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Mariia OLKHOVA*, **Yurii DAVIDICH, Dmytro ROSLAVTSEV**
O.M. Beketov National University of Urban Economy in Kharkiv
Transport Systems and Logistics Department
Revolyutsiyi 12, Kharkiv, Ukraine
Nataliia DAVIDICH
O.M. Beketov National University of Urban Economy in Kharkiv
Department of Project Management of Urban Economy and Civil Engineering
Revolyutsiyi 12, Kharkiv, Ukraine
**Corresponding author*. E-mail: olhovamv@gmail.com

THE EFFICIENCY OF TRANSPORTATING PERISHABLE GOODS BY ROAD AND RAIL

Summary. This research analyses the competitive advantages of road and rail transport through the example of Ukraine transportation market. Spheres of efficient usage of rail and road transport while transporting perishable goods have been studied. The key factors influencing the mode choice, as well as the kinds of cargo that depend on the mode choice have been determined with the help of revealed preference data. A mathematical model of mode choice has been offered. The criterion of the effectiveness of this model is the economical profit of the logistics system 'shipper – carrier – receiver'. The advantage of using the suggested model is the possibility of calculating invisible costs while evaluating alternative transport mode, including funds immobilization and cargo loss. The tools in the study are the methods of system analysis, mathematical modelling, regression analysis and expert evaluations. The acquired results can be used while justifying the mode choice and determining the spheres of efficient usage of various modes of transport. It has been determined that the factor for using the rail is the distance longer than 600 km, as the economical profit of the logistics system is higher in this case. At the same time, with distances shorter than 600 km, road transportation is a better choice.

1. INTRODUCTION

The main modes of transport that carry more than 82 per cent of the total freight in the Ukrainian transportation market are road (about 27 per cent) and rail (more than 55 per cent) transport [1]. The abovementioned modes of transport are the main competitors in the internal market of freight carrying in Ukraine. The liberalization of the pricing policy of PLC 'Ukrzaliznitsiya' and of the freight wagons' lease conditions for transportation companies led to the improvement of the overall level of transportation services and the increased attractiveness of rail transport for potential clients (freight owners). At the same time, the competitiveness of road transport has been lessened by the quick correlation of the transportation costs depending on the price of fuel or currency rate. Such correlation in road transport happened much faster than that in rail transport. The overall situation in the country also led to raising the level of competitiveness between the two modes of transport. The analysis of the freight delivery schemes' effectiveness, including the choice of the transportation mode, is a subject that companies that own freight constantly monitor and pay attention to. The transportation sphere is sensitive to transformations in the country's economy, environmental challenges and modern technological solutions; however, insufficient attention has been given to studying such influence in Ukraine. The transport strategy of Ukraine for the period until 2020 foresees the creation of a stable cost-effective system of freight transport and logistics and fair market competition conditions between

various modes of transport, for both national and international freight carrying [2]. The abovementioned claims imply that the problems of freight carrying effectiveness, including the choice of mode of transportation, continue to be important at the current stage of development of logistics systems and are of a great practical and scientific interest.

2. LITERATURE REVIEW

The most complete analysis of scientific publications dedicated to the issue of transportation mode choice is given in papers [3, 4–7]. Many of the studies are dedicated to the issue of choice of the transportation mode at the middle level – how transportation occurs within the country [3, 6, 8, 9, 10–13]. Many studies are dedicated to the issues of interaction and coordination of road and rail transport [14, 15, 16–19]. Less attention has been given to the issues of choosing the transportation mode and particular kinds of freight [4, 10, 20], or the direction of transporting freight [5, 21, 22].

The main criteria of choosing the mode of transportation are transportation cost (price) [4, 14, 23–25], total logistics costs [18, 20, 26, 27], distance [4, 20, 21], time [4, 20, 24], transportation demand, infrastructure (accessibility, network and density) [4, 5, 20, 21], safety [4, 28], reliability [20, 24, 28], responsiveness [28], lost and damage cost [20], scheduling flexibility [20, 24], service supply characteristics, and freight demand characteristics, such as the commodity type to be transported, the origin of shipment, and highway or railway network [5], fuel cost [5], commodity [5, 21], shipment [5], logistics opportunity costs [8], expenses of the transportation customer [29] and equal expenses distance [15, 23, 30]. The main criterion in the case of absence of the transportation structure is considered to be capital expenses [15, 23].

The methodological basis of studying the problems of the transportation mode choice consists of: discrete choice theory [9, 10, 31, 32], expert methods [4, 6, 9], binary logit and probit models [5, 9, 11, 21], game theory [22, 33], principal components analysis [5], shipping mode choice model based on the analytic hierarchy process [4], what-if/what-to approach [3], decision supportive method for mode choice [4], agent-based modelling [24] and activity-based approach [34]. In these sources [6, 9] determining the mode of transportation choice is based on studying freight demand using Revealed Preference and Stated Preference Methods [10, 12].

