Keywords: cargo transportation; perishable goods; transport mode; road and rail transport

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ASSESSMENT OF THE EFFICIENCY OF METHODS FOR TRANSPORTING PERISHABLE FOODS IN THE CONDITIONS OF KAZAKHSTAN

Summary. The purpose of the paper is to assess the competitiveness of road and rail transport for the transportation of perishable foods in the Republic of Kazakhstan. The study analyzed food consumption and production, as well as the transport network of the Republic of Kazakhstan. An assessment was made of the costs of transporting perishable foods by road, as well as by rail in railway cars and container trains. The modes of transportation were established, and it was found that the transportation of fresh food products in container trains is competitive with road transportation. The scientific novelty of the work is that it improves the method for assessing the competitiveness of road and rail transport for the transportation of fresh food products. The proposed method differs from existing ones in that it takes into account the loss of consumer value of food products over time while also considering the presence of competition by sources when choosing a type of transport. The practical value of the work is that it establishes the types of food products and directions of their transportation, the performance of which is advisable to carry out by container trains in the Republic of Kazakhstan.

1. INTRODUCTION

Providing the population with fresh food is a major socio-economic problem. Its solution is related to the improvement of technologies for the production, storage, transportation, and sale of food. It should be noted that fresh food products are perishable goods that require compliance with deadlines and special transportation conditions. This problem is also relevant for the Republic of Kazakhstan, especially in the context of dynamic population growth, which has been observed over the past decade.

The United Nations considers the spoilage and waste of food products as one of the most significant modern problems. According to [1], 1.3 billion tons of food products are thrown into waste every year. In the Central Asian region, where Kazakhstan is located, about 220 kg of food per person is lost annually. According to [2], the annual food consumption in Kazakhstan is 718 kg per person, meaning the losses amount to 23.4% of produced food products. According to [3], the main losses of food products in the Central Asian region occur at the production and distribution stages. This indicates the need to improve logistics technologies that ensure the delivery of food products to end consumers.

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2. LITERATURE REVIEW

Food loss during transportation can be reduced by maintaining optimal conditions during transportation. In this regard, the problem of choosing refrigeration equipment and the type of transport for the transportation of perishable goods is widely studied in scientific papers.

Domestic transportation of perishable goods is primarily carried out by road [4, 5] and rail transport [6, 7]. These means of transport are also used to transport imported and exported perishable goods to and from border crossings. The advantages of automobile transport are its high mobility and the possibility of door-to-door delivery. The advantages of rail transport are its high carrying capacity, all-weather capability, and low cost. The task of rationally distributing the volume of work on transporting perishable goods between different types of land transport is relevant. The transportation of perishable goods, depending on weather conditions and delivery time, is carried out in isothermal and conventional railway and automobile rolling stock, as well as in universal and isothermal containers. An assessment of the risks arising during the transportation of food products is presented in [8]. These studies show that, at present, the risks arising during the transportation of food products by road and rail have similar values during intermodal transportation and warehousing. In this regard, this study assumes that technical means provide similar conditions during road, rail, and intermodal transportation, as well as during the storage of perishable goods.

Papers [9, 10] have considered the problem of loss of value of perishable goods during transportation. To reduce these losses, the problem of finding routes that minimize the time spent on their delivery to points of sale was solved. In both cases, transportation over relatively short distances was considered: from distribution centers to points of sale (in [9]) and within Slovenia (in [10]).

Olkhova et al. [3] studied the problem of choosing the mode of transport for the transportation of perishable goods. In this paper, rail and road transport were considered as competitors. The zones of their effective application were established by methods of economic and mathematical modeling. The use of railway refrigerated rolling stock requires access roads and specialized warehouse infrastructure at the departure and destination points of the railway cars. This reduces the efficiency of using railway transport. The solution to the problem may be the transportation of perishable goods in containers. The principles of constructing a multimodal network for the transportation of perishable goods are presented in the paper by Mironenko et al. [11]. The paper [10] takes into account the movement of both loaded and empty transport units. The paper [12] examined the problem of constructing an intermodal network for the transportation of food products in order to reduce CO_2 emissions into the atmosphere and reduce the burden on the environment. Steadieseifi et al. [13] examined the problem of organizing multimodal transportation of perishable goods in international traffic under conditions of random demand. Freight transportation under competitive conditions on parallel routes was considered by Kozachenko et al. [14] The behavior of carriers in this work was simulated using game theory methods.

