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MULTI-CRITERIA CHOICE OF THE REGION FOR THE CONSTRUCTION OF A LOGISTICS CENTER BASED ON AHP: CASE STUDY FOR KAZAKHSTAN

Summary. The current state of the regional market of transport and logistics services in Kazakhstan is characterized by a disparity between the increasing demand for logistics services and the lack of logistics capacity. In this article, the authors propose a method for determining the most promising areas of the Republic of Kazakhstan for the construction of a logistics center, based on the Analytic Hierarchy Process (AHP).

1. INTRODUCTION

A modern solution to the problem of increasing the efficiency of the commodity distribution system is the organization of product delivery with the participation of a logistics center. The construction of new logistics centers in the absence of a unified methodology and well-established methods for the formation of transport and logistics infrastructure leads to an unequal distribution of logistics capacity across the country. The insufficient level of both theoretical elaboration and practical placement of logistics facilities makes it necessary to study existing methods for solving this problem, followed by the development of methods for selecting locations of logistics centers based on a comprehensive assessment of the attractiveness of the region [1-3].

This analysis requires detailed information about a variety of technical and economic indicators. Choosing the best alternatives based on this abundance of data requires a sophisticated analysis and modeling technique.

Optimization of the location of the transport and logistics center (TLC) is a rather complicated economic and mathematical problem. To solve this, several analytical methods are currently being used, for example, the “center of gravity” method, the method of mathematical programming by the criterion of minimum total logistic costs, the distribution problem of linear programming and others [4-6]. A common drawback of these methods is the incomplete consideration of possible factors affecting the determination of the location of the logistics center. Taking into account that the problem under consideration is multi-criteria, when choosing locations for the logistics center, it is proposed that it be guided by the attractiveness of the region according to a certain system of factors.

An analysis of the region according to certain criteria allows us to determine the effectiveness of the placement of transport and logistics infrastructure elements in the region, taking into account the influence of the system of socio-economic, infrastructural and transport factors. Since the identified factors are evaluated by both quantitative and qualitative indicators, it is proposed to take into account their impact on the location of logistics infrastructure using the AHP [7-8].

The AHP technique is a modern mathematical method that uses a systematic approach to solve multi-criteria and multi-alternative problems. AHP does not provide for any “correct” solution, but allows you to interactively find an option (alternative) that is best consistent with an understanding of the essence of the problem and the requirements for its solution. This method was created by researchers R. Bellman, B.N. Brooke and V.N. Burkov, but it became widely known only thanks to the work of the American scientist Thomas Saaty, who gave the name to this technique. Saaty's scientific works most fully described the universality of this method, which allowed him to find wide practical application. AHP is currently widely used worldwide to make important decisions in various fields, both at the level of government and in individual problems in business, manufacturing, education, healthcare, etc. [9-12]. This method is so universal due to the fact that AHP includes not only mathematical but also psychological aspects of the problem under study [13].

The main advantage of the AHP is the versatility of the method - it is applicable for solving a variety of problems: when analyzing possible scenarios for the development of situations, allocating resources, creating various ratings, making managerial business decisions, etc. Note that, even for simple problems, the structures of models constructed using the Analytic Hierarchy Process are quite complex schemes. However, this only indicates that the method allows to reveal the real complexity of the tasks that a person has to solve mentally.

The AHP does not require simplification of the structure of task and a priori discarding some features. Therefore, it is more effective than other analytical tools, which allows to take into account the influence of various factors on the choice of solution. This method can serve as an add-on for other methods designed to solve poorly formalized tasks; it provides convenient means of accounting for expert information for solving various problems [14-19]. The method reflects the natural course of human thinking and provides a general approach. It provides not only a way to identify the most preferred solution but also allows to quantitatively signify the degree of preference through rating. Drawing up the structure of a decision-making model can be a time-consuming process. However, if it is composed, then it can further be applied repeatedly. It remains only to adjust this structure and fill it with data, wherein the solution of typical tasks can be put on flow. Thus, the application of the method becomes more efficient. It should be noted that at present, there are a large number of multicriteria decision-making (MCDM) methods. Often, a new method is obtained by combining well-known modern MCDM methods. An example of such work is in the article [24].

2. AHP TECHNIQUE

The process of working with the model begins with the development of a hierarchical structure, including goals, basic criteria and alternatives for solving the problem. At the first level is the goal, which is limited by a number of criteria located at the second level. Each of these criteria has its own characteristics, which are assigned a quantitative assessment, a combination of these criteria as a result of modeling from several alternatives that can be used to solve the problem. Each element in the model matters, and not only material and quantitative factors are taken into account but also intangible and qualitative ones. In addition, not only objective data but also the subjective opinion of the user of the model are of great importance for the model.

The final decision in the AHP model can be made using pairwise comparisons, where the most preferred option is highlighted. The final step in the analysis of hierarchies is to synthesize priorities on hierarchies, as a result of which the priority of alternatives relative to the main goal is determined.

Most preferred is an alternative with maximum priority scores. Under these conditions, the statement of the problem is solved using the AHP, tentatively, as follows:

- common goal of solving the problem;
- a set of alternative solutions to the problem (alternatives); and
- criteria for assessing the alternatives.

It is required to choose the best alternative.

