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Designing and Improving the Efficiency of Placement of Logistics Infrastructure for Storage, Distribution and Trade of Agri-Food Products

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Abstract:

Purpose: The article considers a methodological approach to the formation and determination of potential locations of logistics infrastructure: warehouse storage facilities, wholesale distribution centers for storage, marketing and trade of agro-food products.

Design/methodology/approach: A study of 204 objects - administrative districts and cities of Kazakhstan, where the production, storage, distribution and trade of agri-food products is carried out. The standardization of indicators, cluster, correlation-regression, factor analysis was carried out, the method of ranking and center of gravity.

Findings: At the first stage of the study, potential locations of distribution centers of agricultural products were identified based on the proposed criteria. Based on factor analysis, new factors have been formed in order to determine the criteria for choosing the location of the logistics infrastructure. Cluster analysis made it possible to differentiate territories and determine the characteristics of the logistics infrastructure for their placement, depending on their specialization. At the second stage, the potential locations of logistics infrastructure and the geographical location of objects on the territory of administrative-territorial units were clarified. At the third stage, with the help of weighting coefficients and an integral indicator of the attractiveness of the location of logistics infrastructures, the service area of the logistics infrastructure of storage, sales and trade is determined in accordance with potential locations on the territory. The proposed approach, in contrast to the existing ones, takes into account the peculiarities of the functioning of the storage, marketing and trade infrastructure and links these facilities with transport and warehouse availability in the regions.

Research limitations/implications: The study is aimed at complementing existing approaches and methods for determining the location of logistics infrastructure facilities with a more detailed account of the specialization of districts and the economic potential of regions.

Practical implications: The conclusions allow us to use different criteria when determining the location of logistics infrastructures depending on their purpose. They also provide important information in the process of designing logistics infrastructure, conducting a differentiated investment policy during their construction and operation.

Originality/value: In this article, a new point of view is given on the choice of criteria for the placement and determination of the number of logistics infrastructure, based on their functional purpose, specialization of districts and the potential of regions, which increase their efficiency.

Keywords: methodological approach, logistics infrastructure, selection and placement criteria, wholesale distribution center, transport and warehouse accessibility, transport and warehouse network, perishable products, factor and cluster analysis, storage, distribution and trade of agri-food products

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1. Introduction

In modern conditions it is not only the task of increasing production volumes that is relevant for the agricultural sector, but also the problem of its storage, sale and delivery to the final consumer.

The problem of distribution of agricultural products is always acute for farmers, since these products are often sold without taking into account regional and global market conditions, which allows numerous intermediary structures to buy agricultural products at low prices, make significant profits on their resale and leads to a decrease in the competitiveness of domestic products compared with foreign analogues.

To solve this problem, in most European countries, wholesale trade of all perishable products is organized through wholesale food markets (WFM). Examples of successful distribution networks based on WDC networks are the wholesale market Rungis (France) (http://www.rungisinternational.com/), Mercasa wholesale market network (Spain) (http://www.mercasa.es/) and the Bronisze wholesale market (Poland) (https://www.bronisze.com.pl).

The relevance of the development of the WDC network for the sale of agricultural products in Kazakhstan is due to a number of problems, the solution of which is strategically important for the food security of Kazakhstan.

Firstly, the large territory of the country and low population density, uneven distribution of major agricultural producers and consumers by region are the reason for high shipping costs and high product losses in Kazakhstan. The degree of concentration (placement) of producers of agro-industrial complex (AIC) products and trade facilities in the regions is uneven - it varies from low density to high density of placement.

More than 75% of agricultural products are transported by road. Transportation takes from one to two days, since the length of the territory from west to east exceeds 3,000 km, from south to north - 1,700 km, also causing high costs and product losses.

Despite various measures of state support, there is a large shortage of logistics infrastructure for storage, packaging and transportation, modern trade formats that leads to large losses of products, which amount to up to 40% in the fruit and vegetable sector, and up to 20-25% in animal husbandry. This is especially evident in the activities of small agricultural producers.

Secondly, the rapid growth and expansion of retail chains in the country leads to an increase in imports of products, due to the fact that most of the products of small agricultural producers and their presentation do not meet the requirements of retail chains. There are no stable sales markets. The absence of a WDC limits the ability of local wholesale and retail trade markets to work with large retail chains. The main task of WDC is consolidation, processing, packaging, wholesale and small wholesale of products.

Kazakhstan lacks a system of modern wholesale markets and WDC, capable of optimally accumulating and distributing the products of domestic producers, primarily small producers of agro-industrial complex (AIC) products. The structure of agricultural producers is very heterogeneous. The bulk of them (about 85%) are small households, which produce most of all agricultural and crop production in the country.

Currently, the distribution of goods and services in general along the commodity distribution chain, in our opinion, is irrational and is random.

To solve this problem, in 2020, Kazakhstan decided to build a network of WDC (Trade development concept, 2020).

In this regard, solving the problem of optimal placement and service areas of logistics infrastructures for the storage, distribution and trade of agro-industrial products throughout the country and their effective operation is relevant for Kazakhstan.

Despite numerous scientific developments on the choice of the location of distribution centers for the sale of agri-food products and their design, as well as evaluating the effectiveness of their activities, it can be stated that the available solutions to the scientific problem in the field of organizational and methodological support for the formation of logistics infrastructure require more detailed study, especially in relation to agricultural products.

This is due, firstly, to the industry specifics and the significant difference between agricultural products and products of other types of industrial production. Secondly, there are significant shortcomings in the methodological tools – a shortage of modern methods based on scientifically sound criteria for assessing the rational placement of logistics facilities, which determined the choice of the purpose and objectives of the study. With a large territory and low population density and infrastructure placement, this task requires its own scientifically-based solution, taking into account various factors that affect the choice and efficiency of the logistics infrastructure.

The purpose of the study is to develop organizational and methodological solutions for the formation and effective placement of logistics infrastructure for the storage, marketing and trade of agri-food products, in particular, warehouses and WDC.

In this study, the main attention is focused on logistics infrastructure facilities belonging to the group of intermediary, distribution and trade organizations: warehouse storages of agricultural products (grain, vegetable, fruit, berry, potato storages) and WDC. Since these organizations have a direct impact on the process of commodity circulation of food products, that is, storage, sale and trade.

The methodology allows to design and determine the locations of the WDC on the territory, taking into account transport networks and transit potential, as well as regional factors (socio-economic, environmental, industrial). Currently, there is no such methodology. The proposed locations and proposed capacity are described in various documents on the development of agriculture and trade in Kazakhstan. However, they lack methodological approaches, methodology and recommendations for the development of logistics infrastructure by region.

Solving the problem of rational placement of the WDC makes it possible to implement projects for the development of the agro-industrial complex of the Republic of Kazakhstan for 2021-2025 (Program for the development of agriculture, 2018) and trade for 2021-2025 (Trade development concept, 2020), to determine long-term investments in the development of the WDC by regions of Kazakhstan.

The proposed method could be used both by logistics providers to analyze and select the optimal location of a logistics center, taking into account the existing customer base, owners of agro-industrial and transport zones located directly on the territory of large regions, and government agencies to plan the placement of logistics infrastructures throughout the country.

In this regard, in section 2.1, we presented a review of the literature on the methodology of designing and placing logistics infrastructure. In section 2.2, an analysis of the factors influencing the formation and placement of the logistics infrastructure is carried out. Section 3 contains the methodology of the study, Section 4 contains the results of the study, section 5 contains a discussion of the results of the study, and Section 6 contains a conclusion on the work.

2. Literary Review

2.1. Methodology of Creation and Placement of Logistics Infrastructure of Wholesale Distribution Centers of Agri-Food Products

An important structural component of the distribution system is the logistics infrastructure that provides storage, distribution and trade of products. The role of logistics infrastructure is to optimally locate and ensure efficient cargo delivery with coordinated interaction of multiple structures, elements and links of logistics infrastructure: service, trade, warehouse and transport network (Dablanc & Rakotonarivo, 2010).

The problem of choosing the optimal location of warehouses has existed for a long time, and many models have been proposed to solve it (Dybskaya, 2009; Copacino, 2016; Strdube & Zadek, 2000; Volkhin, 2018). The design and placement of distribution facilities and consumers has been studied in many works. This issue is solved by dividing the territory into areas where distribution points are located (Daskin, 2013), by modeling product demand, population distribution density (Daskin, 1995), taking into account geographical (Geoffrion, Morris & Webster, 1995), socio-economic and infrastructural factors (Romeijn, Shu & Teo, 2007; Popov & Miretskij, 2019).

Many companies are faced with a strategic decision regarding the number of DC's, their location, and the customers they serve (Erlebacher & Meller, 2000). One of the goals of the company making this decision is to maintain an acceptable level of service while minimizing the fixed costs of DC operation, the cost of storing inventory in DC, and transportation costs between plants and DC, as well as DC and customers.

The model of agricultural product supply consists of the functions of distribution, storage, processing, certification and monitoring of infrastructure facilities, information and transport support (Salamon & Mesko, 2022). It is relevant to determine the optimal location of the logistics infrastructure, which means determining a scientifically sound, standardized and practical location. Previous studies have established requirements for assessing the location of logistics infrastructure in terms of: conditions of goods movement (Lu & Qin, 2019), laws and policies (Musolino, Rindone, Polimeni & Vitetta, 2019), resources (Ozmen & Aydogan, 2020), business environment (Sharma & Sungheetha, 2018), the natural environment (Rao, Goh, Zhao & Zheng, 2015), costs and quality of information (Mieczyńska & Czarnowski, 2021).

The analysis of the scientific literature has revealed a significant number of works in which mathematical models and methods for determining the location of networks of warehouses and transport and logistics terminals, logistics centers in the region are proposed.