The efficiency of the organization of transportation of perishable goods can be assessed using various criteria alone or in combinations. Thus, in [13], the goal of improving the organization of transportation of perishable goods was to minimize costs. Yakavenka et al. [15] proposed using the criteria of time, cost, and environmental friendliness to assess the efficiency of the organization of transportation of perishable goods.

Individual countries have specific features that must be taken into account when choosing rational technologies for transporting perishable goods. A special study [16] of food losses in the Republic of Kazakhstan was conducted in 2014. In this study, food products were divided into the following groups: grain, oilseeds and legumes, root crops, meat, and dairy products. The products that were characterized by the greatest loss at the distribution stage in Kazakhstan were root crops and dairy products.

The article [17] studied the conditions for the transportation of agricultural products by road in Kazakhstan, as well as issues of assessing the cost of such transportation. The advantage of road transport in the transportation of agricultural products, according to [18], is its mobility and ability to serve small agricultural enterprises.

In general, the literature shows that the problem of food transportation has a long history but has not been fully explored. This paper examines the problem of choosing a method for performing domestic transportation of fresh food products by road and rail in the context of competition on parallel routes between production and consumption points, as well as competition by source.

The Republic of Kazakhstan is characterized by the following parameters. With an area of 2.7 million km^2, Kazakhstan is one of the largest countries in the world. Kazakhstan is also the most urbanized country in Central Asia, as the urban population comprises more than 60% of the country's residents. Half of the country's population lives in 20 cities. This distribution of the population causes a high concentration of food consumption in a small number of settlements.

This study examines food products that have significant limitations on their shelf lives, such as meat and meat products, milk and dairy products, eggs, and fruits and vegetables. Bread and cereal products, oils and fats, potatoes, sugar, jam, honey, chocolate, and confectioneries are excluded since these products are either produced in places of consumption or have a significant shelf life. Also, this study does not examine fish and seafood, since their production in Kazakhstan is insignificant; 82% of the population's needs are covered by imports.

The purpose of the paper is to assess the competitiveness of road and rail transport for the transportation of fresh food products in the Republic of Kazakhstan.

The research was carried out using methods of the theory of transport processes and systems, economic and mathematical modeling, graph theory, and methods of mathematical optimization.

3. DESCRIPTION OF THE BASIC MATERIAL

The distribution of food consumption in Kazakhstan is presented in Table 1. The main factor that influences the distribution of food consumption across the country is the population of its various regions. Because of this, consumption is unevenly distributed across the country, and a significant share falls on the largest cities: Astana, Almaty, and Shymkent.

The food products presented in Table 1 make up a small share of the total amount of cargo transported in Kazakhstan. Thus, the daily consumption volume of the city of Almaty with the largest population is equivalent to the capacity of 14-20 railway cars. Therefore, the transport system of Kazakhstan is currently capable of fulfilling the required volumes of transportation, and the main task at present is to improve the quality of transport services.

The agro-industrial complex is one of the main components of the economy of Kazakhstan. More than 70% of the country's territory (1.9 million km^2) is occupied by crop and livestock production. The distribution of food production is presented in Table 2. It should be noted that the production of meat and meat products, eggs, and milk and dairy products is distributed relatively evenly across the country. At the same time, due to geographical features, the production of vegetables and fruits is concentrated in the Almaty, Turkestan, and Zhambyl regions.

In the course of the study, both absolute and relative indicators of food consumption and production were analyzed. It should be noted that when conducting statistical studies, meat production is recorded in live weight. Some meat, milk, and eggs are processed. Considering the relatively small amounts of imports and exports of these food products, it can be concluded that they are predominantly redistributed within the country in accordance with the shares indicated in Tables 1 and 2. The volume of vegetable production in Kazakhstan significantly exceeds the volume of consumption. At the same time, the volume of exports is insignificant. This is because not all vegetables are used for consumption by the population. It is accepted that vegetables are redistributed within the country in accordance with the shares indicated in Tables 1 and 2. Fruit consumption in Kazakhstan significantly exceeds production volumes. The main source of these products is imports, and border crossings with China and Uzbekistan are considered additional sources of their production.