The solution to the problem consists of a set of steps, which are as follows:

- defining goals, key criteria and alternatives;

- structuring the system in the form of a hierarchical structure with several levels: goals - criteria – alternatives;
- establishment of directional links indicating the influence of criteria and alternatives on each other;
- pairwise comparison of elements of each level by constructing a matrix of pairwise comparisons of alternatives for each criterion;
- judgments consistency check;
- calculation of a quantitative assessment of the quality (credibility) of alternatives; and
- choosing the best alternative.

Thus, when making a decision by the AHP, the following features exist:

- several different solutions are considered;
- the optimal solution criterion is set; and
- the specific conditions under which the problem must be solved and the reasons that may influence the choice of solution are known.

When determining the location of the future logistics center, it is necessary to take into account already existing logistics facilities, the geographical location in conjunction with the capacities of industrial and resource-raw potential, the population, as this will ensure the availability of labor resources when creating a logistics center, affects the volume of trade, socio-economic indicators to identify promising regions, location taking into account the presence of a transport corridor, etc. For this study, the main criteria were selected on the basis of world experience in the field of logistics and the characteristics of transport industry development in Kazakhstan. Pairwise comparisons of factors are made in terms of the dominance of one indicator over another: which one is most significant from the point of view of an expert. The decision-making process was attended by experts in the field of logistics of the JSC Kazakhstan Highway Research Institute. The work of the expert group was to compare the criteria and determine the criterion that has the greatest impact on the development of logistics infrastructure in Kazakhstan (KZ). A team of nine experts decided on the relative importance of the criteria indicated in Table 1.

The criteria are divided into 2 groups: socio-economic and transport and infrastructure. To simplify the work, a code is assigned to each criterion. For example, when building a matrix of pairwise comparisons, the significance of the factor of the volume of agriculture and industrial production (C2) will be more significant than other factors or, for example, the significance of the factor of the presence in the region of international transport corridors and seaports (C7) prevails over the region's import factor (C5), etc.

In accordance with Table 1, the main criteria are presented that influence the determination of the location of the logistics center. The criteria should consider the following factors:

- economic development of the region, as, for the future functioning of the TLC, a perspective is needed;
- population of the region, as, to fully meet the needs of the population, it is also necessary to understand the security of the TLC with labor resources;
- indicators of export–import activities for the further development of international trade;
- places of generation of significant cargo flows, which allows to determine the level of development of the sphere, its throughput and the need for modernization;
- the level of development of the transport infrastructure, to determine the ability of the TLC to fulfill its tasks;
- crossing the territory of the region with international transport corridors to realize the country's transit potential and increase the TLC's capabilities; and
- the presence in the region of warehouses of various types to avoid the construction of unclaimed logistics centers.

The values of the criteria for all regions of Kazakhstan are presented in Table 2 [20].

It is quite obvious that the number of criteria that could be taken into account is significantly larger. A number of additional criteria are indicated in [23], for example, minimum operating costs, minimizing investor costs, belonging to the climatic zone, etc. However, since these additional criteria act similar to the above, therefore, they were not taken into account in the analysis, i.e. their indirect effect is already taken into account.

Table 1
Criteria for the method and comparison of alternatives for the location of the logistics center in the Republic of Kazakhstan

No.	Criterion Code	Name of the criterion	The order of criteria relevance according to experts
Group of socio-economic factors			
1	C1	Gross Regional Product (GRP)	2
2	C2	Agricultural and industrial production	1
3	C3	Population size (as for January 1, 2019)	7
4	C4	Export of region	3
5	C5	Import of region	8
Group of transport and infrastructure factors			
6	C6	Length of railways	6
7	C7	The presence of international transport corridors (ITC), seaports in the region	4
8	C8	The length of roads with a hard surface	5
9	C9	Volume of cargo carried	9
10	C10	Cargo turnover volume	10
11	C11	The volume of available warehouse space for grain storage	11
12	C12	The volume of available warehouse space for oil and oil products	11
13	C13	The volume of available warehouse space for the storage of other food and non-food goods	11

In accordance with the above criteria, Fig. 1 presents the developed model of the hierarchical structure. The purpose of this model is to determine the most promising construction site of the TLC on the territory of Kazakhstan; all regions of Kazakhstan are taken as alternative options.

Since each factor in varying degrees affects the choice of the location of the logistics center and its future performance, the first stage determines the weight coefficients of each factor by the AHP.

The AHP uses a verbal–numeric scale of relations, which allows to put numbers from 1 to 9 in accordance with the degrees of preference of one indicator over another. For example, 1 – equal importance, 3 – one criterion more important than another is unimportant criterion, 5 – one criterion is much more important than other criteria, 7 – the importance of one criterion greatly exceeds the importance of other criteria and 9 – the importance of one criterion completely surpasses the importance of other criteria. In situations where a compromise solution is needed, the numbers 2, 4, 6 and 8 are used. To determine the region of Kazakhstan that claims to be assigned the status of a priority area necessary for the construction of a logistics center, we will perform calculations by the AHP in the context of the country's regions. Cities of national significance will be included in the regions based on their territorial affiliation. This is due to the fact that it is not possible to determine the values of certain factors in the context of cities, for instance, the presence of ITC on the territory, the length of railways, etc.

