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Improvement of the logistics of container transportation at border stations and terminals

Abstract. Improving the quality of transportation services requires carriers to find better methods of optimizing routes and work with containers when traveling from Ukraine to EU countries. It has been established that container transportation already occupies a significant share of the market and the tendency to use it is only increasing. Ukraine, as a transit state, has great potential for the development of its own railway transportation system. This article studies the optimization of border crossings passage to implement and expand transport capabilities of Ukrainian railways.
Keywords: Ukrainian railways, container, transportation, Ukraine, rail transport.

1. Introduction

Currently, due to political situation in Ukraine, there is an increasing interest in the cooperaion with the EU countries. This creates the need to improve terminals or railway stations of Ukraine, since it is our country that is primarily interested in integration into the EU logistics system. Ukraine's favorable geographical position allows this idea to be implemented. There are 4 out of 10 existing pan-European transport corridors pass through the territory of Ukraine. Due to its location, Ukraine has the highest transport transit rating in Europe - 3.11 points. For instance, Poland has much smaller territory and a transport transit rating of only 2.72 points [3], earns almost 4 billion dollars profit from transportation every year. Ukraine has much better potential. The article primarily considers the involvement of rail transport, which occupies 18% of all container transportation in Ukraine and has a number of advantages that rail transport can provide [10].

Recently, container transportation occupies an increasingly important share in all freight traffic. On practice container transportation allows to reduce the cost of packing operations by more than 2 times, increase labor productivity by 4-5 times, and provide conditions for complex mechanization and automation of transshipment operations[13], [14].

Transport and logistics system of Ukraine is at a rather low level compared to other countries of the world. Transport corridors` development and arrangement level does not meet the growing needs of trans-European communication. Only 70% of the transit potential is used. International transport corridors passing through the territory of Ukraine do not meet international requirements and the market itself is not well-structured. Most of the problems in this area are related to the disproportionate development of transport and logistics services. As a result, according to the logistics efficiency index Ukraine ranks 102nd among 155 countries. Based on this, it is proposed to modernize and expand border terminals and stations, with further integration into the European transport system.

2. Relevance

Despite of the great potential, Ukrainian railways have currently stuck at a rather low level of providing the transporting service. It is clear that this problem has to be resolved in order to have a chance for integration in European rail system and have access to EU market. Thus, we have a challenge of modernizing the border container terminals in Ukraine. The method we propose would help our rail system to resolve a number of issues concerning with delays and safety of cargo during its transportation through the border terminals. It would greatly benefit the country in general and will boost the development of our rail infrastructure.

3. Literature Review

Prominent scientists of different countries and cultures made a significant contribution to the study of the problems of the development of container transportation [14, 15, 16]. A thorough technical analysis of foreign experience in the organization of trailer transportation and features of the technical support of the relevant transportation is carried out in the article[9]. The need to ensure the development of container terminals is a priority task for the modernization of the transport industry in general. At the same time, today the issue of the development of Ukrainian terminals has not been fully investigated. There is no plan for the development of engineering and technical support for container transportation, no technical solutions have been invented that could offer a solution to certain problems and contradictions that cause delays at border terminals.

4. Research Methodology

The railway transport network of Ukraine allows efficient transportation of containers to EU countries with further integration into the European logistics and transport system. The border with Poland has 2 railway crossings that can handle container trains. According to its structure, this is a two-stage transport task, when the transportation of products is carried out in two stages: first from the shipper to the border crossing, then from this border crossing to the receiver (Fig. 2)

