial and agricultural products)", million rubles × 100 ($w_{5.6}$ = 0.3333); $r_{23}$ = "Road density", b/r ($w_{5.23}$ = 03333); $r_{24}$ = "Index of cargo flow density of each municipal district", b/r ($w_{5.24}$ = 0.3333);

*Group 6* "Storage facilities" ($v_6$ = 0.1667): $r_{14}$ = "Availability of built logistics centers (including corporate distribution centers), units. ($w_{6.14}$ = 0.3333); $r_{21}$ = "Amount of existing storage space including corporate distribution centers", thousand square meters ($w_{6.21}$ = 0.3333); $r_{22}$ = "Deficit of storage platforms". presence/absence ($w_{6.22}$ = 0.3333).

The selected groups of criteria presented as initial data in the created hierarchy will have the following kind of a fishbone diagram (see *Fig. 1*).

In the presented TO, the numbers of branches of the second hierarchical level are taken from the table of initial data (column 1). The names of criteria indicators corresponding to the number are given in column 2 of the same table. The numbers of criteria groups (first TO hierarchical level correspond to the numbers of groups generated by DM during semantical (situational) analysis.

Then the weights of all 24 criteria indicators $\omega_i$, i = 1, k = 24 are calculated according to the known rule for hierarchical "trees" – as the product of the weight of the group on and the weight of criteria indicators included in each group, designating the results as the following expression (8):

$$\omega_i = v_i \cdot w_{ji}, \tag{8}$$

where j = 1, 1= 6 – the number of branches of the first TO hierarchical level; i = 1, $k_i$ – the number of branches of the second TO hierarchical level: for the branch of the first TO branch – $k_1$ = 5; for the second branch, $k_2$ = 3; for the third – $k_3$ = 4; for the fourth – $k_4$ = 6; for the fifth – $k_5$ = 3; for the sixth – $k_6$ = 3. In total, the number of branches equals the number of criteria indicators given in *Table 1*: $k_1 + k_2 + k_3 + k_4 + k_5 + k_6 = 5 + 3 + 4 + 6 + 3 + 3 = 24$. Thus, with the known weights of the TO branches of the first hierarchical level $v_j$ and weights of the second hierarchical level $w_{j,I,}$ the weight of each criterion for further calculation can be calculated according to formula (3). The sum of the weights of all 24 terminal branches (TO leaves) $\omega_i$, i = 1.24 will strictly equal to one.

Taking into account the total list of criteria divided by six substantively different groups and placing respective criteria indicators, we get a structured two-level TO, which with the use of formula (8) will give an opportunity to get many degrees of criteria priority (weights) for an equally significant scenario (which is methodologically important further), which for convenience purposes will be summarized in the following expression (9):

