Choice of an efficient mode of transport on the basis of comparison of technical and economic indicators of types of transport

Jamol Shihnazarov[1*], *Diyor* Boboev[1], *Mirali* Dehkonov[1], and *Diyora* Ikramova[1]

[1]Tashkent State Transport University, 1 Temiryulchilar Str., Tashkent 100167, Uzbekistan

Abstract. This article compares the technical and economic indicators of the types of transportation of goods by principle of "from door-to-door". Analyzes the choice of an effective option. The research considers the possibility of choosing the most efficient option of the least expensive type of transportation, depending on the distance and weight of the cargo being transported. Container transport, contrailer transport, road transport and rail transport in covered wagons were selected as modes of transport. Keywords: economic efficiency, container, contrailer, wagon, mode of transport, type of transportation, loading and unloading, transport costs, distance.

1 Introduction

Using modern methods in the process of cargo transportation, choosing and using efficient modes of transport, it is possible to reduce the time of cargo delivery, rationally use loading machines, prevent excessive storage of cargo at transshipment points, and reduce overall logistics costs[7]. To achieve the maximum value of economic efficiency, we can have the best option for the task, seeking to reduce the cost of transportation. In turn, the types of transportation have their own characteristics when comparing container transportation, contrailer transportation, road transportation and railway transportation in a covered wagon [1-3].

The share of container transportation is increasing every year. Unlike traditional transportation, container transportation is based on the cooperation of various modes of transport and services to improve the efficiency of the technological process of cargo delivery. In the system of transport logistics, the basis of container transportation is the efficient organization of long-distance cargo transportation, mainly by rail or water transport, and at the same time the use of road transport by principle "from door-to-door"[8-10].

Contralier transport is defined as the transport of goods in one loading unit or vehicle using two or more modes of transport in a row without handling the goods. At the same time, contralier transportation is transportation by vehicles, trailers and semi-trailers loaded onto a railway platform [14,19]. From this point of view, the effective use of intermodal vehicles based on intermodal technologies in the transport of goods in supply chains is of great importance. The solution of this problem requires the development and implementation of

* Corresponding author: jamol.alisherovich@mail.ru

technologies that ensure the absence of overloading of the cargo unit in the event of a change in the mode of transport during the delivery of cargo[11, 12].

In some cases, it is required to transport goods from the consignor's storage to the consignee's storage only by road. In this case, the whole process is carried out on vehicles, from loading the cargo to unloading the cargo. This type of transport has both negative and positive sides. On the positive side, there is no loading and unloading of cargo during transportation, and the probability of damage to the cargo is small, on the negative side, the cost of transporting cargo over long distances is high compared to other types of transportation[13, 17].

The next type of transportation compared in this study is the carriage of goods in covered wagons by rail. In this case, the goods are loaded into a vehicle at the consignor's storage, secured and transported by road to a railway line or logistics terminal. After that, the cargo received at the railway line or logistics terminal is unloaded from the road transport and loaded into a covered wagon for transportation by rail. In this order, the cargo will be processed and reach its destination at the next transhipment point[4, 15, 21].

2 Research method

The main requirements for cargo transportation are to quickly, safely and cost-effectively deliver cargo to its destination[5,6]. When delivering goods to the destination, the consignor must choose an effective method of transportation and carry out the transportation, taking into account all of the above influencing factors. Table 1 shows the definition of the economics of modes of transport close to contrailer transport.

Table 1. Overview of total transportation costs.

Mode of transportation	**Total cost formula**
By road	$C_{road} = C^1_{load} + C^1_{doc} + C^1_{transport} + C^1_{unload}$
Container transportation	$C_{container} = C^2_{load} + C^2_{doc} + C^2_{storage\to ter} + C^2_{transport} + 2 \cdot C^2_{storage} + 2 \cdot C^2_{overload} + C^2_{ter\to storage} + C^2_{tunload}$
Contrailer transportation	$C_{contrailer} = C^3_{load} + C^3_{doc} + C^3_{tr.byroad\to ter} + C^3_{tem.tr} + C^3_{ter\to trbyroad} + C^3_{unload}$
By railway (in covered wagon)	$C_{railway} = C^4_{roadloading} + C^4_{doc} + C^4_{trbyroad\to ter} + 2 \cdot C^4_{storage} + C^4_{trbyrailway} + 2 \cdot C^4_{overload} + C^4_{ter\to trbyroad} + C^4_{unload}$

The following information was taken into account when conducting the research

1. Transportation of goods is not taken into account in the case of contralier, the car is considered to be loaded into the wagon.
2. transport costs in this research are based on international transport determination politics.
3. All cost estimates in this research will be to change over time and depending on the country in which they are applied, but the methodology used to determine the total transport cost remains the same.