A literature review (Gurrala & Hariga, 2022) of the food supply chain (FSC) for 2010-2021 showed the following: 56% of articles use mathematical and computational methods to optimize the process of determining the location and capacity of logistics facilities, 40% – are advanced technologies, models of planning and optimization of supplies. These studies confirm the importance of the problem of product losses and product spoilage due to inefficient operation of the logistics infrastructure.

Currently, many methods have been developed for solving the problem of optimal placement of a warehouse terminal, among which are the full search method, the heuristic method, the center of gravity method, economic and mathematical models. Table 1 shows some of the most widely used methods in science and practice for choosing the location of logistics facilities.

The following methods and their mixed models are widely used in planning and determining the location of logistics or distribution centers: the integer programming model (Xiaohui, Weina, Cuijuan & Zueyu, 2010; Rios et al., 2021), the method of order preference (Li, Liu & Chen 2011), the method of gravity theory (Liu, 2014); multi-purpose optimization model (Zhu & Zhang, 2015); methods combining K-means clustering theory (Wang et al., 2022), AHP method (Fuzzy Analytical Hierarchy Process), fuzzy integrated assessment method (Cheng & Zhou, 2016), GIS technologies (Yang, 2012; Racaci et al., 2022), P-median model (Huang, Wang & Chen, 2022), integrated model of production and distribution of agricultural products (Herlina, Machfud & Sukardi, 2022).

Method	Description
Sequential iteration method (Ardalan, 1984)	It is used when you need to select a certain number of placements from a large number of options
The full search method (Romeijn, 2007)	the choice of the optimal location of the warehouse is solved by a complete search and evaluation of all possible options for the placement of distribution centers using mathematical programming methods
The method of commercial attraction and the methods of Arthur Geoffrion (Geoffrion et al., 1995), the center of gravity method (Romeijn, Al-Gwaiz & Chao, 2016)	It is based on the calculation of the center of gravity of the warehouse to certain consumers, i.e. the distribution warehouse will be located at a certain point – closer to large customers
The method of calculating the integral indicator of the logistics infrastructure (Carlucci, 2017)	to assess the choice of logistics infrastructure, indices of the development of railway, automobile, road and water transport are used, as well as indicators related to the cost of logistics facilities, the number of transport and logistics specialists
Methods of network modeling, discrete optimization (Klose & Drexl, 2005)	graphic representation of all works, all operations in their strictly technological sequence
Heuristic methods (Thizy, 1993)	It is based on human experience and intuition. An experienced expert analyzes the distribution networks of the region, and unsuitable options are excluded from the task
Economic and mathematical programming methods (linear, nonlinear, dynamic (Hoover, 1948; Rios, Linfati, Morillo-Torres, Derpich & Gatica, 2021)	models of optimal development and placement of large production facilities or infrastructures in individual regions; the criterion of choice is to minimize total costs
The method of minimizing the total transportation costs for the transportation of goods (Crainic, 1998)	a mathematical linear programming problem of a special kind for determining the total costs between consumers and suppliers
AFS Clustering Method (axiomatic fuzzy set) (Wang & Liu, 2007)	splitting a set of objects into groups called clusters. There should be "similar" objects inside each group, and objects of different groups should be combined
K-means clustering theory (Wang, Chen & Zhang, 2022)	The initial data is randomly divided into clusters, and the center of mass for each cluster is iteratively recalculated. Next, using GIS technology, the coordinates of future logistics facilities are determined
GIS technologies (Yang, 2012; Racaci, Erol & Cubuk, 2022)	determining the optimal route and location of the object in real time

Table 1. Methods for selecting locations for logistics facilities

These studies solve the problem of identifying and locating logistics centers (LC). Nevertheless, without detracting from the advantages of each of the above methods, it should be noted that on the one hand, these methods require the use of very many indicators (the process of collection, processing and calculation is very laborious), many methods give approximate estimates, on the other hand, factors that take into account the binding of LC to specific geographical and territorial entities. In addition, they offer no mutual linking of the location of transport and logistics infrastructure on the territory of the country.

In the methodology of designing a distribution network (DND), an important element is the formation of its structure, the determination of the number of echelons and – for each echelon – the type, size, number and location of objects where the product is temporarily stored on the way to the customer (Ballou, 1977; Ambrosino & Scutella, 2005). The issue of designing a variety of distribution networks and choosing the optimal options from them consists of three stages: (Rushton & Saw, 1992; Mourits & Evers, 1996; Mangiaracina, Perego & Song, 2012): 1) generation of configuration options and preliminary evaluation; 2) quantitative evaluation of the created options; 3) detailed design and fine tuning.

The issues of designing a distribution and warehouse network for the food market are considered in the works of Romeijn et al. (2007), Kopylova and Rakhmangulov (2011), Romeijn et al. (2016), Geunes and Romeijn (2016), Popov and Miretskij (2019). In these works, at the initial stage, the attractiveness of the region was assessed on the basis of key socio-economic factors, the choice of a site for a distribution center (DC). At the second stage, an objective function was constructed that minimizes the total costs associated with the movement of goods from suppliers to end consumers using discrete optimization methods. The design of an agricultural DC (Gorlova, 2012) consists in studying the service area and choosing a site for its creation. Popov and Miretskij (2019) proposed two stages in the formation of the logistics infrastructure of the regions: determining the areas where it is advisable to place logistics infrastructure facilities; linking objects on the ground and determining their capacity and type of vehicles.

Eslamipoor (2023), a two-stage planning model has been proposed for the placement of product collection centers for a logistics center based on two models. The deterministic model determines the locations of product collection centers. The stochastic model determines potential product collection sites taking into account environmental and risk factors.

The choice of the LC location was carried out using multi-criteria decision-making methods based on the ranking of preferences for criteria, taking into account various scenarios in which criteria weights are used (Keleş & Pekkaya, 2023). The analysis showed the effectiveness of the combined use of the proposed methods.

The location of the LC affects the economic, social and environmental sustainability of urban logistics (Wang, Li & Lu, 2023). So, travel time, transportation costs, carbon emissions vary from the distance of the LC to the city center, which requires planning of transport routes. The choice of configuration and the process of designing a logistics network is influenced by the seasonality of the supply of perishable products (Orjuela-Castro, Orejuela-Cabrera & Adarme-Jaimes, 2021).

In these studies, the process of designing LC is carried out for specific goods or groups of goods, or LC with narrow functional purposes, while the distribution, storage and trade of food products has its own characteristics that need to be taken into account when determining their location, depending on their functional purpose of storage, distribution and trade facilities.

The models and methods used in practice to determine the optimal location of logistics infrastructure facilities provide an approximate solution. In addition, they do not provide for the process of forming interconnected warehouse and transport infrastructure in the region.

It can be concluded that there is no consensus in the literature on the stages of the design process, the selection and use of indicators that determine the locations of objects that should be optimally followed (prescriptive) when deciding on the selection of elements and the structure of storage or distribution. The beginning of the process and its sequence are also disputed.

The contribution of our research lies in the combined use of different methods at different stages of the study. The use of the method of standardization of indicators, cluster analysis, regression analysis, factor analysis, the center of gravity method, the method of ranking regions according to the criteria we selected for choosing the type of WDC allowed us to develop a more practical way to clarify the number of WDC, which allows us to take into account the factors of demand for WDC by region. This method, taking into account the proposed factors, will avoid the construction of unclaimed WDC.

Another feature of the proposed methodological approach is the construction of an interconnected transport and logistics infrastructure in the region.

In our opinion, the proposed option will significantly increase the efficiency of using transport and logistics infrastructure in the regions in accordance with their needs, taking into account socio-economic, geographical, environmental, production factors and requirements. Meeting these requirements will dramatically improve the process of creating and realizing the consumer value of WDC: systematically provide the customer with exactly what he wants, at the right time and place for him.

It should also be taken into account that the indicators of the placement of agricultural infrastructure for the storage, sale and trade of agri-food products have industry-specific features. WDC storage centers should be as close as possible to farmers in the areas of product growth and provide services for acceptance, storage and primary processing (washing, calibration, packaging, etc.) of products for subsequent sale. WDC trade centers should be located in the suburbs of regional centers and large cities, provide farmers, wholesale traders, distributors, importers, as well as buyers (retail chains, shops and markets, catering, etc.) with free access to trade infrastructure for the sale and purchase of products, temporary storage for the period of sale and other related services. WDC distribution centers should be located within cities or in the suburbs and are intended to provide logistics services for temporary storage and distribution of wholesale batches of products for the needs of retail facilities.

Thus, the distribution, storage and trade of agri-food products in the supply chains have their own characteristics that it should be taken into account when determining the location of their placement, depending on their functional purpose of storage, distribution and trade facilities.

Therefore, from the point of view of the optimality and efficiency of the functioning of the system of storage, distribution and trade of products, one requirement remains fair: the formation of a system of indicators that assesses all the activities of the agricultural sector, trade, warehouse and transport network included in its composition. This leads to the hypothesis, which is as follows.

H1: In the methodology of designing logistics infrastructure for agri-food products, taking into account the factor of differentiation of the territory depending on its specialization and local conditions leads to an increase in the validity of decisions taken when forming logistics infrastructure facilities, based on their functional purpose.

2.2. Factors Influencing the Formation and Placement of the Logistics Infrastructure of Wholesale Distribution Centers of Agro-Food Products

The analysis of the scientific literature has revealed a significant number of works in which mathematical methods and models or approaches to determining the location of a network of warehouses and transport and logistics terminals in the region are proposed.

The choice of location factors is a complex problem, the purpose of which is to make the location determination process more scientific, standardized and practical. Based on previous research, in terms of commodity movement conditions (Lu & Qin, 2019), laws and policies (Musolino et al., 2019), resource conditions (Ozmen & Aydogan, 2020), business environment (Sharma & Sungheetha, 2018), natural environment (Lei & Li, 2021), costs (Bienvenido-Huertas, Marín, Carretero-Ayuso & Rodriguez-Jimenez, 2021), information quality (Mieczyńska & Czarnowski, 2021) and others, a system for estimating the location of a logistics DC has been built.