The results of the research dedicated to transport mode choice or using a certain model to determine the mode choice cannot be generalized without the practical adaptation due to the factors like the practicality of the issue, economical and technical conditions, various approaches to decision-making criteria and systems of restrictions. At the same time, it has to be noted that the mode choice decision-affecting criteria concerning the types of cost effectiveness remain unchanged.

A general tendency is the rising role of factors that characterize the influence on the environment, in particular a great amount of harmful emissions due to use of automobile transport [3, 35, 36]. The European Community stresses the necessity to lessen the use of road transport and use less harmful transport modes due to the high levels of environmental pollution. The UK Department for Transport aims to promote transportation of goods by rail and water transport and reduce the volume of road freight transport. This is due to the high importance of criteria such as environmental and transportation safety [37]. The analysis of scientific publications and the commonly accepted practices shows that in Ukraine, the factors harming the environment, particularly harmful road transport emissions, are not taken into account while choosing the freight transport mode. This is explained by the fact that the ecological factors do not have a direct or indirect influence on the transportation costs.

The results of analyzing the scientific and practical experience show that in mode choice issues, the parameters and requirements of certain participants of the logistics system (shipper, receiver and carrier) are not taken into account. Most research efforts have been focused on the carrier. This does not allow to fully evaluate the economic effect while using a certain transport mode. At the same time, the result of business activity of one scheme participant directly influences the result of the other participants and the system as a whole, so in logistics systems' mode choice issues, the parameters and requirements of all its participants should be taken into account.

The aim of the study is to determine the spheres of effective use of road and rail transport while highway shipments of perishable goods within Ukraine, including the parameters and requirements of all the participants of the logistics system.

3. CRITERIA OF MODE CHOICE

The kind of freight is one of the decisive factors in the transport mode choice. This means that it is necessary to determine the groups of freight which are likely to be moved by road and rail. A more detailed analysis of this aspect is needed to explore the peculiarities of transporting every kind of freight. It is necessary to conduct an analysis of distributing the volumes of transported freight depending on its kind for trunk transportation, as well as to determine other factors that matter while using road or rail transport.

The Delphi method has been used as a tool to solve the abovementioned tasks. Experts who are directly responsible for the transportation process have been interviewed (Center of Transport Service "Liski" branch of the Public Joint Stock Company" Ukrainian Railways" a major Ukrainian enterprise, that ships cargo by rail; forwarder company LLC "Mobilis Logictic", Motor transport enterprise "ATP 16363". This company has its own fleet of about 100 specialized trailers; LLC "Olimp". This manufacturing company distributes its own food goods using rail and road transport under the conditions of insourcing and outsourcing; etc). The questioning was divided into two parts. In the first questionnaire set, the experts answered the questions related to the volumes of transported freight by both road and rail. In the second questionnaire set, the value of mode choice criteria for transporting packeted freight was determined. This was due to a large number of factors that influence the efficient mode choice and the necessity to study each of them in detail.

We surveyed the experts in the 12 largest companies in Kharkiv that are directly related to the road and rail transport use. The results acquired during the first questionnaire are presented in Fig. 1.

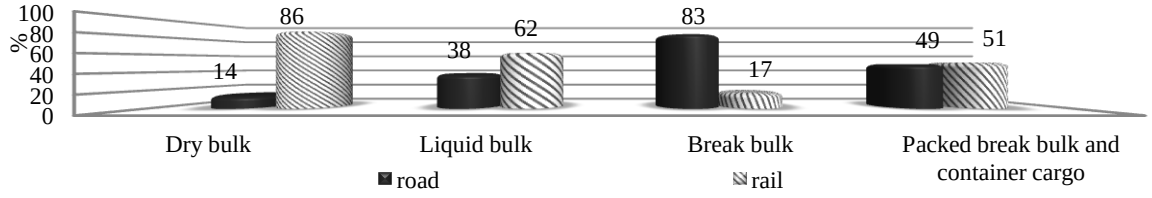

Fig. 1. Distribution of cargo types between road and rail

It has been determined that 86 per cent of bulk cargo is carried in railroad carriages, while 14 per cent is transported by road. Liquid cargo is also mostly transported by rail, at 62 per cent.

At the same time, packed (palletized) cargo is mostly transported by road, with 83 such deliveries out of a hundred done this way. Therefore, transporting packeted freight and freight in containers is done by both road and rail. This can be explained by the tendency to increase volumes of transporting containers by road and increasing of volumes of transported packeted freight while using the rail, especially in isothermal carriages. In the structure of perishable goods that are carried by rail, the majority is constituted of pastry and confectionery goods, beer, drinks, mineral waters, tinned food, meat and meat products, as well as other types of edible freight [38]. The research further ahead will concentrate on the analysis of efficiency of transporting perishable goods by road and rail in Ukraine.

In the second survey, transport costs proved to be the most significant criterion (Fig. 2). The following criteria are also significant: cargo amount, transportation time, distance, cargo safety and being on time. Moreover, factors such as 'carrying capacity', 'formation time spent on orders' and 'transport security' have been determined to have lower importance. In Ukraine, transport security is important one due to cases of robbery and criminal attack while transporting cargo by road and rail. In addition, figures provided by shippers and carriers do not differ much. The importance of expert opinion was tested using the Kendall's coefficient of concordance, amounting to 0.562. Pearson's empirical criteria value has been calculated. We have compared the following: calculated value χ^2 = 67.47 and table value χ_t^2 = 15.51. As a result, we can conclude that expert opinions are not random.