The basis of the transport network of Kazakhstan is railway transport. The operational length of railway tracks is 16,000 km, and it accounts for about 70% of freight turnover. Railways provide transport links between the main cities of the country and industrial centers, as well as transport links between Kazakhstan and other countries. The railway transport system of Kazakhstan has been significantly modernized in recent decades in order to ensure international freight transportation.

The cities of Kazakhstan with the largest populations and a diagram of the railway network are presented in Fig. 1.

Table 1

Food consumption in Kazakhstan

Region	Settlements	Meat and meat products	Milk and dairy products	Egg s	Fruit	Vegetable s
Food consumption, thousand tonnes.						
Republic of Kazakhstan		1577	4520	248	1464	1575
Share in food consumption, %						
Almaty and Almaty region	Almaty	11.8	12.5	13.0	13.5	12.9
	Almaty region	9.1	7.6	7.9	7.5	7.6
Astana and Akmola region	Astana	6.8	8.2	8.4	8.3	6.9
	Kokshetau	1.0	1.1	1.2	0.8	0.7
	Other settlements	3.6	3.7	4.1	2.9	2.4
Shymkent and Turkestan region	Shymkent	4.1	3.7	5.3	5.0	6.1
	Turkestan	0.9	1.1	1.0	1.0	1.5
	Other settlements	7.5	9.1	8.3	8.8	12.4
Zhambyl region	Taraz	2.2	2.1	2.0	2.1	2.2
	Other settlements	4.1	3.9	3.7	3.8	4.0
Aktobe region	Aktobe	2.6	2.6	2.4	2.9	2.3
	Other settlements	1.7	1.7	1.6	1.9	1.5
Karaganda region	Karaganda	3.1	2.7	2.1	2.7	2.8
	Temirtau	1.0	0.9	0.7	0.9	0.9
	Other settlements	2.6	2.3	1.8	2.3	2.4
East Kazakhstan region	Oskemen	2.4	2.7	2.6	2.2	1.8
	Other settlements	1.6	1.9	1.8	1.5	1.2
Pavlodar region	Pavlodar	1.9	1.8	1.7	1.6	1.7
	Ekibastuz	0.7	0.7	0.7	0.6	0.6
	Other settlements	1.7	1.6	1.5	1.4	1.4
Atyrau region	Atyrau	1.9	1.4	1.5	1.3	1.3
	Other settlements	2.2	1.6	1.8	1.6	1.5
Abay region	Semey	1.4	1.6	1.5	1.1	1.1
	Other settlements	1.2	1.3	1.2	1.0	1.0
Kyzylorda region	Kyzylorda	1.1	1.1	1.1	1.4	1.4
	Other settlements	2.2	2.3	2.3	2.9	2.8
Mangistau region	Aktau	1.4	1.2	0.9	1.6	1.3
	Other settlements	2.7	2.3	1.8	3.1	2.5
Kostanay region	Kostanay	1.3	1.3	1.8	1.2	1.4
	Other settlements	2.8	2.6	3.7	2.6	2.9
West Kazakhstan region	Oral	1.3	1.3	1.3	1.2	1.2
	Other settlements	2.2	2.2	2.2	2.1	2.0
North-Kazakhstan region	Petropavlovsk	1.1	1.2	1.4	1.0	0.9
	Other settlements	1.5	1.7	1.9	1.4	1.2
Zhetisut region	Taldykorgan	1.0	0.9	0.7	0.9	0.9
	Other settlements	3.1	2.7	2.1	2.7	2.8
Ulytaut region	Ulytaut region	1.1	1.2	1.3	1.0	0.9