At the stage of comparison of the criteria, pairwise comparison is applied with assignment of scores on a nine-point scale with the compilation of a decision matrix. The matrix elements are the intensity of the appearance of one or another element relative to another element.

An important feature of the method is the inverse symmetry of estimates in accordance with the theory of inverse symmetric matrices. Taking into account additional comparisons of some factors with others can improve the reliability of the results. If more accuracy is required, intermediate values can be accepted between the listed definitions. Matrices for pairwise comparison will be constructed according to formula (1).

$$\begin{pmatrix} 1 & R_{12} & R_{13} & \dots & R_{1n} \\ R_{21} & 1 & R_{23} & \dots & R_{2n} \\ R_{31} & R_{32} & 1 & \dots & R_{3n} \\ \dots & \dots & \dots & \dots & \dots \\ R_{n1} & R_{n2} & R_{n3} & \dots & 1 \end{pmatrix}, \quad (1)$$

$R_{ij} = \frac{1}{R_{ji}}$, if j < i (since the matrix is inverse symmetric), where:

R_{ij} –the degree of influence of one criterion (i) over another criterion (j); n – the number of elements in the row (the number of criteria according to table 1 is 13; or the number of alternatives according to table 2 is 14). After obtaining the matrix of pairwise comparisons, the next step is to calculate the vector of priorities, i.e. weight of significance of objects. From the point of view of matrix analysis, the essence of this operation is to calculate the main eigenvector of the matrix, which, after normalization, becomes a priority vector.

$$\omega_i = \sqrt[n]{\prod_{j=1}^{n} R_{ij}} \quad . \quad (2)$$

Next, calculate the normalized priority vectors (NPV) for each criterion by dividing the eigenvector component by the sum of all eigenvector components by formula (3).

$$\text{NPV}_i = \omega_i \; / \sum_{j=1}^{n} \omega_j \quad . \quad (3)$$

Each NPV_i component represents assessment of importance of the corresponding criterion. The principal basis of calculation of the component of the vector of priorities, which correctly reflect the real situation, is consistency and sequence of expert judgments in paired comparisons of ranked objects. To assess the consistency of the results, a special value $\boldsymbol{\lambda}_{\mathbf{max}}$ is introduced, which is called the consistency index or the maximum eigenvalue of the matrix.

The consistency index $\boldsymbol{\lambda}_{\mathbf{max}}$ is calculated as the sum of the products of the sum of the factor values in the column for each factor and its weight (priority vector) according to formula (4):

$$\boldsymbol{\lambda}_{\mathbf{max}} = \sum_{i=1}^{n} S_i * \text{NPV}_i \quad , \quad (4)$$

where:

$$S_i = \sum_{i=1}^{n} R_{ij} \quad .$$

Next, we enter another value: the so-called consistency index (CI), which shows the degree of consistency of the expert's judgments and is calculated using formula (5):

$$\text{CI} = (\boldsymbol{\lambda}_{\mathbf{max}} - \text{n})/(\text{n} - 1) \quad . \quad (5)$$

It is necessary to check how all the assumptions were consistent in the preparation of the matrix. To determine how accurately CI reflects the consistency of judgments, it must be compared with a random consistency index (RCI), which corresponds to a matrix with random values. For this, according to formula (6), we calculate the consistency ratio (CR).

$$\text{CR} = \text{CI} / \text{RCI} \quad , \quad (6)$$

where RCI – random consistency index, determined theoretically for the case when the values in the matrix are presented randomly, and depending only on the size of the matrix.

At Oakridge National Laboratory, scientists generated average RCI for matrices of the order of 1 to 15 based on 100 random samples. According to the results of the study, RCI grew with increasing order of the matrix. Since the sample size was only 100, statistical fluctuations were observed in the index during the transition from a matrix of one order to another. Therefore, the calculations were repeated at Wharton's school, while increasing the sample to 500 in order matrices up to 11x11; for matrices of order more than 12, 13, 14 and 15, the results of the previous study were used. The average values of the random consistency index for matrices of the order of 11 to 15 are shown in Table 3 [11].

Table 2

Criteria for the method and comparison of alternatives for the location of the TLC