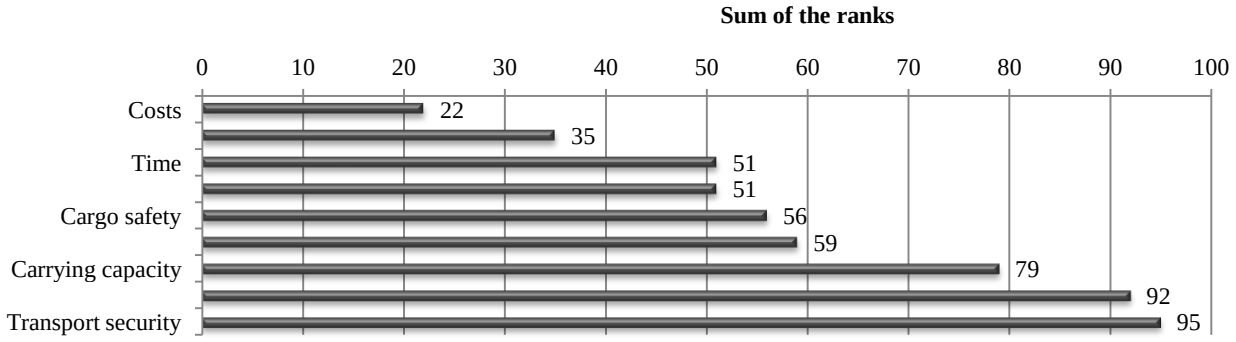

Fig. 2. The significance of mode choice criteria while shipping freight in Ukraine

4. THE TECHNOLOGICAL PROCESS OF SHIPPING BY ROAD AND RAIL

The research was performed by mathematical simulation methods. The limits of the system were defined, namely the participant numbers and their interaction. The logistics system participants are a shipper, a receiver and a carrier, Fig. 3.

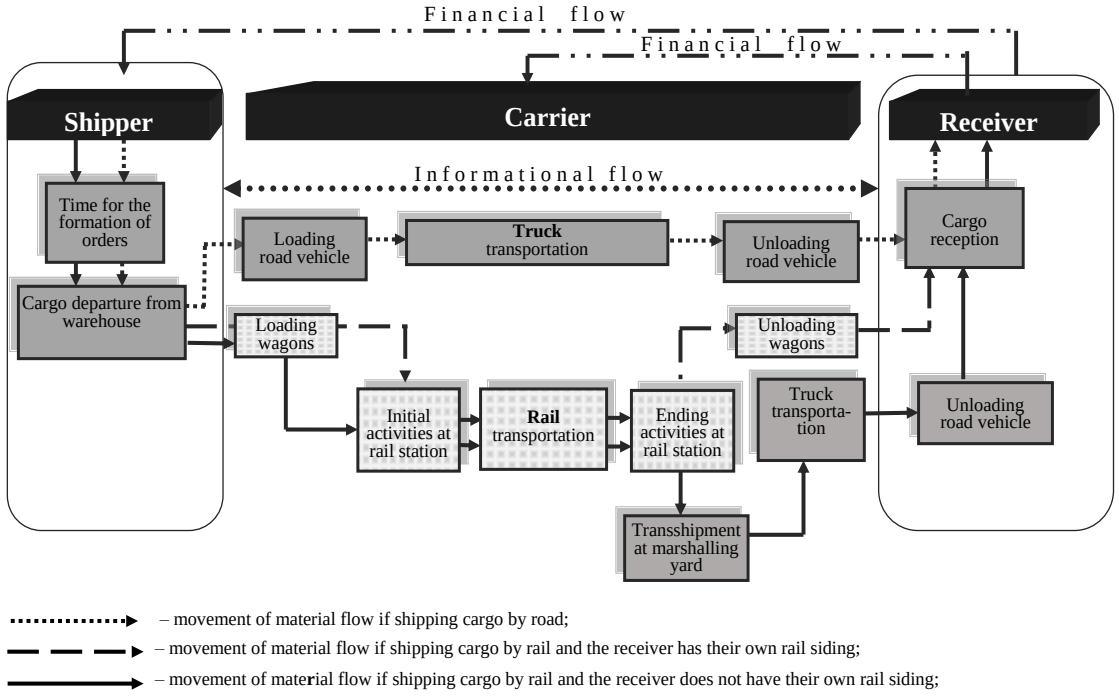

Fig. 3. The scheme of interaction of transport process participants

It is important to study using the rail in two situations: when the freight receiver owns rail siding and the one when they do not. In this case, the shipper owns rail siding. These conditions have been determined by analysing the work of manufacturing enterprises in Ukraine. Consequently, material flow is moving into insulated vehicles in intercity traffic. This way, moving freight by rail is possible in two ways: 1) shipper – rail – receiver and 2) shipper – rail – truck – receiver. In order to compare using road and rail transport, it is necessary to view the transportation process starting with the fulfillment of an order, the length of time from the moment when the shipment order comes through until the shipment is dispatched. This is due to the fact that the time used to fulfill the order differs depending on whether road or rail transport is used. In Ukraine, it takes 3 to 10 days to fulfill an order when using the rail, and up to 3 days when it comes to road transportation. First, it depends on the distance and cargo quantity. According to Tariff law № 1 approved by the decree № 317 of the