Table 2

Food production in Kazakhstan

Region	Meat and meat products	Milk and dairy products	Eggs	Fruit	Vegetables
Food production, thousand tonnes					
Republic of Kazakhstan	2156	6317	328	429	4792
Share in food production, %					
Almaty and Almaty region	13.0	8.5	11.2	30.9	16.8
Astana and Akmola region	8.6	6.5	14.7	0.5	1.0
Shymkent and Turkestan region	11.4	12.3	5.1	41.8	25.0
Zhambyl region	6.7	5.4	2.8	7.9	26.4
Aktobe region	6.8	5.9	7.4	1.0	2.0
Karaganda region	5.6	6.9	13.1	0.6	2.1
East Kazakhstan region	7.1	7.9	1.7	1.8	3.2
Pavlodar region	5.1	6.8	4.7	0.4	5.1
Atyrau region	2.7	1.2	0.4	0.2	2.1
Abay region	8.5	9.1	1.3	1.6	2.4
Kyzylorda region	1.9	1.6	0.3	0.5	2.4
Mangistau region	0.9	0.1	0.0	0.0	0.2
Kostanay region	4.2	6.7	11.4	0.7	1.6
West Kazakhstan region	4.8	3.8	3.8	0.5	1.3
North-Kazakhstan region	5.1	10.3	14.1	2.1	3.5
Zhetisut region	5.8	5.3	7.6	9.1	4.7
Ulytaut region	1.7	1.9	0.5	0.2	0.2

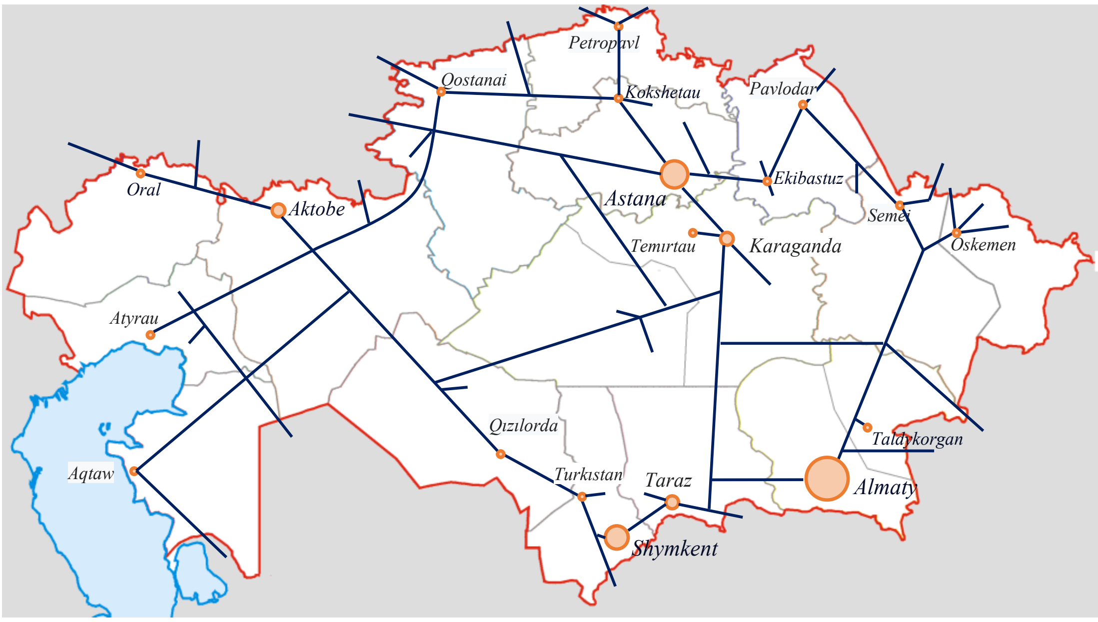

Fig. 1. Cities with the largest populations and the scheme of the railway network of Kazakhstan

The length of Kazakhstan's paved roads is 86,300 km. The length of the national paved road network is 24,800 km. The national road network, like the railway network, mainly connects the country's largest cities with each other and with border crossings.

The formal representation of the problem of providing the population with food products in this study is formulated as follows. Food products are transported from the regions of their production to the regions of their consumption. The oriented parametric graph G(V, E) is used as a model of food distribution. The graph nodes correspond to regions of food production and consumption. It is assumed that food products of the same type do not differ in quality. The parameters characterizing the nodes vi are surpluses and shortages (in shares) of food products si. In this case, the nodes of food production correspond to positive values of the parameter si, and consumption corresponds to negative values. The peaks are also characterized by the cost of food pi USD/kg. The arcs of the graph correspond to transport connections between regions. Each arc is associated with the duration of delivery and the profit that the shipper receives when sending cargo from the point of production to the point of consumption.