No.	Criterion code	Name of criterion	Unit	Akmola	Aktobe	Almaty	Atyrau	West Kazakhstan	Zhambyl	Karagandy	Kostanay	Kyzylorda	Mangystau	Pavlodar	North Kazakhstan	Turkestan	East Kazakhstan
				Kazakhstan region													
				Alternative code													
				A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
Group of socio-economic factors																	
1	C1	GRP volume	million US dollars	24 421	7 869	43 369	22 716	8 108	4 451	13 755	6 012	4 785	11 049	7 980	3 521	11 139	10 428
2	C2	Agricultural and industrial production	million US dollars	2 755	3 030	4 557	10 533	4 302	1 149	6 178	2 097	2 030	6 462	3 209	1 195	3 299	4 369
3	C3	Population size (as for January 1, 2019)	people	1 816 971	869 637	3 893 590	633 791	652 325	1 125 442	1 378 533	872 795	794 334	678 199	753 853	554 517	2 993 053	1 378 527
4	C4	Export of region	million US dollars	6 050,9	2957,2	3 732,9	23 863,8	6 162,4	294,9	4 601,3	1 075,0	666,8	5 079,2	3 072,8	200,2	1 506,9	1 846,9
5	C5	Import of region	million US dollars	4 491,7	1251,6	14 525,1	3 227,0	776,5	341,4	1 805,8	1 164,7	242,4	630,3	1 003,4	367,5	1 629,9	2 201,2
Group of transport and infrastructure factors																	
6	C6	Length of railways	km	1 579,5	1 826,7	1 401,4	742,3	319,7	1 043,5	2 467,1	1 270,3	870,9	1 096,6	788,4	618,7	551,6	1 209,0
7	C7	The presence of international transport corridors (ITC), seaports in the region	presence	yes,no	yes,no	yes,no	yes,yes	yes,no	yes,no	yes,no	yes,no	yes,no	yes,yes	yes,no	yes,no	yes,no	yes,no
8	C8	The length of roads with hard surface	km	7 847,0	5 124,9	8 827,9	2 401,0	4 357,0	4 313,6	8 430,9	7 675,9	2 882,4	2 522,6	4 820,0	7 113,2	6 555,2	10 367,9
9	C9	Volume of cargo carried	thousand tons	279 673	79 130	440 262	173 799	39 468	103 472	825 632	297 051	104 541	237 925	134 638	51 464	187 302	628 360
10	C10	Cargo turnover volume	million tons	15 261	6 424	33 670	61 010	3 083	2 906	10 364	11 593	14 229	8 494	35 171	3 758	9 823	16 119
11	C11	The volume of available warehouse space for grain storage	thousand tons	4 608,8	372,6	218,4	5,0	677,6	27,0	175,8	3 759,0	45,3	22,5	337,3	3 760,7	3,0	1 237,9
12	C12	The volume of available warehouse space for oil and oil products	thousand tons	368,9	33,9	113,3	3,3	123,4	-	-	73,6	3,8	77,2	3,8	132,7	45,6	211,2
13	C13	The volume of available warehouse space for the storage of other food and non-food goods	thousand square meters	408,5	101,2	700,8	18,5	49,9	7,5	55,1	6,8	7,3	1 399,2	27,5	24,5	147,7	3 439,1

The table is compiled according to the Committee on Statistics of the Ministry of National Economy of the Republic of Kazakhstan for 2018.