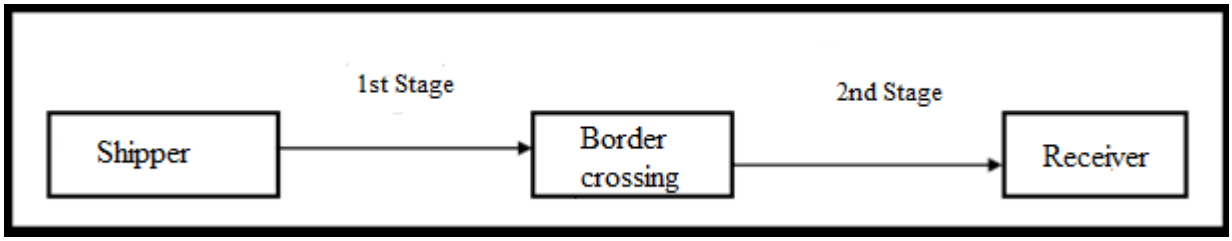

Fig. 1. - Visualization of the two-stage transport problem

Setting up an economic-mathematical model. Transportation from the starting point to the final point takes place in 2 stages. First from the shipper to the border crossing point, and then from the intermediate point to the receiver. We denote the number of shippers by m, and the amount of products available to each of them by $a_i (i - \overline{1,m})$. We denote the number of receivers by n, the demand of each recipient by $b_j (j = \overline{1,n})$. The number of border crossings is denoted by p, and the capacity of each k- border crossings point is denoted by $c_k (k = \overline{1,p})$. The costs of transportation of a unit of production from the i-shipper to the k-border crossing point are denoted by s_{ik} $(i = \overline{1,m}; k = \overline{1,p})$, and the costs of transportation for a unit of production from the k-border crossing point to the j-receiver - through t_{kj} $(k = \overline{1,p}; j = \overline{1,n})$. We need to find volumes x_{ik} transportation of products from shipper to border crossing points $(i = \overline{1,m}; k = \overline{1,p})$ and volumes y_{kj} transportation of products from border crossings point to receivers $(k - \overline{1,p}; j - \overline{1,n})$, so that the total costs z for all routs would be minimal.

Under the given conditions and designations, the economic-mathematical model of the two-stage transport problem can be expressed as:

$$z = \sum_{i=1}^{m}\sum_{k=1}^{p} s_{ik}x_{ik} + \sum_{k=1}^{p} a_k * (v_k + f_k) + \sum_{k=1}^{p}\sum_{j=1}^{n} t_{kj}y_{kj} \to \min \qquad (1.1)$$

$$\sum_{k=1}^{F} x_{ik} \le a_i, \qquad i = \overline{1,m}; \tag{1.2}$$

$$\sum_{k=1}^{p} y_{kj} = b_j, \qquad j = \overline{1,n}; \tag{1.3}$$

$$\sum_{i=1}^{m} x_{ik} = \sum_{j=1}^{n} y_{kj} \le c_k, \qquad k = \overline{1,p}; \tag{1.4}$$

$$x_{ik} \ge 0, \qquad i = \overline{1,m}, \qquad k = \overline{1,p}; \tag{1.5}$$

$$y_{kj} \ge 0, \qquad k = 1,p, \qquad j = 1,n. \tag{1.6}$$

The cost function (1.1) of the problem (1.1) – (1.6) reflects the requirement to find the most economical (currency) plan for product transportation.

a_k – volume of transportation for k terminal,

f_k – waiting costs for k terminal;

v_k - tariff cost of transshipment for k terminal, USD/t.

Other conditions of the problem mean, that:

(1.2) – the volume of products to be exported from each sender must not exceed the available stock;

(1.3) – the volume of products imported to each receiver must correspond to its demand;

(1.4) – all freight brought to each border crossing pint from the shipper must then be sent to the receiver, and the bandwidth capacity of each border crossing point should be taken into account;

(1.5), (1.6) – volumes of transportation for each of the routes must be integral.

Mathematically, problem (1.1) – (1.6) is a linear programming problem with continuous non-negative variables. It can be solved using the simplex method, or it can be reduced to a classic one-stage transport problem and solved using the potential method.