Traditional models of location selection are based on a large number of assumptions that affect the choice of location and involve a rapid assessment of the proposed logistics infrastructure. But in practice, some factors of LC location are not certain, such as geographical factors, environmental factors, transportation time depending on traffic. Thus, an uncertain environment of the LC location is formed. When designing a complex logistics system, these uncertain factors should be taken into account.

The choice and placement of distribution networks of food products is influenced by many factors.

Systemic factors influencing the design of distribution networks, the choice of their location, are proposed (Mangiaracina, Song & Perego, 2015); the structure of product distribution, including the choice of the location of objects (Onstein, Tavasszy & van Damme, 2019); the efficiency of the DC (Kendi, Radjef & Hammoudi, 2020; Makinde, Mowandi, Ayomoh, Munyai & Nesamvuni, 2023); design logistics channel (Prataviera & Melacini, 2023).

Analyzing various socio-economic, social, and geographical factors in connection with the supply chain of agri-food products that affect the choice of location and placement of logistics facilities for storage, distribution, and trade of products, we divided them into five groups of factors: social, economic, regional (infrastructural and geographical), industrial, and environmental. The indicators used in each group of factors may differ in quantity and quality.

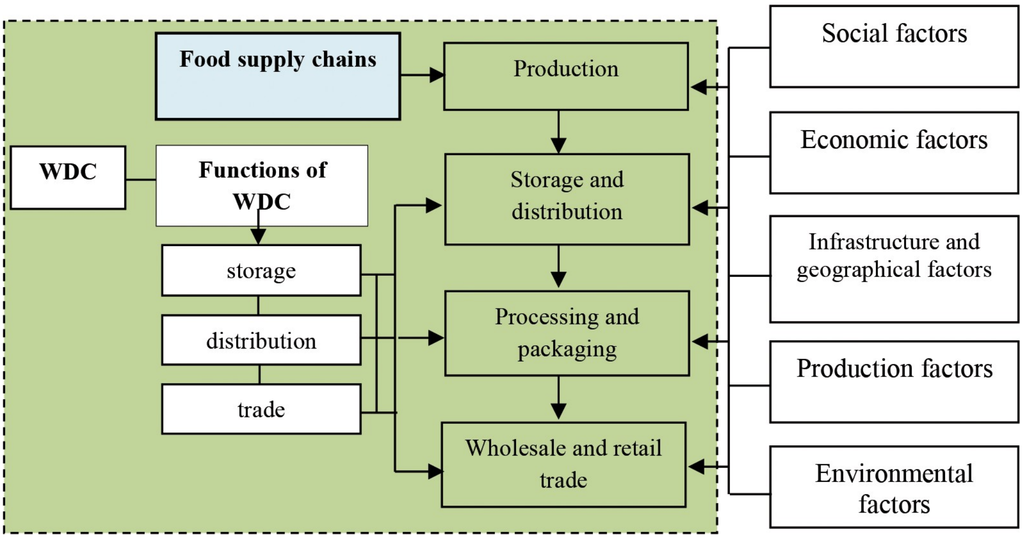

Figure 1. The relationship between the agri-food supply chain and the WDC and the main factors influencing the choice of location of the logistics infrastructure

To select indicators in each group of factors, an analysis of the most frequently used indicators was carried out.

Social factors. Indicators determining the state of the social environment in rural areas should be represented by the size of the population, the level of income and purchasing power of the population (Onstein et al., 2019; Popov & Miretskiy, 2019), the level of consumer satisfaction, and the growth of the aggregate level of consumption (Popov, Miretskij & Loginova, 2017). This necessity is designed to identify the degree of influence of social factors on the economic well-being of territories and determine the further direction of development. The use of indicators such as income per inhabitant, purchasing power in the districts, and the volume of food consumption by the population indicate the presence of a favorable social climate.

Economic factors. To assess the effectiveness of the functioning of the commodity distribution network (CDN) of districts, it is initially necessary to determine which districts form the effectiveness. In view of this, it is appropriate to include such indicators as the number of producers of agri-food products, gross agricultural output (Kuzman, Prdić & Dobraš, 2017), as well as volume indicators of all agricultural products produced in natural terms (Popov et al., 2017), the level of demand for products (Mangiaracina, 2015; Feng, Liu & Chen, 2022; Tingting, Shoufeng, Yuanyuan & Hongyu, 2022; Eslamipoor, 2023), the growth of agricultural organizations, the share of gross production of small businesses in total agricultural production.

The optimal placement could be determined by the cost of selling the final product (Onstein et al., 2019). Efficiency could be determined through the use of the following indicators: profit per producer, profitability of production and sales of products (Wang et al., 2022), the proportion of unprofitable enterprises included in the CDN.

Infrastructural and geographical factors characterize the potential and ability to process, produce and sell products through the network. Their indicators are: the number of enterprises and workshops for the processing and production of agri-food products, the availability of storage facilities, retail space, the number of retail chains, warehouse space, the length of highways, the distance from the district center to the regional center by road, travel time by motor transport, availability of engineering and telecommunications infrastructure, density of roads and railways (Wiederer & Straube, 2019; Banerjee, Duflo & Qian, 2020; Popov & Miretskij, 2019; Nekrasenko, Pittman & Doroshenko, 2019).

Production factors include volume indicators of production and sales of agricultural products (Feng et al., 2022; Tingting et al., 2022);

Environmental factors (Uyanik, Tuzkaya, Kalender & Oguztimur, 2020; Wang. et al., 2023) are characterized by the volume of solid waste during product sales, emissions of pollutants into the atmosphere.

Such allocation is associated with the presence of the corresponding element in the structure of the system. Each of these factors ultimately affects the efficiency and competitiveness of the DC, reliability, sustainability and quality of service.

It should be noted that the choice of the location of logistics facilities depends not only on the above-mentioned factors, but also on their functional purpose, which were not considered in these works.

From the point of view of sustainability, along with economic factors, environmental and social aspects, the geographical and transport capabilities of the region are also important that are essential criteria for choosing the location of the LC (Popov & Miretskij, 2019), which was taken into account in our research.

3. Research methodology and data

Currently, there is an acute shortage of high-quality storage infrastructure for agricultural products in Kazakhstan, which increases the costs of the agricultural sector from year to year. The bulk of the gross harvest of perishable products and potatoes is carried out in the southern regions (Almaty, Turkestan, Zhambyl regions) and in the east of the country (East Kazakhstan region), potatoes – in the northern regions of the country (Pavlodar, Karaganda, North Kazakhstan, Akmola regions).

At the beginning of 2023, the capacity of perishable fruits and vegetables (vegetable and fruit storage) amounted to 1.95 million tons. The storage and distribution capacity of 5 WDC units amounted to 65 thousand tons, the capacity of 8 TLC units - 72 thousand tons. The shortage of storage capacities for fruit and vegetable products amounted to 35.5%.

The lack of storage infrastructure across regions is also uneven. In some regions, the warehouse infrastructure for the storage of fruits and vegetables and foodstuffs is insufficiently developed. The largest deficit (over 500 thousand tons in each region) is observed in Almaty, Zhambyl, Turkestan, North Kazakhstan, Turkestan regions and Shymkent. A deficit in the range of 50-100 thousand tons is observed in Atyrau, Aktobe, East Kazakhstan, West Kazakhstan, Mangystau, Karaganda, Kostanay, North Kazakhstan regions, as well as in Astana.

Agricultural producers are experiencing serious difficulties with the sale of manufactured products. Thus, 45% of agricultural products are sold through wholesale and retail food markets; 5-10% through direct deliveries by farmers to the market; 5-10% through TLC and WDC; 35-40% of small farmers sell their products directly from their farm to merchants; through electronic platform platforms - about 1%.

The largest share in the total volume of retail trade of agri-food products of the republic in 2023 falls on the cities of Almaty (32.2%) and Astana (12.9%), as well as Karaganda (8%) and East Kazakhstan (6%) regions.

To solve the problems of product sales, direct access to retail facilities, and the lack of vegetable storages, the issue of building a WDC for the storage, distribution and trade of агропродовольственной products has become acute.

However, this plan does not consider methodological approaches and does not provide recommendations for the development of the logistics infrastructure of the regions. This determined the problem posed in the framework of this article, the main idea of which is to develop a methodological approach to solving the problem of effective placement of logistics infrastructure facilities in the regions of Kazakhstan.

The construction of the WDC model of agri-food products was carried out in a sequence including the following stages.

Stage 1: Identification of potential WDC locations

Step 1. Analysis and selection of indicators that determine the places of choice and placement

Step.2. Standardization of indicators.

Step.3. Determination of weighting coefficients of indicators

Step.4. Factor analysis of indicators and identification of the most important factors

Step.5. Cluster analysis to identify the territorial distribution of agricultural production and the formation of clusters

Step 6. Calculation of ratings and differentiation of districts according to the level of attractiveness of logistics infrastructure placement

Stage 2. Clarification of potential locations

Step.7. Determining the range of the logistics infrastructure

Step.8. Identification of potential locations

Stage 3. Defining the service area

Step.9. Defining the WDC service area

Step.10. Economic interpretation of the results obtained

Stage 1. Identification of Potential WDC Locations

At this stage, the potential locations of the DC have been identified, based on the selected criteria, by analyzing the production of agricultural products in each district and urban agglomerations, as well as the existing scheme of transport routes, the placement of logistics and transport (rail and road transport) infrastructure.