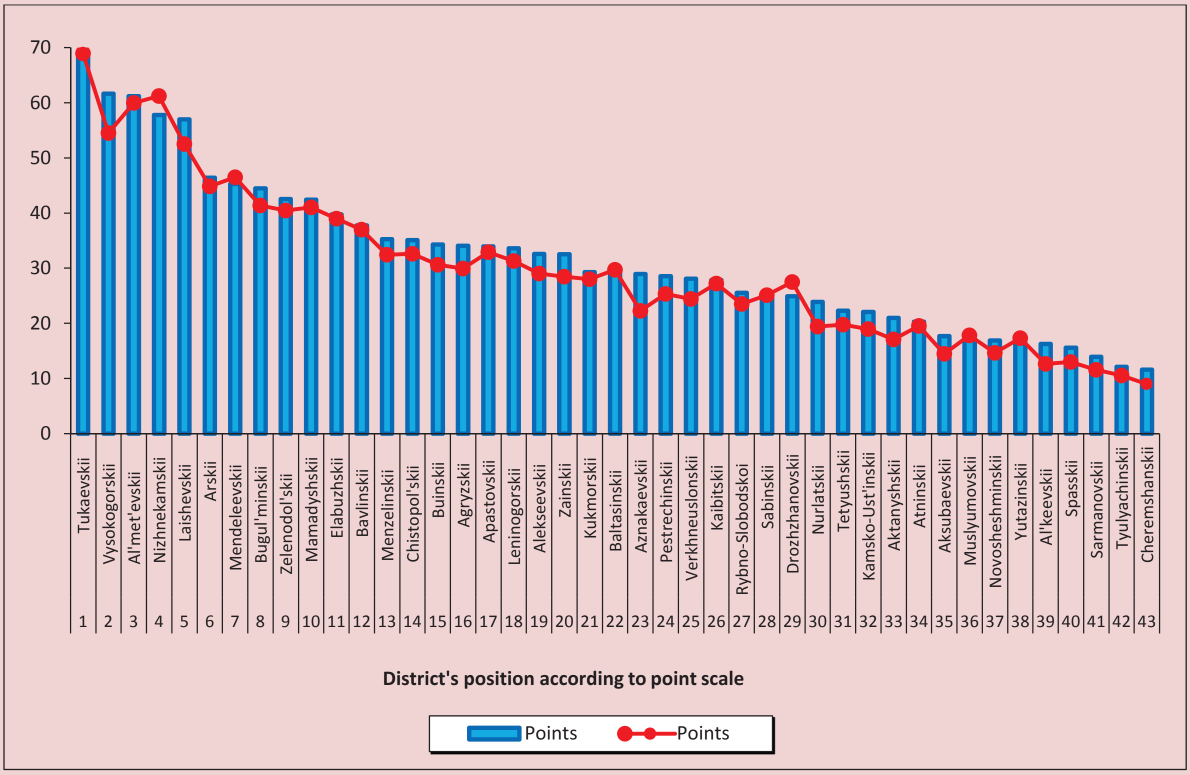
$$\begin{gathered}\omega_1 = \omega_2 = \omega_3 = \omega_4 = \omega_5 = 0.0333;\ \omega_6 = 0.0556;\\ \omega_7 = \omega_8 = \omega_9 = \omega_{10} = 0.0417;\ \omega_{11} = \omega_{12} = 0.0556\\ \omega_{13} = \omega_{14} = 0.0556;\\ \omega_{15} = \omega_{16} = \omega_{17} = \omega_{18} = 0.0278;\\ \omega_{19} = \omega_{20} = 0.0278;\\ \omega_{21} = \omega_{22} = \omega_{23} = \omega_{24} = 0.0556.\end{gathered} \tag{9}$$

The results of the first phase of solving MC DMO which implements dependences (3)–(7) of the two options of criteria weighting are presented in Table 1 and in detain in *Figure 2*.

Table 1. Multi-criteria ranking of districts of the Republic of Tatarstan, points
(for equally significant and partially weighted criteria)