The conditions for the existence of a solution to the problem are as follows:

1) the total stock of products of all shippers allows to satisfy the aggregate demand of all receivers:

$$\sum_{i=1}^{m} a_i \ge \sum_{j=1}^{n} b_j \tag{1.7}$$

2) the bandwidth capacity of all border crossing points is sufficient to process the total flow of products in the transport network:

$$\sum_{j=1}^{n} b_j \ge \sum_{k=1}^{p} c_k \tag{1.8}$$

If the specified condition is not fulfilled, the witing costs for k-border crossing point are entered:

$$f_k = CH_k * \frac{Q_k}{S_k}; \tag{1.9}$$

CH_k – the cost of waiting time at the terminal, cont/h;

Q_k – the total number of containers for processing at k transition, cont;

S_k – processing capacity of transition k per day, cont.

5. Results and Discussion

Most of the freight that run through the territory of Ukraine is transported by rail or road transport, which creates fierce competition within the country's freight transportation market. However, considering the focus on the European freight transport market, there are some factors that will proof rail transport benefit [12]. For example, EU countries pay considerable attention to reducing carbon dioxide emissions. The EU has set itself the goal of reducing greenhouse gas emissions by 55% by 2030. According to preliminary data, net EU emissions in 2020 were 34% below 1990 levels. This means that the majority of road freight transportation at a distance of more than 300 km is planned to be transferred to other modes of transport, for example, railway or sea transport [1]. Transport accounts for 27% of Europe’s total CO2 emissions. Rail is the most energy efficient mode of passenger transport. If more people were to travel by train and more freight transported by rail (rather than more polluting modes) then the CO2 emissions from the transport sector would be greatly reduced [8], [11].

Ukraine has a great transit potential; it is one of the most powerful railway countries in Europe. Ukraine’s rail network is managed by the state and is one of the most extensive in Europe, with over 20,000 km of track (not including the occupied territories, the network of which is not operating today), of which 45% is electrified [7]. In terms of freight transportation, Ukrainian railways rank fourth on the Eurasian continent, losing to the railways of

China, Russia and India. The load capacity of Ukrainian railways (annual volume of transportation per 1 km) is 3-5 times higher than the corresponding indicator of developed European countries.

There are 3 railway transport corridors pass through the territory of Ukraine - No. 3, 5, 9. Through the Ukrainian ports of Ismail and Reni, there is interaction with the pan-European corridor No. 7, which passes through the Danube River. The current length of the national network of railway transit corridors in Ukraine is 3162 km. These are mainly two-track electrified highways equipped with self-locking, characterized by a high level of use of technical means. In addition, transportation along the TRACECA international transport corridor (Europe – Caucasus – Asia) is getting developed.

Ukraine pursues an active policy of supporting European initiatives on the ITC, offers its options for corridors to the European Community.

According to the results of English Rendell Institute research regarding the transit ratio (the ratio of the number of physical tons transshipped by the direct option to the total number of transshipped physical tons) [4]. Ukraine ranks first in Europe, but the utilization of Ukraine's transport infrastructure is still quite low. The creation of transport corridors and their entry into the international transport system is recognized as a national priority for the development of the transport and road infrastructure of Ukraine.

As of November 16, 2022, 5,045 wagons with products were sent abroad and 1,310 wagons with products were imported through the Izov - Hrubeszów crossing, of which 1,851 - with grain, 1,352 - with containers, 820 - with metal products, 141 - with ore . The average daily processing decreased by 36 cars compared to October - to 398 (315 in export, 82 - in import), in particular due to a significant decrease in the transportation of raw ore materials. Currently, the share of such products among the entire cargo flow is 10%, while ore used to occupy up to 60% of the volume.

Therefore, the crossing Izov – Hrubeszów is underloaded by 50% of its capacity (six trains are served daily instead of 12).

1,361 wagons with goods were exported through the Yagodyn station, and 933 were imported. The Polish side reported that the crossing is underloaded with bulk products, as a result of which it loses one train per day in processing. This month, the average daily rate of processing of the fleet is 143 cars (85 - abroad and 58 - to Ukraine).