The selection criteria for the placement and determination of the need for logistics infrastructure facilities was carried out using the example of the WDC in the following sequence:

1) *Analysis and selection of indicators that determine the places of selection and placement according to statistical data for 2019-2021.*

Based on theoretical analysis, and on the purpose of the study to characterize the WDC, we selected 40 indicators from various literary sources that directly or indirectly affect the choice of location of logistics facilities according to statistical data from the Bureau of National Statistics of the Republic of Kazakhstan (BNS RK). The calculation of the correlation matrix for the variables involved in the analysis made it possible to exclude dependent (correlating) parameters and select the most significant 19 factors. Of these, 15 indicators are available on the website of the BNS RK (https://stat.gov.kz/en/), and the remaining 3 indicators (X9, X10 and X11) are selected based on studying the online map (https://yandex.kz/maps/ru/) of transport routes in all regions of Kazakhstan.

The significance of the indicators was assessed and insignificant factors were excluded. Table A1, Appendix A, presents the results of the evaluation of significant correlation indicators by p-value: $p<0.05$; $p<0.01$; $p<0.001$. Table 2 presents the results of the evaluation of significant indicators.

2) *Bringing the indicators to a standard form, due to the disparity of their measurement.*

Standardization of indicators in order to bring unequal values of indicators to homogeneous values, which is necessary for comparing indicators with different units of measurement. The dimension of the matrix is defined as n*m, where n is the number of observation objects or 204 administrative-territorial areas, and m is the number of elementary features (in this case, 19 indicators).

To do this, a transition was made from the matrix of initial data (x) of dimension (204 x 19) to the matrix of standardized indicators (z) of dimension (204 x 19). When recalculating all elements of the matrix into a standardized form , a formula of the following form was used:

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{\sigma_j},$$

where *xij* – *i*-element of *j*-observation;

$x\ j$ – is the average value of the *i*-elements of the *j*-observation;

σj – is the average deviation of the *i*-elements-observation.

3) *Determination of the weighting coefficients of indicators that allow determining their significance for the formation of the rating. These actions were carried out using the SPSS 21.0 program.*

N	Factors	Unit of measure	Full name of Variables	Unit of measurement	Description of the indicator
1	Social	X1	Population, pers.	person	Average annual population
		X2	Per capita income, thousand tenge	thousand tenge	The ratio of the annual amount of monetary income for the number of months and for the average annual population
2	Economic	X3	Number of agricultural producers, units	unit	Shows the concentration level of product manufacturers
		X4	The volume of cargo transportation of agri-food products	ton	Characterizes the volume of agricultural transportation of food products in the regions
		X5	The volume of agricultural production, million tenge	million tenge	Determines the volume of production
		X6	Retail and wholesale turnover of food products, mln tenge	million tenge	Determines the volume of retail and wholesale sales of food products
		X7	Investments in fixed assets of logistics infrastructure (trade, transport and warehousing, communications), thousand tenge	million tenge	Investments in infrastructure in the regions
3	Regional	X8	Availability (availability) of storage capacities for agricultural products (yes -1, average - 0.5; no - 0)	yes - 1, no-0	Physical availability of capacities. It is determined based on statistical data for each region
		X9	Railway accessibility (yes -1, no-0)	no - 0, yes - 1, partially – 0.5	Shows the level of availability of the railway network. It is determined based on the map of the transport roads of the regions https://yandex.kz/maps/ru/
		X10	Average time of transportation by motor transport, hour	hour	An indicator that determines the speed of delivery of products to their destination. The time of transportation from the district center to the regional center. It is determined based on the online map https://yandex.kz/maps/ru/
		X11	Distance from the district center to the regional center by car, km	km	The distance of transportation is determined by the route map https://yandex.kz/maps/ru/
4	Production	X12	Production and sale of meat and milk, tons	tons	The volume of sales in each region
		X13	Production and sale of vegetables and melons, t	tons	
		X14	Production and sale of fruits and berries, tons	tons	
		X15	Grain production, thousand tons	thousand tons	
		X16	The volume of production and sales of eggs, thousand pieces	thousand pieces	
		X17	Volume of production and sales of potatoes, t	ton	

N	Factors	Unit of measure	Full name of Variables	Unit of measurement	Description of the indicator
5	Environmental	X18	The volume of solid waste in the sale of products, t	ton	The amount of waste in the sale of products based on statistics https://stat.gov.kz
		X19	Emissions of pollutants into the atmosphere	ton	Emissions to the atmosphere are determined on the basis of statistics https://stat.gov.kz

Table 2. Variables after exclusion of correlating parameters

4) *Conducting factor analysis in order to identify the most important factors.*

Factor analysis made it possible to form, reduce the number of variables and group them. The analysis allows us to construct matrices of values of F_{ji} factors for all 204 territories (districts, urban agglomeration), which will be used to calculate the rating of the location of logistics facilities obtained using the SPSS 21.0 program;

5) *Conducting cluster analysis based on k-means, forming clusters.*

In this regard, to study the territorial distribution of agricultural production, the districts of Kazakhstan were divided into groups using the cluster analysis method.

Statistical data for 2019-2021 were used for cluster analysis, processing was performed using the SPSS 21.0 program;

6) *Calculation of ratings and determination of the integral indicator, differentiation of districts by the level of rating value.*

The calculation of the rating itself was carried out according to the formula:

$$R_i = \frac{\sum_{i=1}^{n} F_{ji}}{\sum_{i=1}^{n} b_{nji}},$$

where ***Ri*** is an integral indicator of the attractiveness of the location of the WDC *i*-region;

F*ji* – is the value of the *j*-th factor of the *i*-th region; *n* – is the number of factors.

b_{nji} – is the weighting coefficient of the n index of *j* factor of the *i* region.

The integral indicator obtained during the calculation was ranked from the highest number to the lowest. A high rating score indicates the potential attractiveness of placement in the region.

Stage 2. Clarification of Potential Placements

At the second stage, the potential locations of integrated logistics centers in the regions were adjusted using the center of gravity method – based on the areas of concentration of agricultural production, transport accessibility and other technical and economic parameters consolidated in one place;

7) *Determination of the radius of action of the trading infrastructure.*

At this stage, the calculation of the radius of action of the WDC was carried out using the "center of gravity" method (Geoffrion et al., 1995).

8) *Determination of potential locations of the WDC.*

Determination of potential placements based on factor analysis of the matrix of F_i values. The average F_i value of each of the 204 territories was determined. The selection of the types of WDC was carried out according to separately grouped factor loads F_i, which affect the choice of storage, marketing and trade, respectively. Their average value for each district/city was determined. The potential location of objects was determined if their weight-adjusted average value of F_i is greater than one.

Stage 3. Defining the Service Area

9) *At the third stage, WDC service areas (groups of agricultural areas) were identified in accordance with potential locations on the territory of districts and urban agglomerations.*

10) *Economic interpretation of the results obtained.*

4.Results

4.1. Formation and Placement of Wholesale Distribution Centers of Agro-Industrial Products

The construction of the WDC agri-food product placement model was carried out in the following sequence.

Stage 1. Identification of Potential WDC Locations

The analysis of the results will be carried out in stages, according to the above sequence.

1) *Analysis of factors influencing the choice and placement of logistics infrastructure.*

Descriptive statistics of the selected indicators are presented in Table 3.

Indicators	Mean	Standard Deviation	median	Kurtosis	Skewness	Jarque-Bera test	p-value*
X1	93665.9	195561.2	39478.5	55.31	6.67	0.95	0.41
X2	125394.7	38483.4	119790.0	2.32	1.29	1.12	0.24
X3	9267.5	8627.2	6743.0	6.67	2.26	1.35	0.31
X4	233.1	224.4	172.9	5.34	1.82	2.17	0.51
X5	35791.7	25323.2	32653.5	1.87	1.09	1.85	0.05
X6	43085.7	291685.9	1759.4	167.57	12.52	0.87	0.14
X7	3797.8	4533.7	2011.1	8.55	2.36	0.97	0.41
X8	33280.7	60580.9	5825.0	7.95	2.68	1.23	0.15
X9	17.6	26.6	6.0	6.18	2.31	2.47	0.52
X10	3.3	2.0	2.9	0.22	0.75	1.84	0.50
X11	216,0	147.0	195.0	0.03	0.64	0.78	0.34
X12	215.8	150.3	194.8	0.00	0.63	2.68	0.45
X13	36945.1	92134.7	6184.0	27.85	4.82	2.74	0.38
X14	2994.5	10905.2	150.4	49.13	6.50	0.81	0.27
X15	80521.7	107472.3	30717.3	2.26	1.64	1.21	0.31
X16	24655.9	59291.9	6209.3	13.69	3.69	0.87	0.12
X17	19762.7	26773.7	8121.2	5.61	2.24	2.37	0.49
X18	3369.9	3094.9	2435.0	49.46	6.10	1.41	0.34
X19	12983.7	44868.1	2133.2	31.38	5.47	0.97	0.24

Note: *valid at $p<0.05$

Table 3. Descriptive statistics of the selected indicators (n=204, m=19) (Review of statistical data of the Republic of Kazakhstan for 2017-2021)

The coefficient of asymmetry and kurtosis are close to zero, which makes it possible to approach the normal distribution. The hypothesis of normality can be accepted on the basis of Harker's statistics at the level of 5%. Thus, all the parameters studied in Table 2 can be used as methods of parametric statistics for further analysis.

2) *Standardization of indicators was carried out for a matrix of 204 x 19 indicators according to the above formula.*

3) *Determination of the weighting coefficients of the indicators. The use of weighting coefficients allowed us to determine that the selected indicators are significant, since the coefficient of variance is 93.2%* (Table 4).