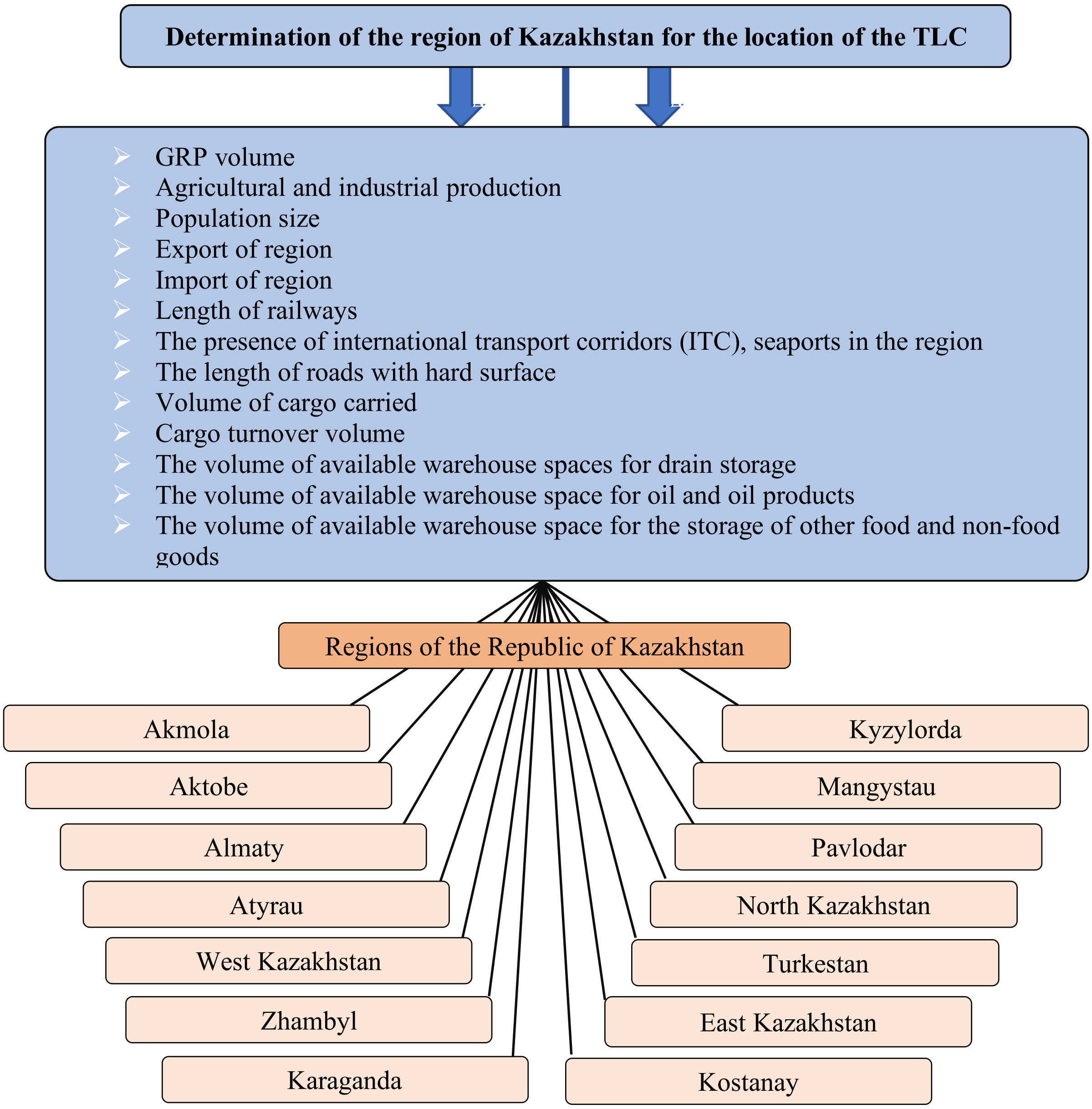

Fig. 1. AHP hierarchical structure model to determine the region of Kazakhstan that is most suitable for construction of the logistics center

Table 3

Random index of randomly generated samples in matrices

n	11	12	13	14	15
RCI	1,51	1,48	1,56	1,57	1,59

Estimates in the matrix are considered consistent if $CR \leq 0.10$; otherwise, the matrices of pairwise comparisons must be revised.

3. DETERMINATION OF THE REGION OF THE REPUBLIC OF KAZAKHSTAN FOR THE CONSTRUCTION OF TLC ON THE BASIS OF AHP

In accordance with formula (1), we construct a matrix and calculate the priority values of the criteria (Table 4).

Calculate the components of the eigenvector:

$\omega_{C1} = \sqrt[13]{10\,692\,000} = 3{,}47$;
$\omega_{C2} = \sqrt[13]{129\,600\,000} = 4{,}21$;
$\omega_{C3} = \sqrt[13]{0{,}729} = 0{,}98$;
$\omega_{C4} = \sqrt[13]{515\,625} = 2{,}75$;
$\omega_{C5} = \sqrt[13]{0{,}1067329} = 0{,}84$;
$\omega_{C6} = \sqrt[13]{13{,}5} = 1{,}22$;
$\omega_{C7} = \sqrt[13]{750} = 1{,}66$;
$\omega_{K8} = \sqrt[13]{105{,}46875} = 1{,}43$;
$\omega_{K9} = \sqrt[13]{0{,}0003795} = 0{,}55$;
$\omega_{C10} = \sqrt[13]{0{,}0002911} = 0{,}53$;
$\omega_{C11} = \sqrt[13]{0{,}0000004} = 0{,}32$;
$\omega_{C12} = \sqrt[13]{0{,}0000004} = 0{,}32$;
$\omega_{C13} = \sqrt[13]{0{,}0000004} = 0{,}32$.

Table 4

Matrix pairwise comparison of criteria

Code	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**
C1	1,00	0,33	5,00	3,00	5,00	5,00	4,00	4,00	5,00	5,00	6,00	6,00	6,00
C2	3,00	1,00	5,00	4,00	5,00	5,00	4,00	4,00	5,00	5,00	6,00	6,00	6,00
C3	0,20	0,20	1,00	0,20	3,00	0,50	0,50	0,50	3,00	3,00	3,00	3,00	3,00
C4	0,33	0,25	5,00	1,00	5,00	5,00	4,00	4,00	5,00	5,00	5,00	5,00	5,00
C5	0,20	0,20	0,33	0,20	1,00	0,33	0,33	0,33	3,00	3,00	5,00	5,00	5,00
C6	0,20	0,20	2,00	0,20	3,00	1,00	0,50	0,50	3,00	3,00	5,00	5,00	5,00
C7	0,25	0,25	2,00	0,25	3,00	2,00	1,00	2,00	4,00	4,00	5,00	5,00	5,00
C8	0,25	0,25	2,00	0,25	3,00	2,00	0,50	1,00	3,00	3,00	5,00	5,00	5,00
C9	0,20	0,20	0,33	0,20	0,33	0,33	0,25	0,33	1,00	2,00	2,00	2,00	2,00
C10	0,20	0,20	0,33	0,20	0,30	0,33	0,25	0,33	0,50	1,00	3,00	3,00	3,00
C11	0,16	0,16	0,33	0,20	0,20	0,20	0,20	0,20	0,50	0,33	1,00	1,00	1,00
C12	0,16	0,16	0,33	0,20	0,20	0,20	0,20	0,20	0,50	0,33	1,00	1,00	1,00
C13	0,16	0,16	0,33	0,20	0,20	0,20	0,20	0,20	0,50	0,33	1,00	1,00	1,00

Calculate the sum of eigenvector components:

$\sum \omega = 3{,}47 + 4{,}21 + 0{,}98 + 2{,}75 + 0{,}84 + 1{,}22 + 1{,}66 + 1{,}43 + 0{,}55 + 0{,}53 + 0{,}32 + 0{,}32 + 0{,}32 = 18{,}62$

Next, the normalized priority vectors are calculated for each criterion:

