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Optimization of Location of Transport and Logistics Centers at the Example of the Republic of Kazakhstan

Aray RAMAZANOVA

Ramazanova, Aray, *Kazakh University of Transport Communications, Almaty, Republic of Kazakhstan*.*

ABSTRACT

Transport links largely determine the potential of a country located within the Asian region to interact with market entities beyond region's borders. Meanwhile, transportation logistics of individual regions, territories, and countries is a complex integrated problem, whose solution is based on the approaches to fundamentals of organisation of the operation of transport infrastructure.

One of the key tasks in organizing the work of the transport system of the Republic of Kazakhstan is to determine the location of the elements of its transport and logistics infrastructure. At present, theoretical and methodological approaches to solving this problem can be divided into multicriteria analysis and coordinate (gravitational method) approach.

The objective of this article is to analyze the possibility of using gravitational and multicriteria methods to find the optimal location for transport and logistics centers using the example of the Republic of Kazakhstan.

Based on that the research was intended as an attempt to find optimal location of transport and logistics centers in the Republic of Kazakhstan. It was clearly shown that the use of the gravitational method has constraints if not supplemented by the use of the multicriteria analysis method when solving the problem of choosing the optimal location of the transport and logistics infrastructure at the example of the Republic of Kazakhstan.

Keywords: *transport, transport and logistics center, production potential, Kazakhstan industry, gravitational method, multicriteria method, infrastructure location coordinates, Khorgos – Vostochnye Vorota FEZ, Altynkol station.*

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*Information about the author:
Ramazanova Aray – Senior Lecturer of the Department of Traffic Management, Transport Management and Logistics of Kazakh University of Transport Communications, Almaty, Republic of Kazakhstan, ayari.r@mail.ru.

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Introduction. The features of the economics of any region are characterized by the quality and quantity of transport and communication links, both established and promising for the regional development, those links determine the potential for interaction of the region with other market entities both inside and outside it. The significance and the role of this factor under modern conditions are particularly important, since this factor determines intensity and effectiveness of integration processes, of resources, information, and goods exchange processes. Moreover, the geographical position of the region is either a favorable or an inhibitory condition for development of those processes [1].

Today, leading manufacturing spheres of the Republic of Kazakhstan are metallurgical (ferrous and non-ferrous metallurgy), petrochemical and chemical industries, mechanical engineering and production of building materials. Kazakhstan exports its products to more than 120 countries.

A feature of the industry of Kazakhstan is that the country is exceptionally endowed with its own mineral reserves. More than 50 % of the world's reserves of tungsten, 21 % of the reserves of uranium, 23 % of chromium ores, 19 % of lead, 13 % of zinc, 10 % of copper and iron are concentrated in the territory of the Republic of Kazakhstan [2].

According to CIS Interstate Statistical Committee, in 2018 compared with the previous year, the industry of Kazakhstan had significantly improved its position according to several indicators, regarding, namely, the electricity production, oil, natural gas, and coal extraction, manufacturing of industrial products, and agriculture production.

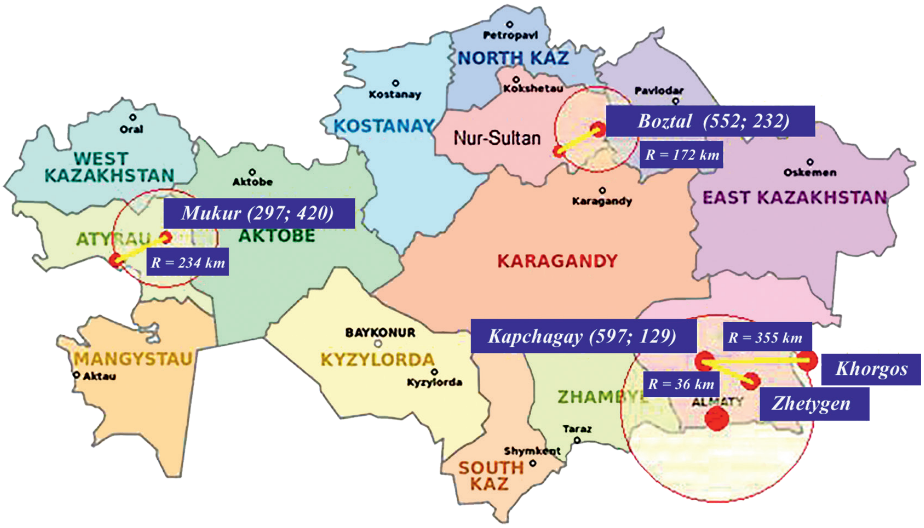
In 2018, crude oil and natural gas production in value terms increased by 4,8 % compared to the previous year. Besides, there was an increase in the cost of produced oil products by 8,8 %. In physical terms, yearly crude oil production amounted to 77,5 million tons (an increase by 6,3 %), gas condensate to 12,8 million tons (a decrease by 3,1 %), and natural gas to 55,5 billion m^3 (an increase by 5 %). In 2018, oil refineries produced almost 4 million tons of gasoline (an increase by 29,8 %), 388,3 thousand tons of kerosene (an increase by 29,4 %), 4,6 million tons of gas (an increase by 7,4 %), and 2,9 million tons of fuel oil (a decrease by 12,9 %) [2].