Indicators	Weight coefficients
Population (X1)	-0,9784
Per capita income (X2)	0,5314
Number of agricultural producers (X3)	-0,9529
The volume of transportation of goods of agricultural products by road (X4)	-0,8194
Sales volume of agricultural products (X5)	0,9930
The volume of wholesale and retail turnover of food products (X6)	0,4546
Investments in fixed assets of logistics infrastructure (X7)	0,4387
Availability (availability) of storage capacities for agricultural products (X8)	0,8754
Railway accessibility* (X9)	0,6654
Time of transporting products by road ** (X10)	-0,8427
Distance from the center of the district to the DC in the regional center** (X11)	-0,7123
Production of agricultural products in physical terms (X12-X17)	0,9508
The volume of solid waste in the sale of products (X18)	-0,6412
Air emissions of pollutants	-0,4517
Total variance	2,2305
Share of total variance	0,9327

Notes: *determined based on the online map of the railways of the Republic of Kazakhstan https://nkregion.kz/info/maps/63-railways.html; **defined based on the map https://www.google.kz/maps.

Table 4. Weighting coefficients of indicators affecting the choice of placement (Overview of statistical data of Kazakhstan)

4) *Factor analysis. In the first block of indicators, the main component explained 27.38% of the xj variation, in the second block – 20.17% of the variation and 15.95; 11.39; 6.76% of the variation, respectively, by components* (Table 5).

Initial eigenvalues	Component				
	1	2	3	4	5
Total	4,108	3,026	2,393	1,709	1,015
% variance	27,387	20,174	15,954	11,393	6,767
Total %	27,387	47,561	63,516	74,908	81,675

Table 5. The explained cumulative variance (the method of the main components) (Calculation Result using SPSS)

The use of this method made it possible to identify the main components in each of the blocks of indicators characterizing the efficiency of the logistics infrastructure by "compressing" variables (Table 6).

According to the factor analysis, the following results are derived: the Cronbach's alpha is 0.81 – the selected variables are acceptable. Kaiser-Meyer-Olkin (KMO) equal to 0.73 is satisfactory.

A matrix of values for five groups of factors was obtained: F1, F2, F3, F4 and F5 for each of the 204 territories.

Indicators	Average component values for 2017-2021				
	F1	F2	F3	F4	F5
X1	0.058	**0.826**	-0.087	-0.193	0.014
X2	-0.346	**0.753**	0.371	0.052	0.035
X3	**0.856**	-0.027	-0.048	-0.074	0.034
X4	**0.854**	-0.057	0.315	0.003	0.196
X5	**0.835**	-0.085	0.280	0.043	0.378
X6	-0.076	**0.972**	-0.047	-0.073	-0.013
X7	-0.455	**0.954**	-0.001	-0.008	0.014
X8	-0.083	-0.014	**0.924**	-0.043	-0.095
X9	0.002	-0.026	**0.922**	-0.077	-0.081
X10	-0.022	-0.088	-0.049	**0.979**	-0.088
X11	-0.007	-0.149	-0.036	**0.976**	-0.077
X12	**0.739**	-0.081	0.010	0.164	0.316
X13	**0.728**	0.036	-0.158	0.011	-0.166
X14	**0.700**	0.050	-0.044	-0.139	-0.247
X15	**0.726**	-0.106	0.204	0.044	0.320
X16	**0.828**	0.040	-0.012	-0.163	0.062
X17	**0.698**	-0.013	0.010	-0.114	0.372
X18	0.024	0.217	-0.171	0.008	**0.854**
X19	0.173	0.018	0.719	0.131	0.042

Note: Factor extraction method: Principal component method. Rotation method: Varimax with Kaiser normalization. The rotation converged in 5 iterations

Table 6. Factor loads by main components for choosing the location of the logistics infrastructure of storage, sales and trade

In the matrix of principal components, the average value of the weighting coefficients was determined by the following variables: F1 (X3, X4, X5, X12, X13, X14, X15, X16, X17), F2 (X1, X2, X6, X7), F3 (X8, X9, X19), F4 (X10, X11), F5 (X18).

Thus, the following factors are identified: factor F1 – production, factors F2 – trade, factor F3 – transport and warehouse availability, factor F4 – geographical (time and distance), factor F5 – environmental.

The contents of factors F1, F3 and F5 determine the summary characteristics of product storage in the region: the number of producers of products, the volume of production and cargo transportation, production volumes in kind, solid waste and emissions of pollutants into the atmosphere.

The content of factors F2 and F4 characterize the distribution and trade opportunities in the region: the number and per capita income of the region, the volume of trade and investment in infrastructure, the time and distance of cargo transportation in the region.

The content of the F2 factor characterizes trade opportunities in the region: the number and per capita income of the region, the volume of trade and investment in infrastructure.

The relationship between variables and the main component is represented by the following dependency:

F1=0.856*X3+0.854*X4+ 0.835*X5 + 0.739*X12+0.728*X13 +0.70*X14 +0.726*X15 +0.828*X16 + 0.698*X17

F2=0.826*X1+0.753*X2+0.972*X6+0.954*X7

F3=0.924*X8+0.922*X9+0.719*X19

F4=0.979*X10 +0.976*X11

F5=0.854*X18

The solution of the equation of the main components was the construction of a matrix of values of factors F1, F2, F3, F4 and F5 for 204 research objects, which became the basis for cluster analysis in order to differentiate regions by the level of readiness for the placement of logistics infrastructure.

5) *Conducting cluster analysis based on k-means, forming clusters.*

In order to determine the significance of the main components that cause clustering, the F-criterion is used. The greater its value, the greater the contribution of the main component to clustering (Table 7).

	Main component				
	F1	F2	F3	F4	F5
F-test value	51.39	58.15	37.69	24.08	8.77

Table 7. Values of the F-criterion of the main components for 2017-2021
(Obtained based on the calculation of F1- F5 models according to Table 6)

The main variables determining the grouping were those related to trade factors, production factors, transport and warehouse availability. Clustering is also determined by the results of variables of social, industrial and least of all environmental factors of the main component. This reflects the state policy of developing the trade infrastructure of the agro-food market in rural areas and districts.

Of all the available methods of cluster analysis, the most popular k-means method was chosen. From the conducted intelligence analysis, it is optimal to divide the regions into six clusters, which include administrative-territorial areas that differ qualitatively from each other.

Of all the available methods for conducting cluster analysis, the most popular k-means method was chosen. From the conducted intelligence analysis, the optimal division of the regions into six clusters, which include administrative-territorial areas that are qualitatively different from each other, was optimal.

The affiliation of territories to clusters has the following features.

The first cluster includes 7 districts that have developed diversified agriculture with the production of crop products. It produces 5% of the volume of agricultural products (in value terms), 11% of potatoes, 36% of eggs, 5.1% of milk, 4.1% of meat (in real terms).

The second cluster includes areas that have a more animal husbandry orientation, as well as developed crop, potato and vegetable growing. This cluster includes 159 districts of all regions. It produces 67.0% of Kazakhstan's agricultural products (in value terms), of which meat - 79.7%, milk - 71.8%, potatoes - 66.2%, cereals - 55.5%, vegetables - 49.9%, fruits and berries - 54.9% (in physical terms).

The third, fifth and sixth clusters form districts and urban districts with a low level of agricultural development with a share of 2.0, 4.7 and 2.3% of output, respectively.

In the third cluster there is one territory (Enbekshikazakh district of Almaty region), where fruits and berries predominate -16.9%, vegetables and melons - 4.1%.

The fourth cluster includes areas with a pronounced development of the crop industry, especially the production of soybeans and cereals (37.8%) and potato (16.3%), as well as animal husbandry of meat and dairy: meat - 10.4%, milk - 15.8%, eggs - 7.3%, fruits and berries - 6.4%. It produces 18.9% of Kazakhstan's agricultural products (in value terms).

In the fifth cluster, crop production is developed: fruits and berries -17.9% of all clusters, vegetables and melons - 22.0%, potatoes - 2.9%, milk - 3.5%, meat - 2.6%, eggs - 3.8%. The share of agricultural production in value terms is 4.7%. This cluster includes areas of the southern regions of Kazakhstan, producing mainly vegetables and fruits.

In the sixth cluster, vegetable growing and melons are also developed - 18.4% of all clusters. The share of output in value terms is 2.3%. This cluster includes the southern regions engaged in the production of melons.

The cluster results obtained are summarized by the production and regional potential characteristics of the infrastructure in the final Table 8.

CN	ND	Characteristics of the production potential	Potential Infrastructure Characteristics
1	7	Crop production (potatoes) and cereals, meat and milk, eggs	grain and potato storage facilities, refrigeration equipment for milk and meat of animals and birds
2	159	Dairy livestock breeding, beekeeping, plant growing (soybeans, oats, corn, buckwheat), potato growing, vegetable growing	grain and potato storages, refrigeration equipment for milk and meat of animals and birds, fruit and berry storages, vegetable storages
3	1	Fruits and berries, vegetables and melons, potatoes, meat, milk	potato storages, fruit and berry storages, vegetable storages, refrigeration equipment for milk and animal meat
4	27	Animal husbandry of meat and dairy direction, poultry farming, plant growing (soybean, wheat, oats, corn, buckwheat), potato growing, vegetable growing	grain and potato storage facilities, refrigeration equipment for milk and meat of animals and birds, fruit and berry storage facilities
5	5	Plant growing (soybeans, oats, corn, buckwheat), potato growing, vegetable growing, fruits and berries, poultry farming	large fruit and berry storages, vegetable storages, potato storages, as well as refrigeration equipment for milk and meat of animals and birds
6	2	Vegetable growing and gourds	large vegetable stores, as well as fruit and berry stores, refrigeration equipment for milk and animal meat

Note: CN- cluster number; Number of districts

Table 8. Characteristics of logistics infrastructure depending on the selected clusters of the Republic of Kazakhstan

Results of cluster classification:

1 cluster - grain and potato storage, refrigeration equipment for milk and meat of animals and birds. The development of the cluster will require elevators, potato storage facilities, refrigeration equipment for storing dairy and meat products.

2 cluster - grain and potato storages, refrigeration equipment for milk and meat of animals and birds, fruit and berry storages, vegetable storages.