$NPV_{C1} = 3{,}47/18{,}62 = 0{,}19$;
$NPV_{C2} = 4{,}21/18{,}62 = 0{,}23$;
$NPV_{C3} = 0{,}98/18{,}62 = 0{,}05$;
$NPV_{C4} = 2{,}75/18{,}62 = 0{,}15$;
$NPV_{C5} = 0{,}84/18{,}62 = 0{,}05$;
$NPV_{C6} = 1{,}22/18{,}62 = 0{,}07$;
$NPV_{C7} = 1{,}66/18{,}62 = 0{,}09$;
$NPV_{C8} = 1{,}43/18{,}62 = 0{,}08$;

NPV_{C9} = 0,55/18,62 = 0,03;
NPV_{C10} = 0,53/18,62 = 0,03;
NPV_{C11} = 0,32/18,62 = 0,02;
NPV_{C12} = 0,32/18,62 = 0,02;
NPV_{C13} = 0,32/18,62 = 0,02;

Calculate the maximum eigenvalue of the matrix:

λ_{max} = 6,31 * 0,19 + 3,56 * 0,23 + 23,98 * 0,05 + 10,10 *0,15 + 29,23 * 0,05 + 22,09 * 0,07 + 15,93 * 0,09 + 17,59 *0,08 + 34 * 0,03 + 34,99 * 0,03 + 48,00 * 0,02 + 48,00 * 0,02 + 48,00 * 0,02 = 14,789;

Calculate the consistency index:

CI = (14,789 – 13) / (13 – 1) = 0,149;

Calculate the consistency ratio:

CR = 0,149 / 1,56 = 0,096;

Consider the matrix to be consistent, because CR condition ≤ 0.10 is completed.

Next, a pair of alternatives for each criterion should be compared in the same way as was done for the criteria. The first criterion is the volume of GRP. We compose a pairwise comparison matrix of all alternatives for this criterion (Table 5).

Next, we calculate the components of the eigenvector, the sum of the components of the eigenvector and the normalized priority vector for each alternative according to the example of their calculation in pairwise comparison of the criteria:

$NPV_{A1} = \sqrt[14]{876\ 253\ 593{,}6}$ / 22,34 = 0,19;
$NPV_{A2} = \sqrt[14]{0{,}0013524}$ / 22,34 = 0,03;
$NPV_{A3} = \sqrt[14]{3\ 919\ 104\ 000}$ / 22,34 = 0,22;
$NPV_{A4} = \sqrt[14]{126\ 772\ 800}$ / 22,34 = 0,17;
$NPV_{A5} = \sqrt[14]{0{,}0216381}$ / 22,34 = 0,03;
$NPV_{A6} = \sqrt[14]{0{,}00000002}$ / 22,34 = 0,01;
$NPV_{A7} = \sqrt[14]{57\ 881{,}25}$ / 22,34 = 0,10;
$NPV_{A8} = \sqrt[14]{0{,}0000111}$ / 22,34 = 0,02;
$NPV_{A9} = \sqrt[14]{0{,}0000001}$ / 22,34 = 0,01;
$NPV_{A10} = \sqrt[14]{34{,}2144}$ / 22,34 = 0,06;
$NPV_{A11} = \sqrt[14]{0{,}0054095}$ / 22,34 = 0,03;
$NPV_{A12} = \sqrt[14]{0{,}0000000003}$ / 22,34 = 0,01;
$NPV_{A13} = \sqrt[14]{114{,}048}$ / 22,34 = 0,06;
$NPV_{A14} = \sqrt[14]{8{,}5536}$ / 22,34 = 0,05.

Calculate the maximum eigenvalue of the matrix according to the criterion “GRP volume”:

λ_{max} = 6,12 * 0,19 + 40,03 * 0,03 + 3,49 * 0,22 + 7,74 * 0,17 + 37,03 * 0,03 + 64,33 * 0,01 + 17,21 * 0,10 + 48,91 * 0,02 + 62,83 * 0,01 + 24,30 * 0,06 + 38,53 * 0,03 + 75,00 * 0,01 + 22,84 * 0,06 +25,80 * 0,05 = 16,024;

Calculate the consistency index according to the criterion “GRP volume”:
CI_{C1} = (16,024 – 14) / (14 – 1) = 0,156;

Calculate the consistency ratio by the criterion “GRP volume”:
CR_{C1} = 0,156 / 1,57 = 0,099;
Consider the matrix to be consistent, since CR condition ≤ 0.10 is completed.

Based on the example of calculations by the first criterion, it is necessary to compare the alternatives for all the remaining twelve criteria. After considering all the alternatives, we combine the results of the analysis of pairwise comparison of alternatives by criteria. For this purpose, we will form a summary table by writing out the average value of the "weight" for each alternative according to all criteria and the normalized priority vectors for each criterion (Table 6).