Ministry of Transport and Communications of Ukraine on the 26th March 2009, there is a restriction on the transportation rail distance (320–400 km per day). In addition, the quantity of cargo impacts the time of terminal operations including receiving, sorting and dispatching the freight at a marshaling yard. For instance, it can take from 1 to 5 days for a train to get deloaded.

Therefore, using the rail significantly increases transportation time, compared to road transportation, which, in its turn, influences the immobilization of funds while the shipment is being carried out. After the order is formed, the freight is dispatched from the warehouse and loaded onto the vehicle or wagon. After the freight is loaded, it is moved to its destination by road or rail. When the freight arrives, it is offloaded and received at the receiver's warehouse. The technological process while loading and offloading the freight while using the rail is more time-consuming than the one used in road transportation. There are a number of other differences too. This process takes place according to the terminal operations, determined by the Railway Code of Ukraine, which was approved by the decree No. 457 of the Cabinet of Ministers of Ukraine on 6th April 1998 and the Tariff law No. 1.

Terminal operations include receiving and dispatching the freight, creating the paperwork for transporting the freight, and delivering the wagons to be loaded and offloaded. If the transportation is done with the help of a different scheme and road transport needs to be used as auxiliary transport mode, the number of technological operations related to loading and offloading of the increases. All of these operations clearly increase the time that it takes for the freight to be delivered by rail transport. However, the rail charges for transporting 1 ton of freight decreases as the distance of delivery increases. Therefore, further study of the road and rail freight transportation is required.

5. A MODE CHOICE MODEL

After analyzing the technological process of delivering the freight by road and rail, choosing the effectiveness criteria is necessary. As a rule, the party which orders transportation (pays for it and expects the freight to be delivered) is most interested in minimizing the expenses and transportation time; however, modern tendencies of the market functioning dictate other requirements. All participants of the transportation process (shipper, carrier and receiver) become interested in maximizing other participants' profits. For example, if a carrier is not able to offer an attractive price, the customer can use the services of another carrier. The same applies to the carrier. If the shipper or receiver of the freight cannot supply a reasonable volume of freight to be shipped, the carrier may find another customer. Therefore, all the participants become directly or indirectly interested in maximizing the profit of others and/or minimization of expenses. Such cooperation can most frequently be observed in the B2B business models. Taking this into account, the study concentrated on choosing the transport mode in the logistics system 'shipper – carrier – receiver' by the criterion of maximum economic profit of the system. This is due to the fact that all-aspect revision related to income leads to the understanding that income calculated in accounting does not reflect the real economic activity outcome [39]. In the process of the freight delivery, there may be invisible costs that cannot be included into an accounting report, although they might have significant influence on the management decision related to mode choice, including factors such as damage and loss of cargo, immobilization and being on time. The studies [8, 40, 41] highlight the need for firms to analyse their modal choice on a regular basis and to base their decisions not only on transport costs but also on total logistics cost, which include not only the visible costs but also the invisible costs.

Studying of the transportation process in logistics systems suggests the analysis of numerous parameters, which have their own restriction range. Taking this into account, in order to formulate the conditions of the task that is being studied, the researchers are to use the mathematics means for the optimization class tasks with both-sided restrictions of the variables.

If all *n* variables (1) denote the vector $\bar{x}^T = \left[Q^{S(Ro)}, Q^{S(Ra)}, ..., T_{1god}^{Ra-Ro}\right]$, the mathematical model of an optimization problem to the limitations on the variables is characterized by the following formula:

$$EP_{sys} = EP_S + EP_C + EP_R \to \max_{\bar{x}\in\Omega\subset R^n}, \quad (1)$$

Ω: $Q^{S(Ro)+} \le Q^{S(Ro)} \le Q^{S(Ro)++}$; $Q^{S(Ra)+} \le Q^{S(Ra)} \le Q^{S(Ra)++}$; $q_{load}^{S+} \le q_{load}^{S} \le q_{load}^{S++}$; $S_{real}^{S+} \le S_{real}^{S} \le S_{real}^{S++}$; $l_{UKR}{}^{+} \le l_{UKR} \le l_{UKR}{}^{++}$; $T_{1km}^{Ro+} \le T_{1km}^{Ro} \le T_{1km}^{Ro++}$; $t_{of}^{Ro+} \le t_{of}^{Ro} \le t_{of}^{Ro++}$; $t_{of}^{Ra+} \le t_{of}^{Ra} \le t_{of}^{Ra++}$; $q_{load}^{R+} \le q_{load}^{R} \le q_{load}^{R++}$; $k_{sx}^{Ro+} \le k_{sx}^{Ro} \le k_{sx}^{Ro++}$; $k_{sx}^{Ra+} \le k_{sx}^{Ra} \le k_{sx}^{Ra++}$; $T_{1god}^{Ra-Ro+} \le T_{1god}^{Ra-Ro} \le T_{1god}^{Ra-Ro++}$,