| District | Equally significant criteria | | Weighted criteria | |
|---|---|---|---|---|
| | Rank | Points | Rank | Points |
| Tukaevskii | 1 | 68.91 | 1 | 68.98 |
| Vysokogorskii | 2 | 61.67 | 4 | 54.54 |
| Al'met'evskii | 3 | 61.18 | 3 | 59.97 |
| Nizhnekamskii | 4 | 57.76 | 2 | 61.22 |
| Laishevskii | 5 | 57.00 | 5 | 52.56 |
| Arskii | 6 | 46.42 | 7 | 44.86 |
| Mendeleevskii | 7 | 45.29 | 6 | 46.52 |
| Bugul'minskii | 8 | 44.44 | 8 | 41.41 |
| Zelenodol'skii | 9 | 42.54 | 10 | 40.51 |
| Mamadyshskii | 10 | 42.41 | 9 | 41.03 |
| Elabuzhskii | 11 | 39.76 | 11 | 38.99 |
| Bavlinskii | 12 | 37.74 | 12 | 37.04 |
| Menzelinskii | 13 | 35.23 | 15 | 32.47 |
| Chistopol'skii | 14 | 35.08 | 14 | 32.61 |
| Buinskii | 15 | 34.30 | 17 | 30.67 |
| Agryzskii | 16 | 34.04 | 18 | 29.95 |
| Apastovskii | 17 | 33.96 | 13 | 32.94 |
| Leninogorskii | 18 | 33.59 | 16 | 31.34 |
| Alekseevskii | 19 | 32.59 | 20 | 29.04 |
| Zainskii | 20 | 32.53 | 21 | 28.50 |
| Kukmorskii | 21 | 29.29 | 22 | 28.01 |
| Baltasinskii | 22 | 29.18 | 19 | 29.76 |
| Aznakaevskii | 23 | 28.95 | 29 | 22.27 |
| Pestrechinskii | 24 | 28.53 | 25 | 25.34 |
| Verkhneuslonskii | 25 | 28.11 | 27 | 24.45 |
| Kaibitskii | 26 | 27.88 | 24 | 27.24 |
| Rybno-Slobodskoi | 27 | 25.55 | 28 | 23.52 |
| Sabinskii | 28 | 25.13 | 26 | 25.15 |
| Drozhzhanovskii | 29 | 24.89 | 23 | 27.49 |
| Nurlatskii | 30 | 23.90 | 32 | 19.42 |
| Tetyushskii | 31 | 22.28 | 30 | 19.78 |
| Kamsko-Ust'inskii | 32 | 22.03 | 33 | 19.00 |
| Aktanyshskii | 33 | 21.00 | 36 | 17.13 |
| Atninskii | 34 | 20.31 | 31 | 19.55 |
| Aksubaevskii | 35 | 17.69 | 38 | 14.49 |
| Muslyumovskii | 36 | 17.08 | 34 | 17.85 |
| Novosheshminskii | 37 | 16.87 | 37 | 14.64 |
| Yutazinskii | 38 | 16.70 | 35 | 17.36 |
| Al'keevskii | 39 | 16.28 | 40 | 12.65 |
| Spasskii | 40 | 15.57 | 39 | 12.99 |
| Sarmanovskii | 41 | 13.95 | 41 | 11.57 |
| Tyulyachinskii | 42 | 12.13 | 42 | 10.59 |
| Cheremshanskii | 43 | 11.62 | 43 | 9.01 |

Figure 2. Comprehensive ranking of districts of RT with equally significant and weighted criteria indicators (in conventional points)




The simulation results with finding optimal and quasi-optimal alternative regions in RT after the implementation of the third variant of criteria weighing, i.e., weighting criteria at all levels of the generated TO, are presented in *Table 2*.

When comparing Table 1 (equally significant, unweighted structured TO) and Table 2 (non-equally significant TO), the feasibility of the chosen approach to the solution of the problem becomes obvious because during the study there is a possibility to evaluate the "weight" of the non-equally significant (weighted) scenario of TO (see Fig. 1): differentiation of the degree of priority of criteria indicators considerably swaps the elements (i.e., RT districts) of the ranked set, which is clearly demonstrated in *Figure 3*.