Table 5

Matrix of pairwise comparison of alternatives in terms of GRP volume

C1	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
A1	1,00	7,00	0,33	2,00	7,00	8,00	5,00	7,00	8,00	6,00	7,00	8,00	6,00	6,00
A2	0,14	1,00	0,16	0,14	0,50	4,00	0,20	3,00	4,00	0,33	0,50	5,00	0,33	0,33
A3	3,00	6,00	1,00	3,00	6,00	8,00	4,00	7,00	8,00	5,00	6,00	9,00	5,00	5,00
A4	0,50	7,00	0,33	1,00	7,00	8,00	5,00	7,00	8,00	5,00	7,00	8,00	5,00	5,00
A5	0,14	2,00	0,16	0,14	1,00	4,00	0,20	3,00	4,00	0,33	2,00	5,00	0,33	0,33
A6	0,13	0,25	0,13	0,13	0,25	1,00	0,14	0,33	0,50	0,20	0,25	3,00	0,20	0,20
A7	0,20	5,00	0,25	0,20	5,00	7,00	1,00	5,00	7,00	3,00	5,00	7,00	3,00	3,00
A8	0,14	0,33	0,14	0,14	0,33	3,00	0,20	1,00	3,00	0,25	0,33	4,00	0,25	0,25
A9	0,13	0,25	0,13	0,13	0,25	2,00	0,14	0,33	1,00	0,20	0,25	3,00	0,20	0,20
A10	0,16	3,00	0,20	0,20	3,00	5,00	0,33	4,00	5,00	1,00	3,00	6,00	0,50	2,00
A11	0,14	2,00	0,16	0,14	0,50	4,00	0,20	3,00	4,00	0,33	1,00	5,00	0,33	0,33
A12	0,13	0,20	0,11	0,13	0,20	0,33	0,14	0,25	0,33	0,16	0,20	1,00	0,20	0,16
A13	0,16	3,00	0,20	0,20	3,00	5,00	0,33	4,00	5,00	2,00	3,00	5,00	1,00	2,00
A14	0,16	3,00	0,20	0,20	3,00	5,00	0,33	4,00	5,00	0,50	3,00	6,00	0,50	1,00

Table 6

Summary of the results of the calculation of the total values of priorities

	NPV	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
C1	0,19	0,19	0,03	0,22	0,17	0,03	0,01	0,10	0,02	0,01	0,06	0,03	0,01	0,06	0,05
C2	0,23	0,03	0,04	0,09	0,25	0,07	0,01	0,14	0,02	0,02	0,16	0,04	0,01	0,05	0,08
C3	0,05	0,12	0,03	0,25	0,01	0,02	0,06	0,09	0,04	0,03	0,02	0,02	0,01	0,22	0,08
C4	0,15	0,14	0,04	0,06	0,28	0,15	0,01	0,08	0,02	0,01	0,10	0,05	0,01	0,02	0,03
C5	0,05	0,19	0,04	0,26	0,14	0,02	0,01	0,07	0,04	0,01	0,02	0,03	0,01	0,06	0,09
C6	0,07	0,11	0,16	0,11	0,02	0,01	0,05	0,23	0,08	0,03	0,06	0,03	0,02	0,02	0,07
C7	0,09	0,03	0,08	0,08	0,18	0,03	0,08	0,08	0,02	0,08	0,18	0,02	0,03	0,08	0,02
C8	0,08	0,10	0,04	0,15	0,01	0,03	0,03	0,14	0,09	0,02	0,01	0,04	0,07	0,06	0,21
C9	0,03	0,08	0,02	0,12	0,04	0,01	0,02	0,24	0,09	0,03	0,06	0,04	0,01	0,05	0,18
C10	0,03	0,07	0,02	0,16	0,27	0,01	0,01	0,04	0,04	0,06	0,03	0,17	0,02	0,03	0,08
C11	0,02	0,25	0,05	0,03	0,01	0,07	0,02	0,03	0,18	0,02	0,01	0,05	0,18	0,01	0,10
C12	0,02	0,27	0,03	0,08	0,02	0,09	0,01	0,01	0,05	0,02	0,05	0,02	0,12	0,03	0,20
C13	0,02	0,10	0,06	0,13	0,02	0,04	0,01	0,04	0,01	0,01	0,19	0,03	0,02	0,08	0,26

In accordance with the results, we calculate the final priorities for each alternative. The calculation of the final priorities of the alternatives is based on the summation of the products of the importance factors of the criteria by the importance factors of the alternatives for each individual alternative:

A1 = 0,19 * 0,19 + 0,03 * 0,23 + 0,12 * 0,05 + 0,14 *0,15 + 0,19 * 0,05 + 0,11 * 0,07 + 0,03 * 0,09 + 0,10 * 0,08 + 0,08 * 0,03 + 0,07 * 0,03 + 0,25 * 0,02 + 0,27 * 0,02 + 0,10 * 0,02 = 0,11.

Using the example of alternative 1, we can calculate the final priorities for each alternative and obtain the result specified in Table 7.

Table 7

Priority Totals

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
0,11	0,05	0,13	0,17	0,06	0,02	0,11	0,04	0,03	0,09	0,04	0,02	0,06	0,08

4. CONCLUSIONS

According to the data obtained, the "choice of the best alternative" for the prospective construction of the TLC in the territory of the Republic of Kazakhstan can be demonstrated on the map in Fig. 2.