3 cluster – potato storages, fruit and berry storages, vegetable storages, refrigeration equipment for milk and animal meat. This cluster needs a crop production infrastructure.

4 cluster - grain and potato storage, refrigeration equipment for milk and meat of animals and birds, fruit and berry storage.

5 cluster – large fruit and berry storages, vegetable storages, potato storages, as well as refrigeration equipment for milk and meat of animals and birds. Districts need universal WDC for storage.

6 cluster – large vegetable storages, as well as fruit and berry storages, refrigeration equipment for milk and animal meat. These areas require the development of infrastructure for the storage of melons and vegetables.

The results of the classification allow us to conclude that it is necessary to place universal storage for agricultural products on the territory of districts included in 1-2, 4-5 clusters.

2 and 3 clusters - granaries, 1, 2 and 4 clusters - potato storage, 1, 2 and 4 clusters – refrigeration equipment for storing animal meat and poultry, 2 and 4 clusters - refrigeration equipment for milk, 2, 3, 4 and 5 clusters - fruit and berry storage, 2, 3, 5 and 6 clusters are vegetable storages. These districts have significant production potential and produce 95.7% of agricultural products of the Republic of Kazakhstan.

Clusters 3 and 6 are dominated by fruits and berries (16.9%), vegetables and melons (18.4%) with a low proportion of the population, therefore these areas should be provided with specialized vegetable and fruit storage facilities.

6) *Calculation of the integral indicator, differentiation of districts by the level of rating value.*

The integral rating of districts/cities was determined by the average values of grouped factors F1-F5, adjusted for their weights.

These groups of factors F1, F2, F3, F4 and F5 were the basis for choosing the types of WDC. The average values of the criteria F1, F2, and F3 - for the selection of the storage WDC, the average values of F2 and F4 – for the selection of the distribution WDC and F3 – for the selection of the trading WDC (Table B1, Appendix B).

Stage 2. Clarification of Potential Locations of Logistics Integrated Distribution Centers

At this stage, the potential locations of logistics integrated DC have been clarified, taking into account the optimal location, minimization of transportation costs and product losses.

7) *Determining the range of the WDC*

To clarify the range of the WDC, the "center of gravity" method was used, the essence of which is to find the location of the WDC in such a way that the distance from the agricultural producer bringing his products to the WDC and from the WDC to the consumer was minimal. The calculation of the center of gravity for choosing the radius of action of the WDC is given in Table B.1. The center of gravity for each region is in the range from 142.2 km (Atyrau region) to 424.2 km (Akmola region), this indicates a large spread (3 times difference) of potential WDC from potential consumers in regional centers. This circumstance leads to an increase in transportation costs and an increase in product losses during transportation, which is also not a rational approach. In this regard, we used a differentiated approach when choosing the location of the WDC. For example, the service of regions that are located within a large service radius (for example, 424.2 km, Akmola) could be transferred to Astana, located closer (within a radius of up to 150 km), and part of the districts could be transferred to Pavlodar (a radius of about 250 km). Thus, it is possible to optimize the service areas of the districts by using a rational location of the WDC and reducing costs.

8) *Identification of potential WDC locations*

Potential locations and the calculation of the center of gravity for choosing the range of WDC storage are presented in the appendix (Table B.2).

The calculations made it possible to clarify the degree of influence of the selected points of WDC formation on nearby territories and create a circle of consumers of WDC services.

The calculation of the ratings of the subjects of the region according to F1-F5 allowed us to identify the main territories where the placement of the WDC is most favorable. To form a large WDC with subsequent inclusion in the national network, it is proposed to use the territories of nearby cities of republican significance: Almaty, Astana (WDC of trade and distribution), Shymkent (WDC of trade), as well as a large regional center of Aktobe and Karaganda (WDC of trade).

Also, distribution centers should be placed closer to large regional centers (Alakol, Zhezkazgan, Beineu, Ayaguz, Kurchum) with high ratings (according to F2 and F4); storage centers - in places of concentration of agricultural production and processing of products – in rural areas with high ratings or in nearby urban agglomerations according to F1, F3 and F5.

In total, there were 25 WDC, of which: WDC of storage - 13 units, WDC of distribution - 7 units, WDC of trade - 5 units.

Stage 3. Defining the WDC Service Area

At the third stage, the WDC service areas and the advantages of their use are defined.

9) *The WDC service areas are defined (groups of agricultural areas) in accordance with potential locations on the territory of districts and urban agglomerations.*

The logistics network of agricultural DC in the Republic of Kazakhstan will be presented as follows:

1. Agricultural DC should serve from 142-kilometer zone (Atyrau) to 424 kilometer zone (Akmola), based on the distance of the districts to the regional center, where it is planned to create an WDC or wholesale market. At the same time, when determining the service area of each WDC, it is necessary to take into account the results obtained for the centers of gravity, which are determined strictly for each region (area) separately. To do this, you can use online maps of the area and based on this, areas that are located far from the consumer center need to select a WDC located nearby, but belonging to another area.
2. Storage centers in the districts (13 centers), in addition to performing basic functions, should become a transshipment base for large districts of the regions. The flows of agricultural products and raw materials can be directed to processing enterprises in urban agglomerations.

10) *Economic interpretation of the results obtained.*

As a result of the formation and further functioning of agricultural enterprises in Kazakhstan, a more efficient system of distribution of agricultural raw materials and food on the basis of an organized market will be created, and the haphazard activities of various intermediaries will be gradually streamlined. The implementation of the agricultural enterprises development system will allow, on the basis of economic incentives for agricultural producers, to increase production volumes and improve product quality, fill the country's food market with domestically produced goods and improve the socio-economic situation in the agro-industrial complex of the region as a whole. The solution of the above tasks will contribute to the realization of a multiplicative (multiplying) effect: reducing losses of producers' products, increasing the inflow of tax revenues, creating new jobs, reducing public spending on the purchase of socially significant food products.

Preliminary calculations show that the creation of a wholesale food market system in Kazakhstan is advisable, both in terms of economic efficiency and social significance.

5. Discussion

The choice of location and its design depend on many factors. The criteria for the selection and placement of regional agricultural infrastructures for the storage and sale of agri-food products are substantiated and proposed. The criteria influencing the choice of the location and distribution of food products, depending on the factors of functioning and operation, differ for storages and warehouses, wholesale food markets, WDC, shopping centers, logistics RC. At the same time, some criteria – socio-economic, infrastructural, regional - correspond to the indicators recommended in the works Mangiaracina et al. (2012), Kopylova and Rakhmangulov (2011), Popov et al. (2017), Popov and Miretskij (2019).

A methodological approach is proposed to determine the potential placement location and their number depending on the integrated matrix indicators, which is the main difference from existing methodological approaches. This approach allows you to quickly and effectively determine the needs based on the purpose of the object, increases the efficiency of the selection and placement of logistics infrastructure.

Optimal placement and effective functioning of trade and sales infrastructure should be based on a differentiated approach to agricultural producers in order to implement targeted agricultural and trade policy and state support, including the development of storage, marketing and trade infrastructure. For this purpose, it is advisable to carry out the typification of territories with similar industrial, infrastructural and socio-economic conditions, which increases the validity of decisions taken when forming logistics infrastructure facilities. This statement is consistent with studies (Popov et al., 2017; Popov & Miretskij, 2019; Rios et al., 2021; Wang et al., 2022; Eslamipoor, 2023)

The typification is based on the calculation of an integral indicator that allows identifying territories that are unfavorable for agricultural production.

The areas identified as the most favorable for the development of crop production (potatoes) and cereals, meat and milk, eggs (clusters 1, 3, 5 and 6) should also be subject to special conditions, consisting not only in increased state assistance in the construction of specialized storage facilities, such as grain and potato storages, fruit- and berry storages, vegetable storages, refrigeration equipment, but also in the development of program documents for these areas that develop an entrepreneurial initiative taking into account the increased risks of agricultural production, as well as special conditions for the interaction of these areas with retail chains. This may concern fast and uninterrupted delivery throughout the year, financing by trade networks of economic entities for the cultivation of agricultural products.

The areas identified as the most favorable for the development of dairy farming, beekeeping, and crop production (clusters 2 and 4) should also include conditions for the construction and development of universal agricultural DC. In the areas included in these clusters, conditions should be created for the joint use of trade and sales infrastructure due to their large number (159 territories out of 204).

The analysis using this technique made it possible to divide the studied areas into 6 clusters, depending on the specialization of production and marketing infrastructure of agricultural products.

The rating score, determined on the basis of an integral indicator, identified the leading regions.

The implementation of the conceptual provisions of the mechanism of functioning of the agri-food market requires a change in traditional approaches to assessing its selection and placement. At the regional level, it is advisable to measure the criteria of optimality and efficiency of placement using an integral multiplicative indicator, as in the works (Mourits & Evers, 1996; Kopylova & Rakhmangulov 2011; Herlina et al., 2022).

The results of the classification allow us to conclude that it is necessary to place universal agricultural plants on the territory of the districts included in clusters 1, 2, 4, 5.

In the areas included in clusters 3 and 6, where the production of fruits and berries (16.9%), vegetables and melons (18.4%) prevails has a low proportion of the population, so it is necessary to provide specialized vegetable and fruit WDC.

3. The methodology for choosing the location of the WDC has been determined, including a territory rating based on factor analysis and the "center of gravity" method, which made it possible to allocate 13 WDC storage, 7 WDC distribution and 5 WDC trade on the territory of Kazakhstan. Our research is consistent with the research conducted in the papers (Popov & Miretskij, 2019; Makinde et al., 2023), with the only difference that our research took into account the contribution of each of the factors for each of the 204 research objects.

The originality of the methodology lies in the fact that it makes it possible to simultaneously take into account the locations of WDC, depending on their purpose (for storage, distribution and trade) and relevant factors.