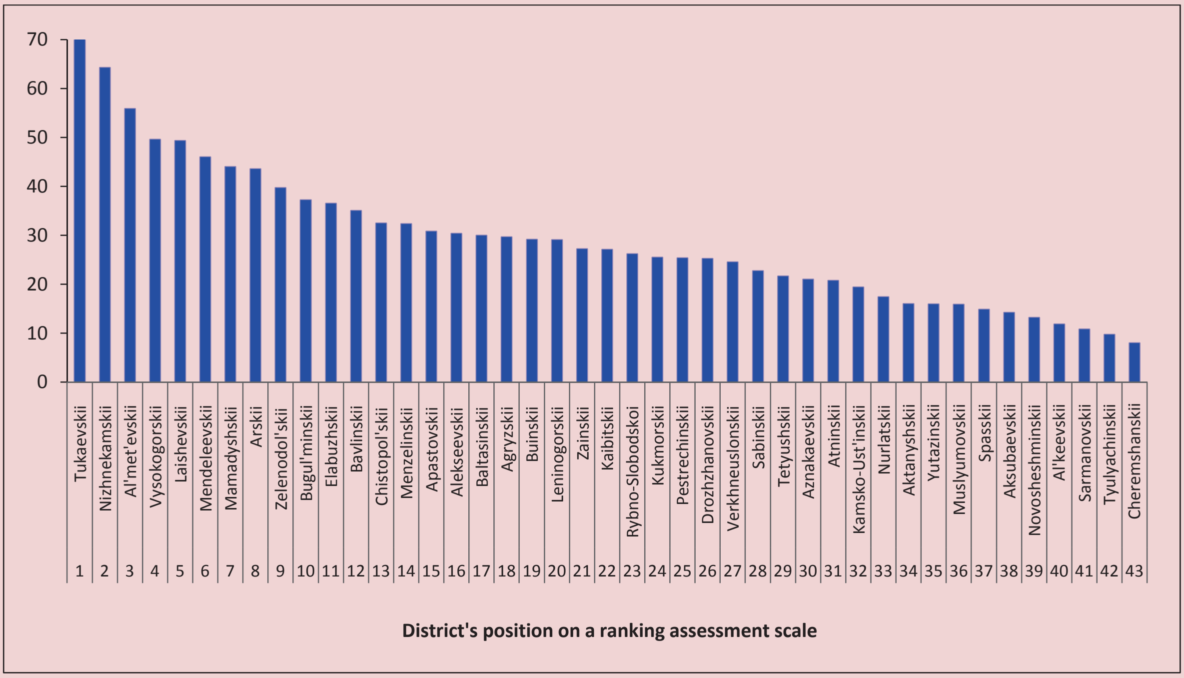
The weighting of criteria at different levels of the hierarchy was performed using both expert methods – ranking the preferences in the rank (ordinal) scale as more preferable [3; 11] with further mapping of the results according to Fishburn [20] into the interval scale, and selective correlation analysis as a means of ensuring relative independence of concepts expressed in the form of TO branches to ensure the required property of additivity.

At the next stage of project design, an opportunity is provided for targeted intervention of the representatives of the region and district

Table 2. Multi-criteria ranking of districts of the Republic of Tatarstan, points (for weighted criteria)

| Rank | District | Points | Rank | District | Points |
|---|---|---|---|---|---|
| 1 | Tukaevskii | 72.51 | 23 | Rybno-Slobodskoi | 26.17 |
| 2 | Nizhnekamskii | 64.25 | 24 | Kukmorskii | 25.49 |
| 3 | Al'met'evskii | 55.89 | 25 | Pestrechinskii | 25.35 |
| 4 | Vysokogorskii | 49.55 | 26 | Drozhzhanovskii | 25.23 |
| 5 | Laishevskii | 49.33 | 27 | Verkhneuslonskii | 24.50 |
| 6 | Mendeleevskii | 46.02 | 28 | Sabinskii | 22.75 |
| 7 | Mamadyshskii | 43.98 | 29 | Tetyushskii | 21.60 |
| 8 | Arskii | 43.58 | 30 | Aznakaevskii | 20.99 |
| 9 | Zelenodol'skii | 39.68 | 31 | Atninskii. | 20.74 |
| 10 | Bugul'minskii | 37.18 | 32 | Kamsko-Ust'inskii | 19.37 |
| 11 | Elabuzhskii | 36.48 | 33 | Nurlatskii | 17.42 |
| 12 | Bavlinskii | 35.02 | 34 | Aktanyshskii | 16.02 |
| 13 | Chistopol'skii | 32.46 | 35 | Yutazinskii | 15.91 |
| 14 | Menzelinskii | 32.31 | 36 | Muslyumovskii | 15.85 |
| 15 | Apastovskii | 30.78 | 37 | Spasskii | 14.82 |
| 16 | Alekseevskii | 30.37 | 38 | Aksubaevskii | 14.18 |
| 17 | Baltasinskii | 29.99 | 39 | Novosheshminskii | 13.14 |
| 18 | Agryzskii | 29.64 | 40 | Al'keevskii | 11.84 |
| 19 | Buinskii | 29.14 | 41 | Sarmanovskii | 10.81 |
| 20 | Leninogorskii | 29.09 | 42 | Tyulyachinskii | 9.71 |
| 21 | Zainskii | 27.20 | 43 | Cheremshanskii | 8.00 |
| 22 | Kaibitskii | 27.06 | | | |