The favorable situation in the oil and gas sector had a positive impact on the foreign trade turnover of the Republic of Kazakhstan. Over the specified period, foreign trade turnover grew by 20,5 % and amounted to 84,344 billion US dollars. The export grew by 26,4 %, which amounted to 54,673 billion US dollars, and import grew by 11,1 % (29,671 billion US dollars).

Transport logistics of the Republic of Kazakhstan is a comprehensive complex task, which is based on the solution of fundamental problems of organisation of the operation of transport infrastructure. The development of transport systems in regions and cities has been the subject of many works by domestic and foreign scientists [3–6].

One of the key tasks in organizing the work of the transport systems of the Republic of Kazakhstan is the problem of determining the location of the elements of transport and logistics infrastructure. Currently, theoretical and methodological approaches to their placement can be divided into a multi-criteria analysis and coordinate approach. In the first case, the best option is selected based on totality of the considered criteria, among which may be area and configuration of the site of a probable location, degree of development of transport infrastructure at the location, remoteness from consumers, cost of land acquisition, etc. In the second case, when solving location problems, geometric arguments (coordinates) are of key importance. These approaches allow achieving a high level of research accuracy when combining them at various stages of solving the problem. The coordinate method allows to select the most preferred region at the macro level for solving the problem, and the multicriteria method allows to select a specific location for placing the element within the region in question.

A lot of works have been devoted to the use of coordinate methods in solving the placement problem [5–8]. For example, A. G. Kirillova in her work [5] considered density of container flows using the «center of mass» method to search for the coordinates of container terminals. The coordinates of the center of mass are then found using the integrals. In the same way, it is assumed that it is reasonable in region D to search for the optimal location of the logistics center using the integral formulas (1)–(3):



Pic. 1. Industrial map of the Republic of Kazakhstan.

Table 1

Results obtained using gravitational method

Cluster	Obtained results	Settlement name
1st cluster	597; 129	Kapchagay
2nd cluster	552; 232	Boztal
3rd cluster	297; 420	Mukur

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

$$y_0 = \frac{1}{M}\int_D yr(x,y)dxdy, \quad (2)$$

where D is density of container transportation, and

$$M = \int_D r(x,y)dxdy. \quad (3)$$

The work of G. I. Prosvetov [8] is also devoted to solving the problem of finding the location of logistics centers. He, using the gravitational method on OXY coordinate plane, determined the location of the transport infrastructure relative to the supply volume using the formulas below (4; 5):

$$C = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}; \quad (4)$$

$$C = \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i}, \quad (5)$$

where w_i is the volume of products delivery;

x_i, y_i are coordinates of facilities.

The advantage of this method is rapid receipt of results, but when placing the transport infrastructure at the micro level, the results may turn to be impractical.

Objective. The *objective* of the article is to analyze applicability of gravitational and multicriteria *methods* for assessing the optimal placement of transport and logistics centers at the example of the Republic of Kazakhstan.

Results.

The analysis of the industrial potential of the regions of the Republic of Kazakhstan allows us to conditionally divide the country into three production clusters, shown in Pic. 1. To determine the centers of gravity of cargo flows, we will study each of these clusters to determine demand for transport logistics in them. The main consumers of transport services shall mean settlements and industrial enterprises. As initial data, we will operate the population size, the number of large enterprises in the regions under consideration, and the coordinate characteristics of the facilities under consideration. These characteristics directly reflect demand for transportation services and products in the region.

Large industrial centers of Kazakhstan are located mainly in the northern and northeastern areas of the country. The further displayed coordinates of the estimated location of respective transport and logistics centers (hereinafter TLC) were obtained using the gravitational method (Table 1). The basic input data were statistical data of large enterprises of the Republic of Kazakhstan with the number of employees of at least 500 people. Also data on transport activity and city population density were used.