The proposed methodology for selecting locations for transport and logistics capacities, based on the consideration of identified socio-economic and infrastructural factors, could be recommended when drawing up state programs for the development of logistics in the regions, as well as large companies when deciding to invest in the logistics industry.

The methodology for choosing WDC locations for storage, distribution and trade could be recommended for state planning of the development of the logistics infrastructure of the country's regions, as well as for large companies when deciding to invest in the logistics industry.

The calculation method consists in forming a system of indicators characterizing the optimal placement and efficiency of using elements of the logistics infrastructure, determining indices indicating their change in the time interval, calculating an aggregated indicator representing the average value of the indices.

The calculation according to the presented methodology using statistical data and data from the online map of regional transport networks allowed us to identify potential regions most suitable for the construction of WDC storage, WDC distribution and WDC trade in various regions of Kazakhstan. For example, according to the F3 factor, we selected 5 trade WDC in major cities of Kazakhstan: Almaty, Astana, Shymkent, Aktobe and Karaganda.

Based on the calculation results obtained, the number, potential locations, as well as service areas of storage WDC, distribution WDC, trade WDC are determined. The results obtained are consistent with the activities of the Government of the Republic of Kazakhstan on the creation of a commodity distribution system within which it is planned to create vegetable storages and a network of WDC, where the construction of 24 WDC for 273 billion tenge is envisaged (Trade development concept, 2020).

6. Conclusions and Future Research

The article examines the problem of creating a logistics infrastructure for the distribution, storage and trade of agricultural products. To solve it, the authors proposed a methodological approach that allowed forming a model and determining the location of key logistics infrastructure facilities.

A set of indicators of socio-economic, regional, industrial and environmental factors of the region served as a key parameter in solving the problem of effective placement of the warehouse network.

The methodology for selecting indicators and placing logistics infrastructure facilities was carried out on the basis of calculating an integral indicator, determining the effective location, service areas and their number in the regions.

The proposed methodological approach consists of three stages. At the first stage, territories (districts and urban agglomerations) are determined where it is advisable to place key logistics infrastructure facilities. To solve this problem, the authors propose to use an approach based on the use of the combined potential of two-stage cluster, factor analysis and the rating method. The consistency of the results of the joint use of these methods is demonstrated by the authors on the example of Kazakhstan. At the second stage, the geographical linking of logistics infrastructure facilities on the ground is carried out. To do this, the center of gravity method is used to determine the optimal infrastructure locations, taking into account the time and distance of transportation by road. The corresponding optimization tasks are solved in order to minimize the costs of promoting the material flow from suppliers to consumers. At the third stage, WDC service areas are determined based on minimizing the cost of servicing each area.

A distinctive feature of the proposed methodology is that when forming a logistics infrastructure, it becomes possible to simultaneously take into account the intended purpose and type of commodity carrier: storage, sales, trade. Based on this, it is possible to choose the necessary capacities, types of refrigeration and ventilation equipment, specialized vehicles (refrigerators, insulated vans), etc..

The methodology for choosing WDC locations for storage, distribution and trade could be recommended for state planning of the development of the logistics infrastructure of the country's regions, as well as for large companies when deciding to invest in the logistics industry.

The use of this methodology allows public authorities or private investors to calculate in advance, before making a decision on the design or modernization of existing distribution networks, possible options for their optimal placement, based on population density and transport, logistics and trade infrastructure, economic and physical accessibility of food and other factors, which allows to increase production and sales efficiency and sustainability of agri-food supply chains.

The authors believe that the following areas of research may be related to determining the capacity of logistics infrastructures as information accumulates on the volumes of consumption, production, imports and exports in each region. Also, future studies could be improved by including more specific factors, such as climate factors, which we believe may also influence site selection and capacity.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix A

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
X1	1																		
X2	0.070	1																	
X3	0.051	-0.003	1																
X4	-0.049	0.009	0.630**	1															
X5	-0.062	0.195*	0.654**	0.895***	1														
X6	0.859***	0.215*	-0.080	-0.103*	-0.133*	1													
X7	-0.072	0.057	0.178*	0.552**	0.585**	-0.075	1												
X8	-0.064	0.052	-0.070	0.150*	0.111*	-0.047	0.214*	1											
X9	-0.070	0.051	0.026	0.220*	0.184*	-0.060	0.238*	0.903***	1										
X10	-0.168*	-0.074	-0.146	0.135*	-0.115*	-0.046	-0.237*	-0.079	-0.032	1									
X11	-0.381*	-0.055	-0.068	-0.055	-0.033	-0.336*	-0.169*	-0.052	-0.083	0.795***	1								
X12	-0.320*	-0.068	0.351*	-0.037	0.314*	0.186*	-0.163*	0.346**	0.175*	0.695***	1.000	1							
X13	0.092	-0.030	0.549**	0.658**	0.450**	0.626**	0.042	0.432**	0.108*	0.014	0.024	0.0281	1						
X14	0.123*	0.030	0.574 **	0.426**	0.429**	0.545**	0.063	0.346**	0.218*	-0.097	-0.085	-0.084	0.248*	1					
X15	-0.190*	0.036	0.490**	0.569**	0.559**	0.698**	0.651	0.473**	0.480**	-0.120*	-0.041	-0.024	-0.078	0.005	1				
X16	0,117*	0.041	0.151*	0.154*	0.247*	0.506 **	0.215	0.532**	0.250*	-0.172*	-0.166*	-0.071	0.037	0.016	0.076	1			
X17	0.026	0.080	0.385**	0.518**	0.545**	0.481**	0.347	0.230*	0.317*	-0.205*	-0.181*	-0.016	0.021	0.022	0.065	0.014	1		
X18	0.760***	0.128*	-0.144*	-0.093	-0.074	0.778***	0.021	0.262*	0.017	0.126*	0.086	0.103*	0.115*	0.248*	0.130*	0.310*	0.493*	1	
X19	0.651**	0.043	-0.135*	-0.148*	-0.174*	0.586**	0.069	0.315*	0.021	0.398*	-0.103*	-0.191*	-0.053	-0.035	-0.058	0.023	0.032	0.562**	1

Appendix B

Regions / cities of republican significance	Urban agglomerations (u.a.) and districts *	Cargo transportation volume, thousand tons	Distance, km	Center of gravity (weighted average distance of transportation of 1 ton of cargo), km
Almaty	Taldykorgan u.a.	52,1	260	**357,0**
	Kapshagai u.a.	153,5	76	
	Tekeli u.a.	20,6	288	
	Aksu	147,0	350	
	Alakol	203,8	600	
	Balkhash	72,8	340	
	Enbekshikazakh	800,8	121	
	Zhambyl	200,0	63	
	Kegen	68,1	256	
	Kerbulak	188,8	281	
	Koksu	126,8	242	
	Karatal	159,8	390	
	Karasai	254,7	28	
	Panfilov	220,7	298	
	Rayymbek	127,2	320	
	Sarkand	222,5	450	
	Talgar	311,2	40	
	Eskeldin	170,2	310	
	Uighur	147,0	275	
	Ili	406,5	114	
	Total: Almaty region	**4054,0**		
Akmola	Kokshetau u.a.	22,283	1	**424,2**
	Stepnogorsk u.a.	17,692	288	
	Akkol	115,428	252	
	Arshalyn	135,619	390	
	Astrakhan	260,621	283	
	Atbasar	225,374	236	
	Burabay	164,530	76	
	Bulandin	195,118	195	
	Birzhan sal	84,438	145	
	Egindykol	184,593	340	
	Yerementau	94,490	410	
	Yesil	203,124	350	
	Zhaksy	238,292	267	
	Zharka	182,543	410	
	Zerendi	220,163	33	
	Korgalzhyn	88,367	420	
	Sandyktau	251,140	122	
	Tselinograd	232,037	350	

Regions / cities of republican significance	Urban agglomerations (u.a.) and districts *	Cargo transportation volume, thousand tons	Distance, km	Center of gravity (weighted average distance of transportation of 1 ton of cargo), km
	Shortandi	169,653	248	
	Total: Akmola region	**3085,505**		
Aktobe	Aktobe city	81,4	1	**248,0**
	Alga	49,2	58	
	Aiteke bi	65,7	286	
	Baiganino	17,8	329	
	Kargaly	121,4	112	
	Kobda	49,5	187	
	Martuk	108,5	98	
	Mugaljar	41,6	182	
	Uil	20,6	297	
	Temir	33,4	257	
	Khromtau	86,9	131	
	Shalkar	23,8	376	
	Irgiz	16,6	416	
	Total Aktobe region	**716,4**		
Atyrau	Atyrau u.a.	71,3	1	**142,2**
	Zhylyoi	10,9	251	
	Inder	34,4	141	
	Isatay	7,8	118	
	Kurmangazy	23,3	118	
	Kyzylorda	18,9	179	
	Makat	1,6	124	
	Makhambet	74,7	78	
	Total Atyrau region	**242,9**		
West Kazakhstan	Akzhaik	41,3	201	**207,7**
	Bokeyordi	13,8	379	
	Burli	24,5	155	
	Zhangali	12,0	273	
	Zhanibek	13,0	373	
	Baiterek	187,0	28	
	Kaztalov	26,8	330	
	Karatobi	11,0	256	
	Syrym	24,5	266	
	Taskali	35,0	129	
	Terekti	53,1	92	
	Chingirlau	27,1	193	
	Uralsk city	40,4	1	
	Total: West Kazakhstan region	**509,5**		
Zhambyl	Taraz	49,5	1	**388,9**
	Bayzak	296,6	71	
	Zhambyl	404,5	362	