Figure 3. Comprehensive ranking of RT districts with structured weighted criteria indicators (in conventional points)



(administration, investors, other stakeholders) in terms of separate district's approaching to a leading position.

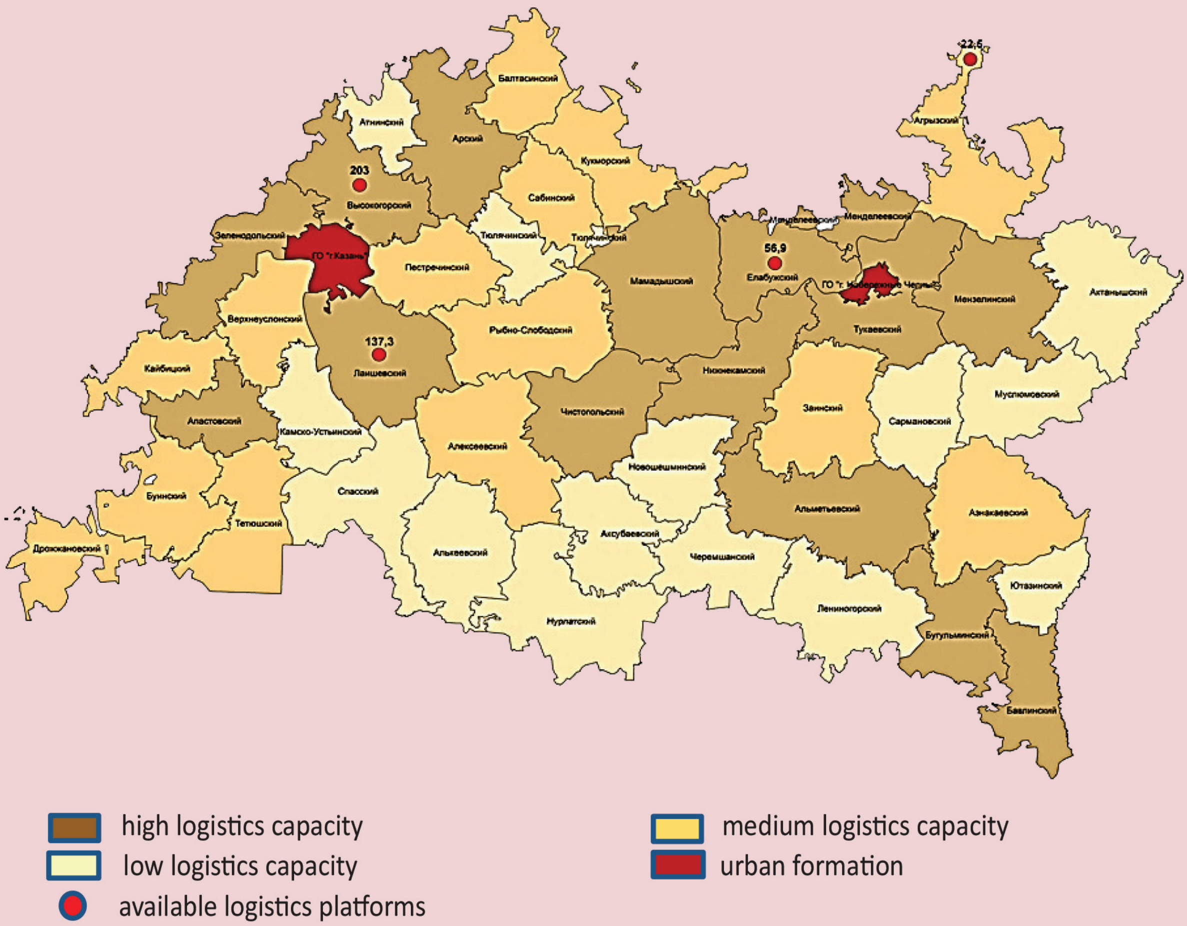
The study identified 16 leading districts. The mapping assessment of districts by amount of logistics potential is presented in *Figure 4*.