In the first cluster, the estimated location of the transport and logistics facility is located on the border of Almaty and Zhambyl regions of the Republic, at a distance of 77,5 km from the city of Almaty and 562,1 km from the city of Taraz in the southern part of Kazakhstan, that is in the city of Kapchagay (with coordinates 597; 129) of Almaty region (Pic. 1).

Almaty region is a large industrial and agricultural region of Kazakhstan. Besides, mechanical engineering and metalworking industries are developed in the region, which include a machine-tool plant, a heavy machine-building plant, factories that produce spare parts for oil and gas equipment, as well as automobile and agricultural machines. Along with the above sectors of the industries there are furniture, printing, pharmaceutical and food industries in the region which are also successfully developing. The population of Almaty region as of December 1, 2018 amounted to more than 2 million people. According to the draft government decree «On approval of the long-term plan for development of Almaty agglomeration until 2030» (hereinafter referred to as Almaty plan) it is planned to increase its number to 5 million people. One of the objectives of the Almaty plan is to develop the transport and logistics infrastructure of the region.

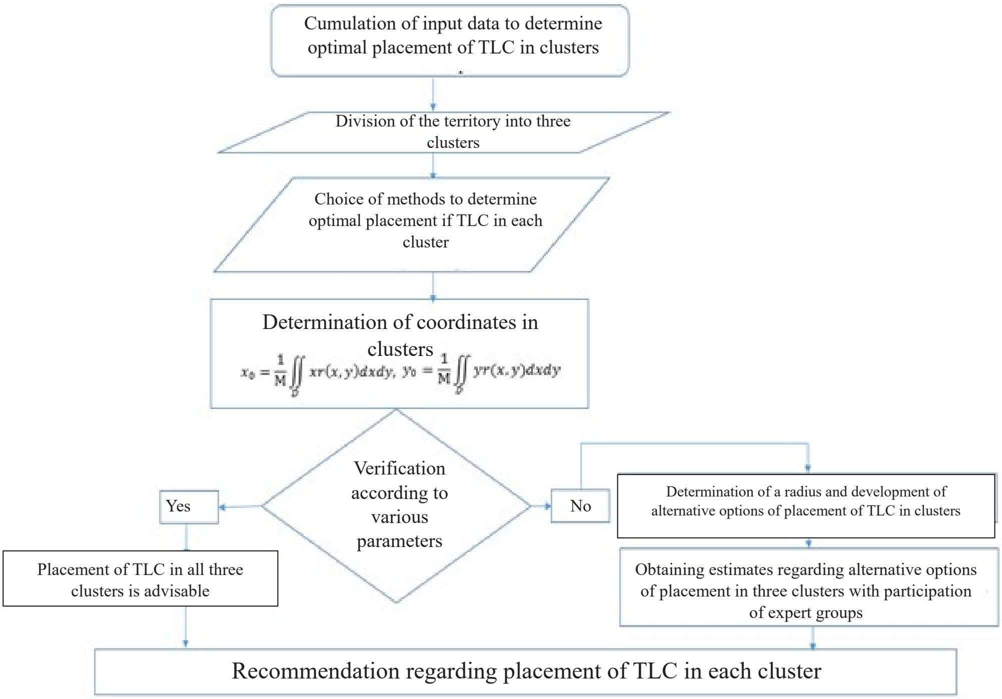
The city of Kapchagay is in Almaty region, and its population density is more than 61643 people. Highways and railways connect this city with China, Russia and the countries of Central Asia. The river port in the region allows passenger ships and cargo barges to make voyages to China. As a railway junction and according to the purpose and nature of the operations performed, Kapchagay is a fifth-class station.

The results obtained by gravitational method (597; 129) (Pic.1) are not quite satisfactory, since this method is suboptimal, and does not take into account important criteria such as the degree of development of transport infrastructure, population, territorial development, development of production enterprises, presence of hub stations, and possibility of servicing several types of transport, etc. To take them into account in order to adjust the result obtained earlier, the multicriteria analysis method should be applied.

In this regard, within the framework of this cluster, we will consider options for the optimal placement of TLC in Almaty region. Let us note that the objects that will further be considered are located wihin a radius of not more than 355 km from the results obtained by gravitational method.

1. Zhetygen station. According to the purpose and nature of the operations performed, it is a junction station (for Zhetygen—Almaty, Zhetygen—Altynkol, Zhetygen—Ushtobe lines) of the fourth class, has eight receiving-departure tracks, of which two tracks operate in the direction of Altynkol. The station plays a special role in increasing the capacity of the railway network of Kazakhstan and is one of the key stations of the «bridge» connecting Europe and Asia.