The duration of cargo delivery is determined by the following formula:

$$t_{ij}(m) = t_{se}(m) + \frac{l_{ij}}{v(m)} + t_{s,j}(m), \quad (1)$$

where:
$t_{se}(m)$ is the duration of initial and final operations in regions of production and consumption of products, in days;
l_{ij} is the transportation distance between the *i-th* and *j-th* regions, in km;
m is the type of transport unit used for transportation;
$v(m)$ is the speed of cargo delivery, depending on the method m, in km/day;
$t_{s,j}(m)$ is time spent on selling a batch of cargo, in days.

The transport units considered are a railway car; containers of 10, 20, and 40 feet when transported by a container train; and cars with a body volume of 8, 20, 50, 60, and 96 m^3.

The duration of the initial and final operations during transportation is one day by road, two days in a container train, and three days in a rail car. The speed of a truck is 1200 km/day. The speed of transportation in an isothermal or refrigerated rail car is 330 km/day. It is accepted that transportation in container trains is carried out on the Almaty-Astana and Shymkent-Taraz-Astana routes. The durations of a container train's trip are as follows: one day from Almaty to Astana; two days from Shymkent and Taraz to Astana and for container trains from Almaty to Astana including blocks of rail cars following the Astana-Aktobe and Astana-Atyrau routes; and three days from Astana to Aktau and Astana to Oral.

The amount of profit for shippers in USD/kg is estimated using the following formula:

$$b_{ij}(m) = p_j - p_i - T_{ij}(m), \quad (2)$$

where $\underline{T_{ij}}(m)$ are the costs of delivering products to consumers depending on the selected type of transport unit, in USD/kg.

The cost of delivering food products to consumers is estimated as

$$T_{ij}(m) = \frac{t_{ij}(m)p_i}{t_r} - \frac{c_0(m)+c(m)l_{ij}}{1000w}. \quad (3)$$

where:
$c(m)$ is the cost of transportation of 1 m^3 of cargo per 1 km, in USD;
$c_0(m)$ is cost of the initial-final operation per 1 m^3 of cargo, in USD;
t_r is the maximum shelf life of products, in days
w is the loading weight, in t/m^3.

The cost of transporting goods *c(m)* depends on the size of the cargo consignment and the type of transport unit. The corresponding dependencies are presented in Fig. 2.

The maximum shelf life of fresh food products, subject to the relevant requirements for their storage and transportation, is given in Table 3.

There is competition on parallel routes between road and rail transport, as well as competition between sources. Competition on parallel routes occurs when transportation from some vertex v_i to some vertex v_j can be performed in different ways. Competition between sources occurs when food products can be delivered to the same consumption vertex v_j from different production points $v_i \in \mathbf{V}_s$ (here, $\mathbf{V}_s$ is the set of vertices corresponding to food production points). The competitiveness of different methods of transporting food products on parallel routes is determined by Expressions (2) and (3).

Considering that the cost of cargo p_i and p_j at the production and consumption peaks on parallel routes are the same, transportation by rail will be more efficient than transportation by road, assuming similar route lengths, if the following condition is met:

$$\frac{p_i}{t_r} < \frac{\Delta c l_{ij} - c_{0,r}}{1000 w \Delta t_{ij}}, \quad (4)$$

where:

$\Delta c = c_l - c_r$, USD/m^3km;
c_l, c_r is the cost of transporting 1 m^3 of cargo per 1 km by road and container train, respectively, USD;
$\Delta t_{ij} = t_{ij,r} - t_{ij,l}$, days;
$t_{ij,l}$, $t_{ij,r}$ are the duration of cargo delivery by truck and container train, respectively, in days;
$c_{0,r}$ is the cost of the initial-final operation with a container per 1 m^3 of cargo, in USD.