The cost of works is given below [C_{min}; C_{max}], the average cost of the workflow was calculated as (C_{min}+C_{max})/2. This cost may increase or decrease over time in other countries as well.

In which: C^1_{load}- the cost of loading and fastening a unit of transported cargo to a vehicle, in this research, the mass of cargo is assumed to be 20 tons. The amount of this cost was taken within (2.4-2.7 million sums).

C^1_{doc}- the cost of documents for the transportation of goods by road, the amount of this cost was taken within the limits (0.3-0.45 million).

$C^1_{transport}$- the cost of cargo transportation from the sender to the recipient in a full vehicle is determined by the following formula

$$C^1_{transport} = \alpha_A \cdot S \cdot t$$

where: α_A - is a variable coefficient depending on the volume of transportation, mass, volume, distance of transportation, domestic or international transportation;

t - is the mass of the transported cargo, tons.

Based on table 2, below is the cost of transportation depending on the given parameters.

Table 2. The cost of transportation depending on the given parameters.

Distance	**100 km**	**200 km**	**500 km**	**800 km**	**1000 km**	**1200 km**	**1500 km**	**2000 km**	**2500 km**
$C^1_{transport}$, *mln*	3.893	6.899	12.441	15.834	20.244	22.620	28.275	33.935	40.716

C^1_{unload}- the cost of unloading cargo from the vehicle, the amount of this cost (2.3-2.8 million sums).

C^2_{load} - the cost of loading and securing a cargo unit in a 40-foot container, the amount of this cost is accepted within the limits (2.4-2.7 million sums).

C^2_{doc} - the cost of documents for container transportation, the amount of this cost is accepted in the range (0.3-0.45 million sums).

$C^2_{omb\to ter}$ - the cost of transporting a container from the consignor's storage to the cargo terminal by road, the amount of this cost depends on the distance between points, is taken at a distance of 20-30 km (0.9-1.4 million).

$C^2_{storage}$ - the cost of storage of transported containers at the container site, depending on the period of storage, is accepted within the limits (0.8-1.2 million sums).

C^2_{reload} - the cost of reloading the transported container at the cargo terminal, the amount of this cost is in the range (0.2-0.35 million sums).

$C^2_{ter\to storage}$ - the cost of transporting a container from the cargo terminal to the storage of the consignee by road, the amount of this cost is accepted within 20-30 km (0.9-1.4 million sums) depending on the distance between points.

C^2_{unload} - the cost of unloading the container to the storage of the consignee, the amount of this cost was accepted within the limits (2.2-2.8 million sums).

$C^2_{transport}$ - the cost of transportation between railway stations.

Based on table 3, the cost of transportation is presented at the rate of international transportation, depending on the weight of the cargo and the distance of transportation.

Table 3. The cost of transportation is presented at the rate of international transportation, depending on the weight of the cargo and the distance of transportation.

Distance	**100 km**	**200 km**	**500 km**	**800 km**	**1000 km**	**1200 km**	**1500 km**	**2000 km**	**2500 km**
$C^2_{transport}$, *mln*	3.767	5.112	8.636	13.029	16.344	16.681	17.075	17.747	18.419

C^3_{load} - the cost of loading and securing the contrailer to the trucking out the inversion transportation, the amount of this cost was accepted in the range (2.3-2.8 million sums).

C^3_{doc} - the cost of registration of transport documents for the implementation of contrailer transportation, the amount of this cost is accepted in the range (0.3-0.4 million sums).

$C^3_{trbyroad\rightarrow ter}$- the cost of transporting the truck to the terminal, the amount of this cost is accepted within 20-30 km (0.9-1.4 million sums) depending on the distance between the points.