At the crossing Mostyska 2 - Medyka this month, the daily transfer of rolling stock increased by 33 cars to 209. In total, 2,008 cars were transferred from Ukraine. There are 712 wagons in the queue (-147 compared to the beginning of the month).

The representative of PKP Cargo reported that the operator is ready to provide locomotives for receiving cargo at night. However, in light of recent events, the company has yet to develop a clear regulation of the actions of co-workers during air-raid alert.

Ukrainian shippers initiated the process of approving the passage of rolling stock with an axle load of 25 tons through this transition. During the meeting, it was concluded that the Ukrainian rail near the border is not adapted to such process of. Meanwhile, the rails in Poland are designed for the movement of such transport, with the exception of non-general use rails of some terminals.

Only 92 wagons were processed at the Rava-Rusk - Verkhrat crossing in 16 days of November, the daily transfer was reduced from 12 to 6 wagons in October. The receiving stations (Verhrata, Szczecin) are clogged with wagons with clay. The representative of the Polish operator assumes that the acceptance of clay will resume under the conditions of reducing the accumulation of such rolling stock to 200 units. However, other products can be accepted without delay.

Based on the purpose of this article, the ability of Ukrzaliznytsia stations to process container trains bound for EU countries is considered. Currently, Ukraine has at its disposal 5 container terminals at the border stations of Ukraine. That is why it is advisable to highlight the terminals at the border crossing segment:

1. Mostyska-Medyka (Poland)
2. Jagodin-Dorohusk (Poland)
3. Vadul Siret - Dornesti (Romania)
4. Chop — Chierna nad Tisou (Slovakia) / Zahon (Hungary) [9]

All processing capacity data are listed in the table below.

Table 1. **Transshipment terminals at border stations of Ukraine**

Termina l No	Name of the transition	Station/ Terminal (Ukraine)	Processing capacity wagons/day
1	Mostyska-Medyka	Mostyska-2/MC Lviv	180
2	Yagodin-Dorogusk	Yagodin/Avtokom	25
3	Vadul Siret - Dornesti	Vadul-Siret/MC Lviv	70
4	Chop — Chierna nad Tisou	Chop/MC Lviv	25
		Chop/Lesky	50
		Chop/Exporttransbud	25
		Batiove/Terminal Karpaty	25

Based on the above-mentioned data, the Mostyska-Medyka and Chop — Chierna nad Tysou crossings are the most in demand, demonstrating the processing capacity of 180 and 125 wagons per day, respectively.

Taking into account the queue of wagons for foreign operators in the UZ (Ukrzaliznytsia) network, as of January 4, 18,800 wagons addressed to foreign operators are waiting in the UZ network, in particular, 32 were loaded before November 1, 3,119 - in November, 12,900 – in December, etc.