According to Almaty plan, by 2021, it is planned to build Zhetygen—Kazbek-Bek railway bypass line (5 hauls of 15 km each, 4 separate points, 2 stations, 2 double-track sections and 3—4 receiving-departure tracks with a length of 1050 m) bypassing Almaty-1 junction station to increase the throughput capacity and transit train capacity. According to this plan, it is also expected in 2021—2024 to construct BRT (Bus Rapid Transit) line with its subsequent transformation into the light rail line (LRT) from the projected North bus station in the north direction along the regional highway Almaty—Zhetygen—Kapchagay Reservoir, linking the agglomeration city center with Iliysky district settlements (village Otegen-Batyr, station and village Zhetygen with access to the city of Kapchagay) and Talgar district (village Zhanalyk) [9]. This location is most suitable for hosting a transport and logistics center, since transit flows to Europe pass through Zhetygen station.



Pic. 2. The algorithm for search for optimal location of TLC.

2. Free Economic Zone (FEZ) «Khorgos – Vostochnye Vorota [*Eastern Gates*]». One of the important large industrial projects in implementation of the comprehensive plan for formation of the transport and logistics system of the Republic of Kazakhstan is «Khorgos – Vostochnye Vorota FEZ» (hereinafter Khorgos FEZ), which includes the Khorgos International Center for Cross-Border Cooperation (ICBC Khorgos)) The total area of Khorgos FEZ is 5740 hectares, it consists of three zones:

I – dry port (129 ha);

II – logistics zone (225 ha);

III – industrial zone (225 ha), and is located in Panfilov district of Almaty region on Kazakh-Chinese border.

All three zones are connected by the «Western Europe–Western China» highway with a total length of 8445 km, of which 2787 km pass through Kazakhstan. This corridor plays an important role in increasing the transit potential of the entire Eurasian region, reducing time of delivery of goods from China to Europe and being one of the first important projects in revival of the New Silk Road. The territory of the dry port of Khorgos FEZ comprises a border station Altynkol. By the nature of the operations it belongs to the extra-class station. The length of the track from Zhetygen station to Altynkol station is 293 km. To complete the entire range of transportation operations at the station, there are three receiving-departure parks, connecting tracks, three transshipment sites, exhaust tracks and access roads. The main task of Altynkol station is transshipment of containers from a wide (1520 mm) gauge to a narrow (1435 mm) gauge and vice versa. To date, processing capacity of the station is more than 1889 TEU, that is an average of 37 trains per day, about 14 000 trains per year. Works are envisaged that will significantly accelerate formation and disbandment of arriving and departing trains and will provide unhindered reception and departure of trains at Altynkol station:

• construction of a non-mechanized low-capacity humping yard and 12 tracks of humping yard yard «G» of 1520 mm gauge;

• construction of a humping yard yard with 5 tracks along the 1520 mm gauge track, and additionally of at least 5 receiving-departure tracks along the 1435 mm gauge track;

• construction of a dead end for sludge of passenger cars, which will create favorable conditions, due to release of station tracks for shunting operations of the station;

• construction of ramps, which will make it possible to overload vehicles;

• construction of a higher track for loading and unloading of local goods of the agro-industrial complex (corn, molasses, starch, etc.), as well as of coal.

FEZ Khorgos plays an important role for the growth of transit transportation capacity of the Republic of Kazakhstan. Railway and highway passing through the territory of Khorgos FEZ are also important for the implementation of the global concept of New Silk Road. The favorable location of Khorgos FEZ, presence of several zones, a border station where cargo is being transshipped from a narrow gauge to a wide one, the possibility of using innovative technologies, creation of production enterprises (mechanical engineering, food, chemical and light industry), simplification of customs procedures, introduction of the «one-stop shop» principle, development of intermodal and multimodal services, possibility of access to the seaports of Aktau and Kuryk are priority factors. Also, construction of a large class A TLC Verona Capital, which occupies 9,5 ha, is now continuing within the territory of Khorgos FEZ. It is planned to build dry warehouses with an area of 24 694 m^2 and warehouses with a controlled temperature regime of 14 516 m^2.

Cities in the northern and central parts of the country are included in the second cluster (Pic. 1). In the considered part of the Republic of Kazakhstan, the proposed location of TLC is the village of Boztal of Ereymentau district (with coordinates 552; 232) of Akmola region located at a distance of 169 km from the city of Nur-Sultan. The population of the village is about 5 thousand people. As the results of the analysis show in relation to this cluster, given small population number, lack of a railway station and the worn-out state of roads, placement of TLC in the village of Boztal is impractical.