$C^3_{trbyrailway}$- the cost of contrailer transportation depending on the distance.

Based on table 4 below, the cost of transportation is presented at the rate of international transportation, depending on the parameters of the cargo and the distance of transportation.

Table 4. The cost of transportation is presented at the rate of international transportation, depending on the parameters of the cargo and the distance of transportation.

Distance	**100 km**	**200 km**	**500 km**	**800 km**	**1000 km**	**1200 km**	**1500 km**	**2000 km**	**2500 km**
$C^3_{trbyrailway}$, *mln*	4.193	7.299	10.441	11.244	12.556	15.066	17.833	21.91	24.785

$C^3_{ter\rightarrow trbyroad}$ - the cost of transporting a truck from the terminal to the consignee, the amount of this cost is expected to be within 20-30 km (1.1-1.5 million sums) depending on the distance between the points.

C^3_{unload} - the cost of unloading cargo from a truck, the amount of this cost was accepted within the limits (2.3-2.8 million sums).

$C^4_{loadtoroad}$ - the cost of loading and securing the transported cargo to the road transport, the amount of this cost (2.3-2.9 million sums) is accepted.

C^4_{doc} – expenses for registration of transport documents for the transportation of goods by road and rail, the amount of these expenses is 0.3-0.4 million sums.

$C^4_{trbyroad\rightarrow ter}$- the cost of transportation from the consignor to the railway station, the amount of this cost is from 20-30 km (1.1-1.8 million sums) depending on the distance between the points of reception.

C^4_{saq} - the cost of storing cargo at the transport point, the amount of this cost is accepted within the limits (0.9-1.3 million sums).

$C^4_{trbyrailway}$ - distance-dependent cost of transporting cargo of a given mass in a closed implementation of railway transport.

Based on table 5 below, the cost of transportation is presented at the rate of international transportation, depending on the parameters of the cargo and the distance of transportation.

Table 5. the cost of transportation is presented at the rate of international transportation, depending on the parameters of the cargo and the distance of transportation.

Distance	**100 km**	**200 km**	**500 km**	**800 km**	**1000 km**	**1200 km**	**1500 km**	**2000 km**	**2500 km**
$C^4_{trbyrailway}$, *mln*	3.128	4.718	8.888	12.934	15.429	16.210	17.460	19.543	21.425

C^4_{reload}- the cost of reloading the cargo at the place of changing the mode of transport during the transportation of cargo, the amount of this cost is in the range (0.3-0.4 million sums).

$C^4_{ter\rightarrow trbyroad}$ - the cost of transportation of the transported cargo from the terminal to the consignee, the amount of this cost depends on the distance between the points, is accepted for a transportation distance of 20-30 km (1.0-1.8 million sums)

C^4_{unload} - the cost of unloading cargo from the wagon, the amount of this cost was accepted within the limits (2.2-2.8 million sums).

Comparison of the types of transportation for full road transportation, container transportation, contrailer transportation and transportation of goods in covered wagons shows [16, 18, 20] the total cost of transportation depending on the distance and cargo parameters, calculated according to table 6:

Table 6. The total cost of transportation depending on the distance and cargo parameters.

Types of transport	**100 km**	**200 km**	**500 km**	**800 km**	**1000 km**	**1200 km**	**1500 km**	**2000 km**	**2500 km**
S_{road}, mln	9.368	12.374	17.916	21.309	25.719	29.695	33.75	39.41	46.191
$S_{container}$, mln	16.542	17.887	21.411	25.804	29.119	29.456	29.85	30.522	31.194
$S_{contrailer}$, mln	12.093	16.199	18.341	21.144	23.456	24.966	26.733	29.91	32.985
$S_{railway}$, mln	15.328	16.918	21.088	25.134	27.629	28.41	29.66	31.743	33.625

The change in the cost of transportation of 20 tons of cargo, provided for transportation on the basis of table 6, for given distances by mode of transport is shown in the diagram in fig. 1.