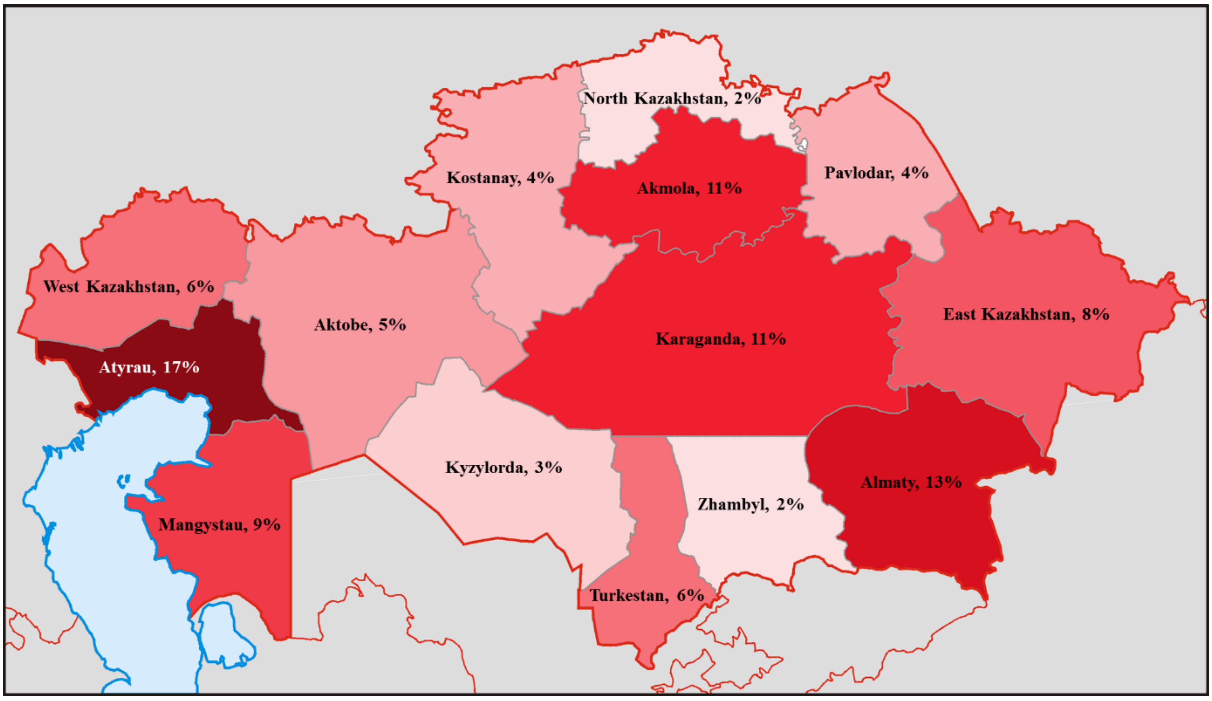

Fig. 2. The most promising region of the Republic of Kazakhstan for the construction of the TLC based on HAM

The color designation on the map determines the degree of priority for the implementation of the construction of the logistics center: the brighter the color, the higher the priority of the region.

Atyrau region is definitely one of the leaders of national economy. The region occupies a leading position in such indicators as the volume of gross regional product, including per capita, industrial production, the attraction of foreign investment and the nominal wage indicator. The region, which is one of the main donor regions, makes a significant contribution to the republican budget. Atyrau region has one of the largest economic potentials among the regions of Kazakhstan due to its large reserves of oil and gas.

International transport corridors such as TRACECA, North-South and the international automobile corridor Astrakhan-Atyrau-Aktau-Turkmenistan pass through the territory of the Atyrau region. Access to the marine space of the Caspian is another vector of the region's perspective development.

Today, the development of transport and logistics infrastructure is one of the priority tasks of the country. As part of the «Nurly Zhol» state program, a national highway of Aktobe-Atyrau-Astrakhan (Russian Federation) is being reconstructed. According to the program, it was planned to update 432 kilometers of the route. The first stage, namely, 60 kilometers, will be completed by mid-2021, and the rest in 2022. After beginning route into operation, the turnover might increase significantly.

Taking into consideration the favorable geographical location, on the border with the largest trading partner - the Russian Federation, and access to the Caspian Sea, transit traffic is a real direction for the development of the region. The growth of international trade determines the process of transport development and provides the prospect of realizing the country's transit potential. The region meets all the requirements for the prospective implementation of infrastructural logistics construction.

A complete calculation using AHP allowed us to achieve the goal, resulting in the best alternative for the construction of the TLC in Kazakhstan. Thus, according to the results of calculation of the final priority values, according to the proposed system of factors, it is advisable to create a logistics center in the territory of Atyrau region.

The presented methodology for a comprehensive assessment of the region's priority for the location of a logistics center, as well as the calculations to take into account the main socio-economic, infrastructural factors and indicators of transport work, can be recommended for use in drawing up state programs for the development of transport and logistics infrastructure of the regions, as well as when large companies need find decisions about investing in the development of the logistics industry [21-22].

The use of the AHP method, which is the oldest of the MCDM methods, proposed by the authors in the article for analyzing the situation in Kazakhstan is not free from drawbacks. This method has a number of known disadvantages, the main one being the need for a large number of pairwise comparisons and, as a consequence, the considerable complexity of using the method with an increase in the number of alternatives. This is the reason for the instability of the AHP method to errors of judgment. In the future, it is planned to conduct an analysis of the stability of the solution and comparison with the results obtained using other MCDM methods.

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