Where EP_{sys} is the economic profit of logistics system "shipper – transport – receiver"; EP_S, EP_C, EP_R are the economic profits of a shipper, a carrier and a receiver, respectively; $Q^{S(Ro)}$ and $Q^{S(Ra)}$ are the cargo amounts while transporting cargo by road and rail for the period, respectively (in ton); q_{load}^{S} is the production capacity of handling mechanisms in the shipper's store (tons per day); S_{real}^{S} is 1 ton of cargo value (UAH/ton); T_{1km}^{Ro} and $T_{1km-UKR}^{trans(Ra)}$ are the transportation fares while transporting cargo by road and rail, respectively (UAH/km); t_{of}^{Ro} and t_{of}^{Ra} is the formation time that is spent on orders while transporting cargo by road and rail, respectively (days); q_{load}^{R} is the production capacity of handling mechanisms in the receiver's store (tons per day); k_{sx}^{Ro} and k_{sx}^{Ra} are the safety degrees while transporting cargo by road and rail, respectively; T_{1god}^{Ra-Ro} is the transportation time, waiting time and loading time from the rail station to the receiver store (hr) and symbols '+' and '++' in the restrictions mean the lowest and highest margin of the variables, respectively.

Solving optimization tasks with both-sided restrictions of the variables requires the use of coordinate descent and differential algorithm methods. For this, a multi-step procedure of coming closer to the optimum needs to be carried out. At each step, one has to carry out a multitude of calculations [42]. At the same time, the parameters of the system that is being studied are discreet; therefore, solving the problem by this method will allow to determine the value of the logistics system economic profit, which will be close to the optimal one. Taking this into account, further solving of this problem was done with the help of mathematics modelling.

Economic profit is a function of income and total costs. The objective function (1) is transformed into the following:

$$EP_{sys} = (D_S - C_S) + (D_C - C_C) + (D_R - C_R) \to \max, \quad (2)$$

where D_S is shipper income, UAH; C_S is shipper total costs, UAH; D_C is carrier income, UAH; C_C is carrier's total costs, UAH; D_R is receiver's income, UAH; and C_R is receiver's total costs, UAH.

If the economic profit of the logistics system while using road transport is higher, rather than rail, road transportation is effective. Otherwise, if the economic profit of the logistics system while using road transport is less, rather than rail, rail transportation is effective.

This model is based on using the transport mode in one direction, both with and without receivers' rail sidings. The model does not describe in detail the income formation of the logistics system participants, such as technology, manufacturing process and fines for poor service. The income for the shipper is based on the amount of produce commodity flow and selling value of a commodity flow unit, while it is based on profit margins when it concerns the receiver. It is assumed that the cost of selling value of a commodity flow does not change a transportation distance. Indicators of a commodity flow amount, distance and fare are a basis for vehicle budget incomes of a carrier.

Shipper expenditures include the manufacture prices and dispatch expenditures. These expenditures are dependent on the vehicle mode, because the time of dispatch is different for road and rail. A similar situation is for receiver expenditures. A cargo amount is based on the formation of receiver expenditures. The transportation expenditures were determined by using the average rate of profitability and income. Expenditures that are not dependent on the transport mode have not been considered in the model.

The analysis of the statistics data related to aforementioned enterprises (sec. 3) makes it clear that the factor of the cargo being intact has a significant influence on freight mode choice [43]. It has been determined that different quantities of spoilt freight occur while using road and rail. Therefore, a

'safety degree' characteristic while using road and rail has been included in the model. This value compares the volume of the delivered freight to the volume of freight dispatched from the supplier's warehouse. While these data were being analyzed, the minimal and maximum values of the level of freight safety while transporting by land and rail were determined. This thesis reviews only the average values of this indicator, as due to a higher volume of information, it is impossible to study the influence of the indicator on the freight transportation mode choice.

6. APPLICATION OF THE PROPOSED METHODOLOGY – CASE OF UKRAINE

After the mathematical model had been built, the factors of the model were analyzed. First, the ones that characterize one object or a process in the work of the system were identified. Such factors within the limits of one system should not be viewed separately from each other, as they in combination create the overall characteristics of an object or a transportation process. During such studies, several factor values could be changed. This means that if one factor that characterizes an object or a work process changes, the other factors that characterize this object might change too. For example, changing of the rail transportation fare depends on the freight volume, distance of transportation, kind of freight, ownership of the wagon (as belonging to the railway or the shipper), etc. Therefore, if the transportation distance and volume of freight increases, the rail transportation fare increases as well, according to the railway tariff scheme. Changing of the warehouse operations volume influences the exploitation expenses for loading and offloading machines. In order to use these indicators in the mathematical model, an additional study, which was related to determining of the variation range of all factors, was conducted. The report data from the distribution centers of companies in the city of Kharkiv was analyzed. Revealed preference data were collected from distribution centres and aggregated to be used in this study.