The mechanism of interaction of region's administration with the working group of project developers can be visually illustrated by the following example consisting of problem formulation and ways of its solution with output visualization of the projected management.

Suppose that a representative of one of AD (their district is ranked 11th in the ranking list) wants to improve the ranking of the district as a place for appropriate location of logistics facilities. However, they may have funds in the amount of Q million rubles. The question is: what criteria indicators must they have an impact on to achieve maximum effect increasing the district's logistics attractiveness. In fact, the formulation of this objective can be divided into two aspects. First: which criteria indicators are possible to be influenced from the management point of view? Second: what is the most efficient way of using available resources?

In terms of the implementation of the first aspect of the participation problem, it is clear

Figure 4. Logistics capacity of administrative divisions



that the representative of an AD has no power over the size of the territory (criterion $r_1$ measured on an interval scale, $km^2$). They also have no authority in relation to the objectively recorded degree of centrality of location relative to the regional center (criterion $r_2$ measured in a binary linguistic scale "close – far"); however, there are some criteria which are possible to be administratively influenced in varying degrees by a representative of an AD or of the region as a whole (or both) (for example, increasing production capacities, traffic volumes by various means of transport, length and quality of communications lines, etc.).

For further certainty, let the representative of the district for, say, one year will be able to raise "District's production capacity, million rubles" (criterion $r_2$) by, say, 6 %; during the same period increase "Length of land roads, kilometers" (criterion $r_7$) by 52 km; increase "Road cargo carriage volume, thousand tons" (criterion $r_{16}$) by 5–7 %. This, according to the district's representative, is where the district's potential for the next year is exhausted; the representatives are not required deeper understanding of the process of design and software development, their resource capacity; they report it the way they find it most convenient. The statement of the problem is finished.

The working team of developers before starting the simulation process specifies the price (cost) equivalents of units of quantitative indicators of criteria which require improvement; they may vary from region to region. The results are recorded in a temporary data file (in particular, in this case, in FoxPro for Windows environment in a .dbf file; other software products can also be used) in the form of point or interval estimates. The district's representative participating in the computational experiment is offered the whole list of criteria which are possible to be administratively influenced (in this example, the representative selected the impact on criteria $r_2$; $r_7$ and $r_{16}$).

The total estimated cost of special software crucial module with the .prg extension is calculated and formed; a new working table is built which has the following form: second, third and fourth lines are filled with the selected criteria, the first line is the allocated sum computed by the program with an option of a grade by $q_1, q_2, ..., q_k$, expressed in million rubles ($\Sigma q_k = Q$ million rubles). Then this software module generates the so-called "utility function" in the form of a matrix of the appropriate size (in this case, $3 \times k$). The first row of the new working table, as mentioned, represents funds in million rubles: $q_1, q_2, ..., q_k$ – the total – k columns.