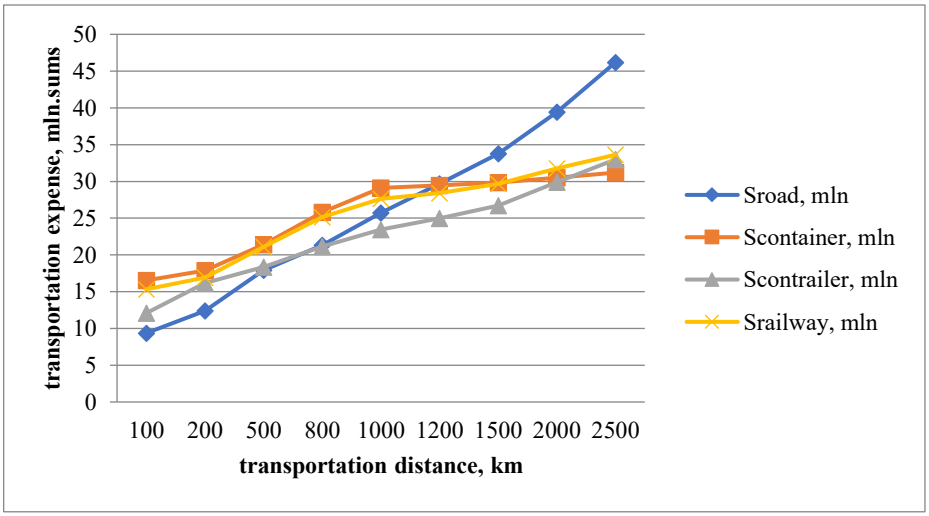

Fig. 1. The cost of transportation for the specified distances by mode of transport.

As can be seen from the diagram in Figure 1, we can see that the cost of transportation increases with increasing distance. In this case, consignors can choose the method of transportation, knowing exactly the distance of transportation according to the scheme.

Table 7. Change in transport costs per 1 t-km for given distances by modes of transport.

Types of transport	100 km	200 km	500 km	800 km	1000km	1200 km	1500 km	2000 km	2500 km
S_{road}, mln	4.684	3.0935	1.7916	1.331813	1.28595	1.18475	1.125	0.98525	0.92382
$S_{container}$, mln	8.271	4.47175	2.1411	1.61275	1.45595	1.227333	0.995	0.76305	0.62388
$S_{contrailer}$, mln	6.0465	4.04975	1.8341	1.3215	1.1728	1.04025	0.8911	0.74775	0.6597
$S_{railway}$, mln	7.664	4.2295	2.1088	1.570875	1.38145	1.18375	0.988667	0.793575	0.6725

Change in transport costs per 1 t-km for given distances by modes of transport provided for transportation on the basis of Table. 7 is shown in the diagram in fig. 2.

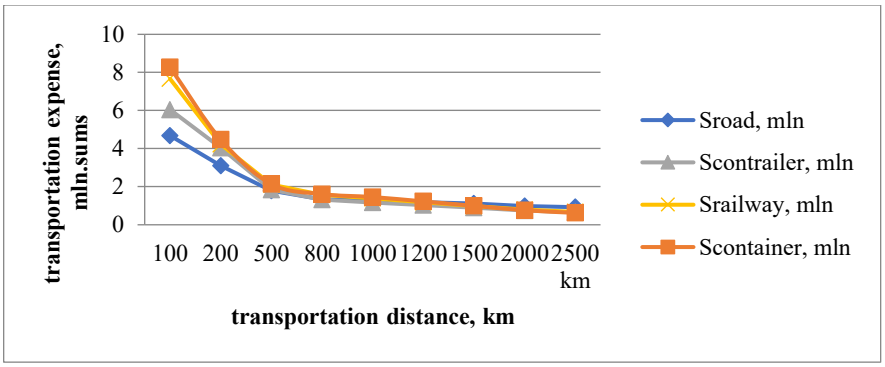

Fig. 2. The cost of transportation of 1 t-km for given distances by mode of transport.

3 Conclusion

According to the results of this research, consignors have the opportunity to choose an effective type of transportation depending on the distance and weight of the cargo. Based on table 1, the cost of transporting goods by road for short-range transportation, container transportation, contrailer transportation and rail transportation for long-distance transportation is presented. Thanks to the presented results, consignors and organizations can choose an inexpensive way to transport goods.

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