Also during the experiment, significant differences in highway and railway mileage in Ukraine were analysed. Regression analysis was used to study the distances between 24 major cities of Ukraine in highway and railway mileage using Statgraphics software, whereby a regression model was obtained:

$$l_h = 0{,}979 \cdot l_r, \tag{3}$$

where l_h is highway mileage (distance), km; l_r is railway mileage, km.

The model estimations are the following: standard error is 0,00337111, t-statistic is 290,403, R-squared is 99,754 % and F-Ratio is 84334,10. The difference in highway and railway mileage has a slight deviation of about 2%. According to this end result, the distance is accepted as being the same for road and rail between a receiver and a shipper. The experiment conditions were as follows: transportation is provided within Ukraine, cargo is transported in insulated vehicles, and road and rail vehicle capacity are 20 tons and 50 tons, respectively (vehicle capacity does not change over the quantity transported). The rail wagons are owned by the rail enterprise. The model is an analogue of the real existing logistics system in which the international beer company is the shipper. The variation ranges of the model have been adopted on the actual data analysis of the shipper, receiver and carrier: Q^{Coer} = 2000 tons/month; k_{sx}^{Ro} = 0.948; k_{sx}^{Ra} = 0.951; T_{1km}^{Ro} = 12 UAH/km; t_{of}^{Ro} = 2; t_{of}^{Ra} = 6; S_{real}^{Coer} = 2900 UAH/ton; T_{1god}^{Ra-Ro} = 6 hours. These average figures were derived by using the statistical data (revealed preference data) of logistics divisions of enterprises during one year. The shipper is a major international manufacturer that uses rail and road transport while delivering their goods in Ukraine.

It is known that the amount of cargo and distance of transportation are the main parameters of the transportation process, the ones which the transportation fare is based upon. Therefore, the expenses of the customer who ordered the shipment depend on them too. Thus, we are going to analyse the influence of these parameters on the economic profit of the logistics system while carrying cargo by road and by rail, Figs. 4 and 5.

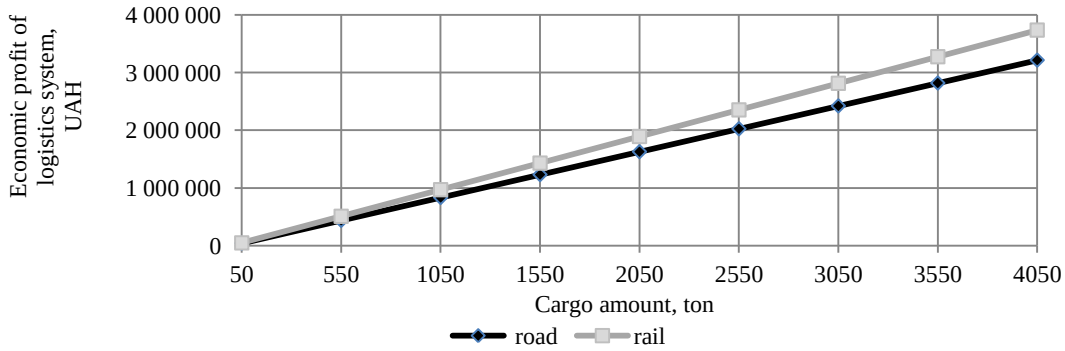

Fig. 4. Economic profit of logistics system with respect to cargo amount if the receiver has his/her own rail siding (distance 1200 km)

According to statistical data, the minimum and maximum amount of cargo was determined. The minimum cargo amount shipped by rail is 50 tons (vehicle capacity). In most cases, if the amount of cargo is less, the shipper will use road transport. Therefore, competitive cargo amount for both transport modes begin from 50 tons. Increasing the amount of transported cargo leads to increasing of the logistics system economic profit while using either mode of transport. At the same time, the larger the amount of transported cargo, the bigger the difference between the economic profit of the system while using road and rail transport, in favour of the latter. While the difference of profit may be relatively small while transporting 50 tons of cargo across 1200 km (This difference equals 6186 hrivnyas), it is multiplied by 11 if the amount of transported cargo is more than 550 tons. Therefore, if the amount of cargo is less than 50 tons, which is less than one rail wagon can fit, and the distance is 1200 km, it is sensible to use road transport. In this case, we take the distance of 1200 km due to competitive transportation distance while shipping freight by road and rail in Ukraine. If the economic profit of each participant is analysed, it can be seen that the transport mode does not influence the profit of a shipper; using the rail increases the profit of a receiver and lessens that of a carrier. This is due to the fact that the criteria that the shipper is characterized by do not depend on the transport mode. The same amount of dispatched cargo is comparable, which is done by the same loading and offloading machines in the shipper's storage warehouse.