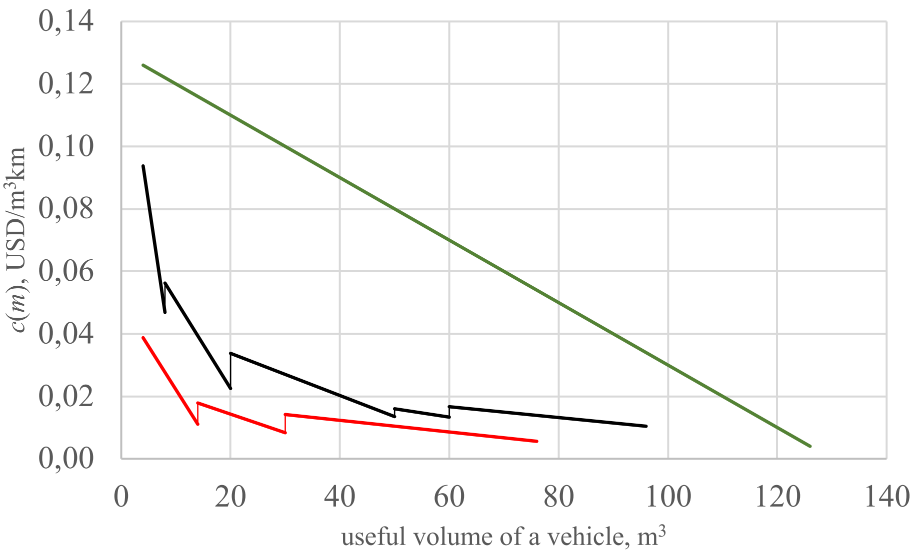

Fig. 2. Cost of cargo transportation (USD/m^3) depending on the volume of the cargo being transported

Table 3

The maximum shelf life of fresh food products

Title	Loading weight w, t/m^3	Shelf life t_r, days	Cost p per kg, USD
Chilled meat	0.17	5–12	5.4–7.6
Milk, dairy products	0.60–0.75	5–90	0.8–1.9
Eggs	0.27–0.32	7–120	1.9–2.2
Fruits	0.35	28–210	0.8–3.4
Vegetables	0.35	7–240	0.5–2.6

An analysis of Expression (4) shows that transportation by road is more competitive compared to rail transportation both in railway cars and in containers for high-cost, short-term food products. Such products include chilled meat, dietary eggs, and greenhouse vegetables. When transporting them, the lower cost of rail transportation compared to road transportation does not compensate for the loss of consumer value of the products, which occurs due to the longer delivery time. The lowest cost of transportation of food products is achieved when they are transported in railway cars (see Fig. 2). However, due to the 3.6-times lower transportation speed (two days longer for initial and final operations) and the high cost of cargo operations, the indicators of the option of delivery of fresh food products in railway cars are inferior to the indicators of their transportation by cars and container trains for any distances possible in the Republic of Kazakhstan.

The use of railway cars for the transportation of fresh food products is possible due to seasonal fluctuations when the capacity limitation of other methods of delivery is reached. A separate issue, which is not considered in this paper and which requires additional research, is the transportation of live fish, crustaceans, and mollusks. The speed of transportation of fresh food products in container trains is close to the speed of transportation by road. In such conditions, the competitiveness of the rail transportation option increases with increasing distance l_{ij}. Figure 3 shows the limitations on the transportation distance $L(p_i/t_r)$, separating the areas of efficient use of road vehicles and container trains for different values of Dc and Dt_{ij} (the arrows indicate areas where transportation by container trains is more efficient). The figure also shows the limitations of the value p_i/t_r, typical for vegetables, fruits, and table eggs.

In general, the transportation of vegetables, fruits, table eggs, and milk and dairy products by container trains may be appropriate when the cost of delivery by rail is lower than the delivery speed by road transport by 0.02 USD per m^3 per km. For the conditions of Kazakhstan, transportation in container trains is more efficient compared to road transport for providing Astana with vegetables and fruits from the Zhambyl and Turkestan regions; fruits from the Almaty, Zhambyl, and Turkestan regions; and milk and dairy products from the Aktobe region. The rail transportation of imported fruits to Astana from China and Uzbekistan is also effective. Fruit transportation from the Almaty region by container trains to Aktobe, Atyrau, Aktau, and Oral is less cost-effective due to the significantly shorter length of automobile routes compared to railway routes via Astana. When assigning container trains on the routes from Shymkent to Aktobe, Atyrau, Aktau, and Oral, the transportation of vegetables and fruits is competitive with automobile transportation. The greatest competitive advantages of road transport are demonstrated when small consignments of food products are transported (see Fig. 2). This is due to the lack of transport units for such rail transportation. The solution to the problem may be the development and implementation of specialized medium-tonnage containers with a load capacity of 3–5 tons. On the one hand, such a solution would reduce the duration of the accumulation and consumption of transport consignments of cargo; on the other hand, it would reduce the requirements for the load capacity of vehicles performing cargo operations.