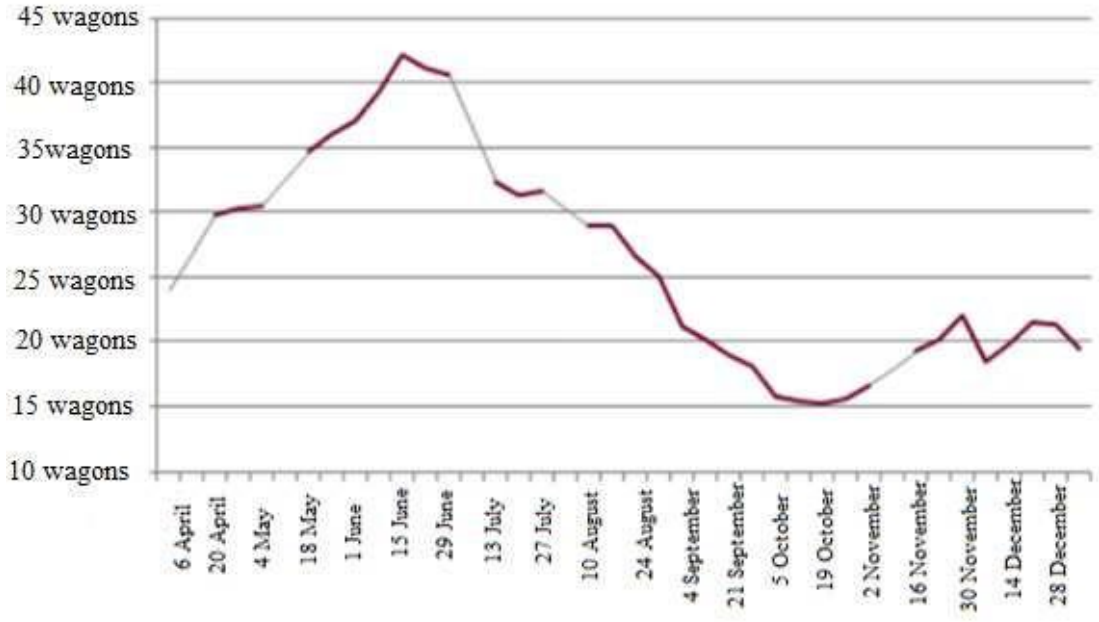

Fig. 2. Dynamics of changes of wagons awaiting transfer through land border crossings, thousands of units

The method proposed above will significantly improve the process of identifying problems at transport border crossings. This will make it possible to develop a plan for the modernization of terminals depending on the number of incoming containers. Moreover, the method allows you to choose the most optimal way of distributing containers in order to reduce the business of terminals. The method will find application based on Ukraine's interest in integration into the European transport market.

6. Conclusion

The introduction of this method allows us to highlight certain advantages:

- investing in the development of logistics border centers that increase the efficiency of logistics operations and the indicators of container processing;

- development of the transport system, optimization of container transportation routes;

- increasing the competitiveness of railways compared to other modes of transport;

- creation of a favorable climate for Ukraine's integration into the EU transport system;

- the cargo owner receives a better delivery time to the reduction of wagon waiting hours, and the carrier improves the quality of service provided, expanding the number of customers;

- opens the prospect of modernization and expansion of border crossings, due to the identification of shortcomings and problems.

In 12 months of 2022, 150.6 million tons of freight were transported, which is 52.1% less comparatively to the previous year. According to the results of December, Ukrzaliznytsia transported 10.2 million tons of cargo, which was the worst indicator since July. The best figures in 2022 were pre-war January and February - 26.2 million and 22.3 million tons, respectively. March was the worst month - 8.3 million tons. From then until the end of the year, volumes increased by 23%.

More than half of the freight had to be transported within Ukraine, 39.4% for export, 8.2% for import, and 1.8% for transit. 76.1 million tons were inside the country, 59.4 million tons were exported. The largest amount of grain was transported for export - 22.5 million tons, in the total amount of export, grain makes up 38%. Cargo transportation in containers was 257.2 thousand TEU [6].

To draw the conclusion, it would be fair to mention that rail container transportation is quite sought –after in Ukraine and has a positive tendency to use in the future. Therefore, based on the above-mentioned statistics and method we consider it one of the most efficient way of modernizing the Ukrainian border terminals.

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Д. В. Ломотько, Д. Д. Ковальов. Удосконалення логістики контейнерних перевезень на прикордонних станціях і терміналах

Анотація. Підвищення якості транспортних послуг вимагає від перевізників пошуку кращих методів оптимізації маршрутів та роботи з контейнерами під час перевезень з України до країн ЄС. Встановлено, що контейнерні перевезення вже займають значну частку ринку і тенденція до їх використання тільки зростає. Україна, як транзитна держава, має великий потенціал для розвитку власної системи залізничного транспорту. У статті досліджено питання оптимізації пропуску через державний кордон для реалізації та розширення транспортних можливостей залізниць України.

Ключові слова: Українські залізниці, контейнер, перевезення, Україна, залізничний транспорт.

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