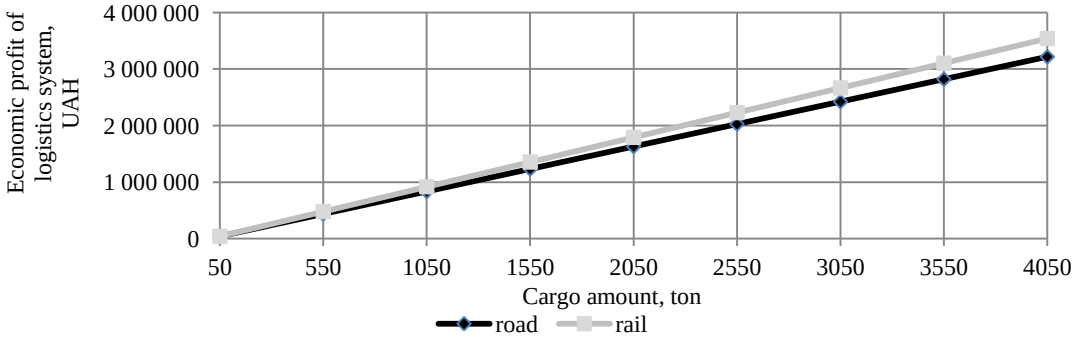

Fig. 5. Economic profit of logistics system with respect to cargo amount if the receiver does not own rail siding (distance 1200 km)

The economic result of the carrier is different while using these different modes of transport. While using the road, the profit of the carrier is much higher that while using the rail. This is explained by the fact that while using the rail, more goods are damaged or lost and the time of delivery increases, which influences the immobilization of funds. In turn, the receiver of the freight gets the highest profit while using the rail, because the expenses while using this transport mode are lower than the ones that exist while using the road.

Let us analyse the situation when the receiver does not own the rail sidings (Fig. 5). Under these conditions, the receiver will incur extra expenses while using the rail. These expenses will be connected with having to use the road transport as an auxiliary mode. Due to this fact, the profit difference between using the road and the rail while transporting 50 tons over the distance of 1200 km

is only half of the profit difference that occurs when the receiver owns their rail siding. The rest of the economic profit dependency on the amount of cargo for all the participants of the system is the same, regardless of who the rail siding belongs to.

Another significant factor that influences the mode choice is distance. The paper analyses the influence of the shipment distance on the economic profit of the system participants and the system on the whole. As a result of analysing the statistical data of companies and a poll, it has been determined that the distance when a choice between road and rail is to be made is 300 km. Road transport is normally used for distances shorter than that. The maximum distance has been chosen to be 2100 km, since it is the maximum distance the railroad in Ukraine stretches over, according to the Tariff Law №1. The results of the calculations have been obtained while using the suggested model and with the amount of cargo equaling 2000 tons.

Let us analyse the change of the economic profit of each participant of the transportation process and determine the reasons for the change, Fig. 6, 7.

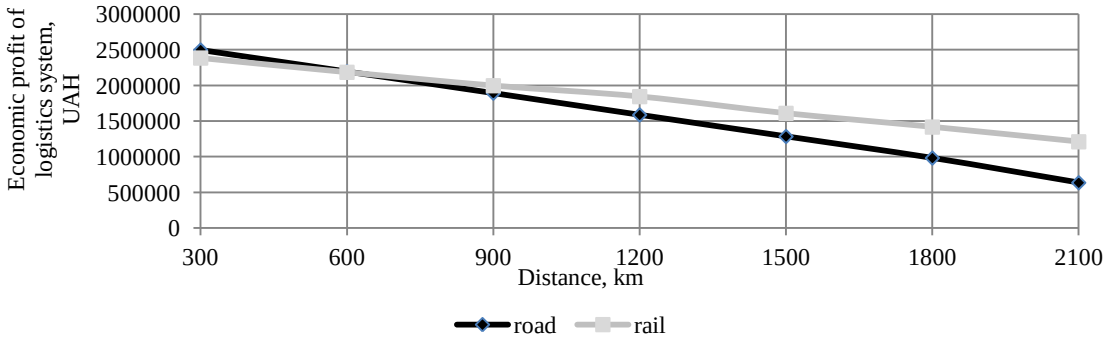

Fig. 6. Economic profit of logistics system with respect to distance if the receiver has their own rail siding

It can be seen that the shipper's profit remains unchanged if the distance of shipment changes. This is explained by the conditions of the experiment: the characteristics that describe the shipper do not depend on the mode choice.

The carrier's situation is different: the profit increases with increased shipment distance. It should be noted that the carrier's profit is much higher when using the road than the rail. This tendency is based on the fact that the carrier's profit is based on a certain hryvnias (Ukrainian currency) per kilometre tariff. However, this tariff does not depend on the distance while using the road, unlike the rail, where 'the higher the distance, the lower the tariff' rule applies. The reverse tendency is observed in the 'receiver' fields. The higher the shipment distance, the lower the profit; this is caused by increased transport expenses. For instance, if road transport is used to transport the cargo over 2100 km, the losses of the shipper will constitute 273622 UAH. Therefore, the receiver will not be using the road under these conditions. Using the rail is more reasonable in this situation.