The cost of food products p_i in individual regions of Kazakhstan varies significantly depending on the volume of local production, the distance to the region of production, and the consumer capacity of the population. For example, the cost of fruit in Astana and Aktau is 1.5 times higher than in Turkestan and Shymkent. In such conditions, the delivery of food products from regions with lower costs to regions with higher costs potentially increases the profits of producers. Agricultural production in Kazakhstan is mainly carried out by small and medium-sized enterprises. It is assumed that these enterprises operate independently and that their goal is to maximize their profits. When delivering to one point of consumption, enterprises with greater profits have an advantage in selling their products since a slight decrease in the cost of their products makes them more attractive to consumers.

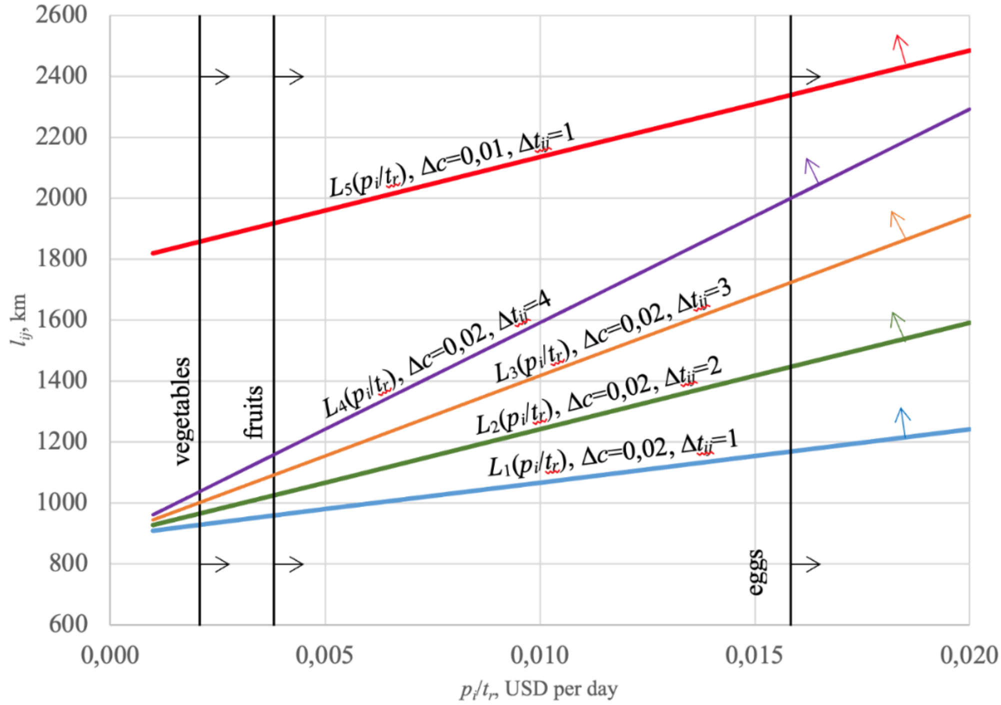

Fig. 3. Limitations of the areas of application of container trains for the transportation of fresh food products

The following algorithm is proposed to solve the problem of distributing fresh food flows between road and rail transport in conditions of competition by sources:

Step 1. Based on the directed graph *G(V, E),* create a matrix of profits of senders **B** of size $s \times d$ (here, s is the number of regions that supply food products, and d is the number of regions that consume food products). The rows of the matrix are assigned to the stocks of cargo at production points r_i, $i = \overline{1..s}$; the columns of the matrix are assigned to the needs for cargo h_j $j = \overline{1..d}$; and the cells of the matrix are assigned to the shipper's profit $b_{ij}=\max\{b_{ij}(m)\}$. The volumes of transportation from supplier regions to consumer regions are assumed to be equal to $w_{ij}=0$.

Step 2. Find rows with positive inventory volume $r_i>0$. If the matrix does not contain rows with positive inventory levels, then end the solution.