Regions / cities of republican significance	Urban agglomerations (u.a.) and districts *	Cargo transportation volume, thousand tons	Distance, km	Center of gravity (weighted average distance of transportation of 1 ton of cargo), km
	Zhualyn	162,7	84	
	Kordai	410,5	330	
	T. Ryskulov	148,6	115	
	Merke	177,3	165	
	Moyynkum	15,7	249	
	Sarysus	46,9	243	
	Talas	32,1	181	
	Shu	833,6	261	
	Total: Zhambyl region	**2578,0**		
Karagandy	Karaganda u.a.	35,0	1	**322,3**
	Balkhash u.a.	5,1	380	
	Zhezkazgan u.a.	18,3	530	
	Karazhal u.a.	10,4	450	
	Priozersk	0,7	530	
	Saran u.a.	8,9	22	
	Satpayev u.a.	3,4	550	
	Temirtau u.a.	19,8	34	
	Shakhtinsk u.a.	14,1	45	
	Abai	207,7	77	
	Aktogay	33,5	440	
	Bukhar-Zhyrau	204,8	113	
	Zhanaarka	59,0	319	
	Karkaralinsk	80,5	264	
	Nurinsk	195,3	245	
	Osakarovsk	302,4	113	
	Ulytau	62,7	549	
	Shet	115,7	310	
	Total: Karaganda region	**1377,2**		
Kostanay	Kostanay	20,5	1	**264,5**
	Arkalyk u.a.	84,5	460	
	Lisakovsk u.a.	8,6	114	
	Rudny u.a.	24,2	47	
	Altynsarinsk	119,0	80	
	Amangeldi	65,7	393	
	Auliekol	91,3	127	
	Denisovsky	100,7	183	
	Dzhangeldi	38,3	510	
	Zhitikari	52,3	255	
	Kamysti	88,4	290	
	Karabalyk	133,8	161	
	Karasu	317,5	191	
	Kostanay	305,7	7	

Regions / cities of republican significance	Urban agglomerations (u.a.) and districts *	Cargo transportation volume, thousand tons	Distance, km	Center of gravity (weighted average distance of transportation of 1 ton of cargo), km
	Mendykari	216,9	111	
	Naurzumsk	68,8	263	
	Sarykol	241,9	154	
	Beimbet Maylin	89,5	128	
	Uzunkol	199,5	179	
	Fedorovsk	246,9	94	
	Total: Kostanay region	**2514,1**		
Kyzylorda	Kyzylorda u.a.	50,5	1	**264,5**
	Aralsk	10,3	510	
	Zhalagash	115,7	105	
	Zhanakorgan	82,1	256	
	Casali	60,0	450	
	Karmakshi	72,8	165	
	Syrdarya	96,9	91	
	Shieli	144,9	145	
	Baikonir u.a.	0,0	251	
	Total: Kyzylorda region	**633,3**		
Mangystau	Aktau u.a.	1,0	1	**340,6**
	Zhanaozen u.a.	1,1	150	
	Beyneu	1,7	560	
	Karakiyan	5,8	204	
	Mangistau	8,5	266	
	Munailinsk	3,2	34	
	Tupkaragan	3,9	119	
	Total: Mangystau region	**25,2**		
Pavlodar	Pavlodar u.a.	61,8	1	**340,6**
	Aksu u.a.	184,3	48	
	Ekibastuz u.a.	45,6	142	
	Aktogay	106,8	177	
	Bayanaul	39,1	235	
	Zhelezi	213,9	185	
	Irtysh	213,8	228	
	Terenkol	286,7	128	
	Akkuly	111,0	126	
	Maysk	38,8	145	
	Pavlodar	328,7	30	
	Uspensk	198,2	120	
	Shcherbakti	156,1	108	
	Total: Pavlodar region	**1984,8**		
North Kazakhstan	Petropavlovsk	59,8	1	**200,4**
	Aiyrtau	302,9	243	
	Akzharsk	209,8	300	

Regions / cities of republican significance	Urban agglomerations (u.a.) and districts *	Cargo transportation volume, thousand tons	Distance, km	Center of gravity (weighted average distance of transportation of 1 ton of cargo), km
	M.Zhumabaev	360,3	130	
	Yesil	255,8	120	
	Zhambyl	219,6	169	
	Kyzylzhar	360,7	54	
	Mamlut	169,0	76	
	Shal akyna	228,2	176	
	Akkayyn	268,7	76	
	Taiynshi	481,9	181	
	Timiryazev	171,6	239	
	Ualikhanovsk	140,2	380	
	Musrepov	450,1	350	
	Total North Kazakhstan region	**3678,7**		
Turkestan	Turkestan	31,4	1	**309,5**
	Arys u.a.	85,5	148	
	Kentau u.a.	77,6	33	
	Baidibek	97,5	135	
	Zhetysai	498,5	380	
	Kelessk	392,0	320	
	Kazygurt	112,8	234	
	Maktaaral	383,4	400	
	Ordabasy	230,3	144	
	Otrar	152,9	203	
	Sairam	417,0	188	
	Saryagash	481,8	253	
	Sauran	333,3	28	
	Suzak	54,1	162	
	Tolebi	162,2	218	
	Tyulkubas	154,3	214	
	Shardari	288,1	202	
	Total: Turkestan region	**3952,8**		
East Kazakhstan	Ust-Kamenogorsk	75,7	1	**393,1**
	Kurchatov	2,5	350	
	Ridder	33,0	133	
	Semey	129,2	218	
	Abay	50,3	410	
	Ayagoz	87,1	650	
	Beskaragai	145,1	330	
	Borodulikha	396,2	201	
	Glubokov	289,7	57	
	Jarmin	64,9	195	
	Zaysan	109,3	490	
	Altai	187,2	196	

Regions / cities of republican significance	Urban agglomerations (u.a.) and districts *	Cargo transportation volume, thousand tons	Distance, km	Center of gravity (weighted average distance of transportation of 1 ton of cargo), km
	Kokpekti	203,2	229	
	Kurchumsk	145,0	680	
	Katon-Karagai	117,7	380	
	Tarbagatai	154,9	400	
	Ulan	193,5	30	
	Urjar	372,0	480	
	Shemonaikha	321,0	139	
	Total: East Kazakhstan region	**3077,7**		
Astana	Astana u.a.			
Almaty	Almaty u.a.			
Shymkent	Shymkent u.a.			

Note: At the end of 2022, the territory of Kazakhstan consisted of 14 regions, 201 districts, 87 cities, 31 villages and 6828 rural settlements

Table B.1. Calculation of the center of gravity for selecting the range of the WDC

Regions/district or city agglomeration	Average rating by factor loads (F1-F5)	The volume of transportation from the district center to the proposed WDC, t	WDC storage				WDC distribution		WDC trade	
			Center of gravity, thousand tons km	Sum of center of gravity, km	Rating* by (F1+F3+F5)/3	Quantity	Rating* by (F2+ F4)/2	Quantity	Rating* by F2	Quantity
Almaty	**1.425**	**4054.0**	**1447523.4**	**357.0**	**6.177**					
Alakolsky	0.942	153.7	156.7				1.244	1		
Enbekshikazakh	1.127	800.8	161504.2		2.286	1				
Karasai	0.879	254.7	12312.8		1.281	1				
Ili	0.661	406.5	77243.9		1.159	1				
Akmola	**0.665**	**3085.5**	**1308932.6**	**424.2**	**6.635**					
Aktobe	**2.019**	**716.4**	**177641.3**	**248.0**	**-4.410**					
Aktobe city	0.981	81.4	135.6		0.430				1.112	1
Zhambyl	**1.271**	**2578.0**	**1002831.3**	**388.9**	**0.475**					
Korday region	-0.543	410.5	225767.1		1.010	1				
Shu district	0.584	833.6	362622.7		1.047	1				
Karaganda	**3.325**	**1377.2**	**443908.3**	**322.3**	**-2.667**					
Karaganda city agglomeration	0.662	35.0	58.3		-0.470				1.678	1
Zhezgazkan city agglomeration	0.187				0.345		1.2083	1		
Abai	0.863	207.7	26652.7		1.129	1				
Bukhar-Zhyrau	0.615	204.8	38573.2		1.105	1				
Kostanay	**3.497**	**2514.1**	**665015.2**	**264.5**	**3.306**					
Karasu	0.111	317.5	101056.2		1.406	1				

Regions/district or city agglomeration	Average rating by factor loads (F1-F5)	The volume of transportation from the district center to the proposed WDC, t	WDC storage				WDC distribution		WDC trade	
			Center of gravity, thousand tons km	Sum of center of gravity, km	Rating* by (F1+F3+F5)/3	Quantity	Rating* by (F2+ F4)/2	Quantity	Rating* by F2	Quantity
Kostanay city agglomeration	-0.487	305.7	3566.6		1.521	1				
Mangistau	**-1.304**	**25.2**	**8567.1**	**340.6**	**-4.770**					
Beineu	0.089						1.1295	1		
North Kazakhstan	**-1.503**	**3678.7**	**1138718.5**	**309.5**	**6.694**					
Kyzylzhar	0.648	360.7	32460.0		1.388	1				
Taiynshinsky	-0.649	481.9	145361.3		1.613	1				
Turkestan	**0.976**	**3952.8**	**1553670.8**	**393.0**	**2.033**					
Sairam	0.436	417.0	130665.9		1.118	1				
Saryagash	-0.798	481.8	203146.8		1.281	1				
East Kazakhstan	**-1.242**	**3077.7**	**1397588.3**	**454.1**	**-0.391**					
Ayaguz	0.451	215.3	21354.3		0.345		1.578	1		
Kurchumsky	0.649	312.7	34572.6		0.451		1.660	1		
Astana city agglomeration	0.979				-0.601		1.738	1	4.417	1
Almaty city agglomeration	0.571				-0.204		6.574	1	12.638	1
Shymkentskaya city agglomeration	0.611				0.238				2.611	1
Total: 25						**13**		**7**		**5**

Note: *ratings are determined based on the ranking of average F1-F5 indicators, ** potential placements are selected if the estimated value of ratings is greater than one

Table B2. Potential locations and center of gravity for selecting the radius of action of the WDC