Hence, we suggest considering the option of placement of TLC in Nur-Sultan city located within the radius of 172 km from Boztal village since the combination of methods allows searching for the optimal option of placement of TLC in that cluster. Since 2015, in the framework of Nurly Zhol state program, in Akmola region, at a distance of 12 km from the city of Nur-Sultan, an A+ class TLC has been operating. It was the first in the country of that class, has a total area of about 40 000 m^2, a cargo container terminal of 7 ha, with a convenient transport car–railway interchange, access roads with a length of 5 km. Warehouse complexes, where dry and climatic functions are equipped with the advanced technology. The warehouse complexes have the advantages to handle more than 300 000 tons of cargo per year. Capacity of the loading and unloading zone is about 1000 pallets per day, the capacity of the container terminal is up to 4000 large-tonnage containers (the ability to handle more than 1 000 000 tons of cargo per year). Besides, the center includes customs control zones and a distribution center. TLC is located along the republican highway Nur-Sultan–Karaganda, not far from Sorokovaya railway station (1,6 km). Sorokovaya station by the nature of the operations is a railway district station and belongs to the 1st class. The number of tracks at the station is 20, there is one receiving-departure yard. The cargo turnover of the station for 4 months of 2018 amounted to about 3 000 wagons.

The rural district of Mukur (with coordinates 297; 420) has been identified as the proposed location for TLC in the third cluster (Pic. 1) using the gravitational method. This rural district makes part of Kyzylkoginsky district of Atyrau region, while Atyrau region is in the west of the country and borders Astrakhan region of Russia from the outside. The leading industries of the region are fuel, chemical and fishing industries. The region as the oil region of Kazakhstan ranks third in the country in terms of GRP and first in terms of GRP per capita. According to the Ministry of National Economy of the Republic of Kazakhstan, in 2018, due to an increase in crude oil production, the industrial production index was by 23,8 % higher as compared to the same period of 2017.

The village of Mukur is located at 235 km distance from the regional center. The population of the village is about 7 thousand people. Mukur belongs to intermediate stations of the fourth class, has 4 receiving-departure tracks. The road connecting the village to the regional center is in unsatisfactory condition. Given deterioration of the highway and of the railway line, the small population number, it is not advisable to place TLC in the territory of the village of Mukur. It can be seen that the use of gravitational method for this cluster did not give positive practical results for placement of TLC either.

Based on the results obtained, in this cluster, as in the previous ones, it is practical to use a combination of gravitational method and multicriteria analysis to determine the location of TLC. In this case, according to the same criteria that were taken into account for the first and second clusters, the proposed location for TLC will be the city of Atyrau, located within the radius of 234 km from Mukur village.

According to the census in 2018, the population of the city amounted to 268840 people. Atyrau station, by the nature of the operations, is a railway district station and belongs to the 1st class. There are 9 receiving-departure tracks, 2 yards (sorting and receiving-departure), the sorting yard consists of 6 tracks, there are 13 access roads. The 366 km long transit corridor Atyrau–Astrakhan passes through the territory, allowing passage of vehicles with a load of 13 tons per axle. Cargo is delivered towards the Black Sea ports, to the Caucasus, and then to Europe. The corridor is also part of the Western Europe–Western China route. By 2020, it is planned to increase revenues from transit traffic to 5 billion US dollars per year, hence there is a need for warehouse space of about 3 mln m^2.

Conclusions. Based on the above, when constructing TLC in the regions of the Republic of Kazakhstan, it is necessary to consider the set of important aspects, comprising the degree of development of transport and service infrastructure and transport logistics, population density, movement of export cargo, the capacity of the station (border stations), etc.

Analyzing the data obtained for the three clusters, we can conclude that the use of the gravitational method allows to quickly obtain an acceptable result in less detail at the macro level, it in the future is subject to some adjustment. A specific feature of application of the gravitational method is that the results do not fully take into account additional indicators, such as territorial development, the volume of consumption of transport products, and the degree of development of transport infrastructure. None of the locations found in three clusters can be unambiguously used to place TLC, since they are located at a considerable distance from all the consumers of transport services considered.

A more accurate result can be obtained by adjusting and using the multicriteria analysis method for all three clusters.

Thus, for actual application in determining the optimal placement of TLC, it is recommended to use a combination of methods.

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