Step 3. In the rows with positive inventory volume, find the cell with the largest profit value $b_{\max}$. If $b_{\max} < 0$, then end the solution.

Step 4. Distribute stocks from supplier regions to consumer regions based on the following conditions:

$$\begin{cases} \min(w_{ij}) \to \max \\ \sum_{j=1}^{d} w_{ij} \le r_i, \\ \sum_{i=1}^{s} w_{ij} \le h_i, \\ b_{ij} = b_{\max}, \\ i = \overline{1..s}, j = \overline{1..d} \end{cases} \tag{5}$$

Step 5. Reduce the stocks in the rows and the requirements in the columns by the volume of the distributed cargo flow and go to step 2.

From solving the problem, it was established that transportation in container trains within Kazakhstan is appropriate for providing Astana with vegetables from the Zhambyl and Turkestan regions, as well as fruits from the Almaty, Zhambyl, and Turkestan regions. These types of transportation are characterized by the coincidence of a high concentration of a population with high purchasing power in the capital of the country (Astana) and a high concentration of production of vegetables and fruits in the south of Kazakhstan. It has also been established that despite the competitiveness of rail transport when transporting eggs and milk and dairy products on parallel routes, transporting these products is not practical since deliveries by road from alternative production points are more cost-effective.

In general, the **scientific novelty** of the work lies in the fact that it improves the method of assessing the competitiveness of automobile and rail transport in the transportation of fresh food products. The proposed method differs from existing ones in that it comprehensively takes into account the parameters of the railway and road transport units used for their transportation, as well as the loss of consumer value of food products over time. Based on the studies carried out, areas were established within which it is more efficient to transport fresh products by container trains than by road. The paper also presents a method for selecting a mode of transport for the transportation of fresh food products that takes into account the presence of competition by sources. This is important because the development of agricultural technologies ensures that food production points are closer to large cities than areas where road transport is certainly more competitive.

The practical value of this paper lies in the fact that it establishes the types of food products and the directions of their transportation, which should be carried out by container trains in the Republic of Kazakhstan. It has been established that for the conditions of Kazakhstan, transportation of open-ground vegetables to large cities in container trains can be more efficient compared to road transport. The competitiveness of rail transport can be enhanced by increasing the network served by container trains, as well as by introducing medium-tonnage containers for the transportation of food products in small batches.

4. CONCLUSIONS

The problem of reducing food losses at the stage of their delivery from producers to consumers is relevant for the Republic of Kazakhstan. The domestic transportation of food products in the Republic of Kazakhstan is carried out by rail and road transport, between which there is competition for freight flows.

Automobile transport, due to its mobility and lower time and monetary costs for initial and final operations, has significant competitive advantages in the transportation of fresh food products. The option of transporting food products in isothermal and refrigerated railway cars in the conditions of Kazakhstan, as a rule, is inferior to other methods of transportation since the lower cost of transportation does not compensate for the decreased consumer value of the products, which arises due to the longer delivery time. The transportation of fresh food products by container trains can be competitive with transportation by road over distances of over 900 km, depending on the ratio of the cost of products and the period of their sale. The conditions under which the use of container trains for the transportation of food products is effective is the high concentration of their production and consumption in certain regions. In the conditions of Kazakhstan, container trains can deliver vegetables from the Zhambyl and Turkestan regions, as well as fruits from the Almaty, Zhambyl, and Turkestan regions to supply Astana.

The container train transportation of table eggs and milk and dairy products is competitive with road transport on parallel routes. However, given the relatively even distribution of production of these products across the country, road transport is more efficient, as it provides the ability to transport over the shortest distances.

In the conditions of Kazakhstan, automobile transport is more efficient than container trains when transporting chilled meat, dietary eggs, and greenhouse vegetables. When delivering these food products to consumers, the lower cost of rail transport compared to automobile transportation does not compensate for the loss of consumer value of the products, which occurs due to the longer delivery time.

The lack of transport units for the transportation of small consignments of cargo reduces the competitiveness of rail transport in the supply chains of fresh food products. The solution to the problem may be the development and implementation of specialized medium-tonnage containers with a load capacity of 3–5 tons. On the one hand, this will reduce the duration of accumulation and consumption of transport consignments of cargo; on the other hand, it will reduce the requirements for the load capacity of vehicles performing cargo operations.

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