Now we formulate the objective: how to distribute the available funds between improving criteria $r_2$; $r_7$ and $r_{16}$ most efficiently (as effectively as possible – for maximum promotion of values of the initial ranking to higher ranking)? In econometrics, to address the problems of this kind there is an efficient method of Bellman's discrete optimization – dynamic programming equation [4; 6; 15]. The designed and refined software module tested on model examples helps in the framework of the method of reverse run perform the stage of conditional and then unconditional optimization with consistent calculation of state equations using the elements of the first row in the new table. As a result, we will obtain new criteria values for $r_2$; $r_7$ and $r_{16}$ which will help use the district's available Q sum as efficiently as possible.

The former criteria characteristics of the program are duplicated and modified according to the results of solving the optimization problem of dynamic programming, the solution of MC DMO on the duplicated (modified) data file is performed again and other things being equal (the image for the rest of them –42 districts – remains the same) the studied district is moved, say, from 11th place in the initial (weighted) solution to, for example, 8th or 5th place, thereby increasing its reserve ranking of logistics capacity and opportunities of locating a logistics facility on its territory. The problem is solved. However, it is quite possible that the same representative of the simulated district may not be fully satisfied with the results. Then their intentions are specified and optimization problems and MC DMO in general are solved again as many times as necessary. After the final series of computational experiments the results of which are stored in a special data file the district's representative is offered the best one.

A computer program is currently being written and debugged; it aims to create a user working table in an interactive (dialogue) mode with obtaining discrete values of utility functions depending on arguments in the form of options of investment influence with the gradation of the form $q_1$, $q_2$, ..., $q_k$ for Bellman optimization scheme (which will be used for the implementation of the MC DMO for calculating vectors of priority based on district's real financial capacity rather than on model values).

At the same time, efforts are being made to geographically visualize the possible location of logistics facilities in a dialog mode within the leading districts and districts having the greatest production growth potential including agricultural. By now, experts have identified the places of location of logistics facilities in particular districts with regard to surveys of all responsible decision-makers in leading administrative divisions (official survey was conducted with the assistance of the Ministry of Transport and Roads of the Republic of Tatarstan), as well as taking into account assessments of experts of the working group by all initially established criteria. Approximate coordinates of location (geographical and rectangular) are identified, as well as the type of logistics facilities; recommendations are proposed on the size of the occupied territory, classes and types of located storage facilities, rational use and mutual influence of existing and planned centers both on the territory of the Republic of Tatarstan and in nearby regions.

The proposed visualization of location of logistics centers in districts, as one of the options, can be supplemented with known gravity models. However, preliminary conducted calculations indicated the inappropriateness of applying these models in determining the specific coordinates on a specific territory; the accuracy of gravitational methods in the case of a large number of diversified cargo traffic linking various consignors and consignees, including transit cargo traffic, has led to criticism from many researchers [14; 17].

For districts leading in the assessment of logistics capacity we performed statistical forecasting of ground cargo carriage volume, as well as production capacity of districts by extrapolative methods and based on neural intelligent trainable networks for a three-year forecast horizon. The forecast has revealed positive dynamics by main indicators: production capacity and ground cargo carriage volume, which finally confirmed the leading position of districts and helped recommend the location of logistics facilities on their territories (a detailed description of statistical forecasting is presented in [13]).

The obtained results help draw the following conclusions:

1. The proposed authors' method of multi-criteria optimization with the evaluation of options of locating logistics facilities in the district takes into account both existing opportunities of logistics capacity of each administrative division and any dynamics (positive, negative) of changes in criteria indicators of the district's logistics attractiveness from its area and length of communication lines to changes in production capacity and cargo turnover capacity (by any means of transport).

2. The use of the authors' approach to the implementation of a multi-criteria decision-making objective provides an opportunity to improve transport and logistics infrastructure in the region in practice by arranging freight traffic with direct participation of all stakeholders, namely authorities at all levels of regional administration, representatives of cargo carriers, industrial business units and potential investors.

3. The proposed software, including the author's program adapted to Windows, implies accelerated selection of options for locating facilities through influence on criteria indicators of logistics capacity taking into account the financial capacity of each region's administrative division.

The pilot project is under consideration to be implemented on the territory of the Republic of Tatarstan.

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