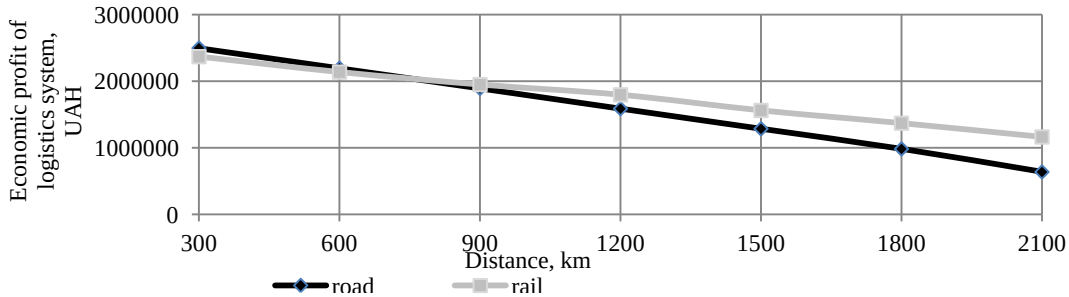

Fig. 7. Economic profit of logistics system with respect to distance if the receiver does not own rail siding

The general tendency remains while using the rail: the receiver's profit decreases, but it remains stably high. If the receiver does not own the rail sidings, the pattern of the profit change remains the same, but the profit is less than when the rail sidings exist and belong to the receiver. It can be explained by increasing the expenses for transporting the cargo by road from the loading rail station to

the receiver and increasing of the transportation time, which leads to increasing of the expenses connected to the immobilization of funds.

It can be seen from the graphs (Fig. 6, 7) that increasing of the distance of shipment in the logistics system decreases its economic profit in the linear dependency. It is explained by the fact that while modelling it is considered that the cost of a cargo unit does not depend on the distance of shipment (pricing method according to the geographical principle). Having said this, the higher the shipment distance, the bigger the difference in the economic profit while using road and rail. It can be seen that there is an intersection of the lines that mark the dependency of the economic profit of the logistics system on the distance of transporting freight by road and rail (Fig. 6, 7). The intersection point of two lines indicates the same economic profit value of a logistics system. This point can be called 'equal expenses distance'. The 'equal expenses distance' is the distance with equal efficiency (based on various criteria, such as expenses, time, profit) of using different transport modes [44]. Using the graphic method of determining the optimum point, we have found out that if the distance of transportation equals 600 km, using road and rail is equally efficient, as the economic profit is almost the same (2185662 UAH and 2194856 UAH). From graph 5 we can determine that the sphere of using the rail is the distance longer than 600 km, as the profit value of the logistics system is higher in this case. At the same time, with distances shorter than 600 km, road transportation is a better choice.

However, it is necessary to note the fact that not all the information was taken into account while determining the efficiency of using road and rail, which leads to the situation when there may be several decisions, each of which may turn out to be correct under certain conditions and with various combinations of factors [15]. This problem can be solved if the zone of equal economic decisions is used. Using the graphic method, it can be determined that the zone of the equal economic decisions lies in the range from 500 to 700 km. So, if it is necessary to transport perishable freight over the distance of 500 – 700 km within Ukraine, using both road and rail is almost equal if judged by the economic profit of the system (under the condition that both the shipper and the receiver own the rail sidings). If the receiver does not own the rail sidings, the values are slightly different (Fig. 7). Under these conditions, the equal expenses distance is about 750 km and the zone of equal economic decisions is within the 600 – 900 km range.

So, if the receiver of the freight does not have their own rail siding, the sphere of efficient use of rail transport begins at the distance of 900 km.

7. RECOMMENDED SOLUTIONS

Let us analyse the difference between the economic profit of the system while using the road and rail under two conditions: with and without the rail sidings in the receiver's possession. If the receiver owns the rail sidings, using road transport is justified at the distance of 300 km. With this distance, the economic profit of the system is 4 per cent higher if road, rather than rail, is used (Fig. 8).

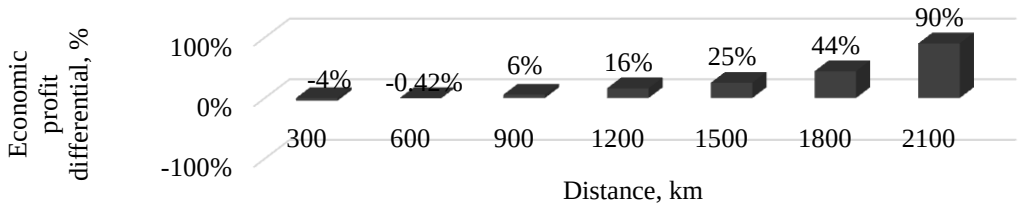

Fig. 8. Economic profit differential if the receiver uses rail transport and has his/her own rail siding

With the distance being 600 km, using both transport modes is equally efficient, as the economic profit is almost the same. If the receiver has the rail sidings, rail transport is preferable at the distance of 900 km. The economic profit of the system in this case is 6 per cent higher than while using road transport. It can be seen (Fig. 9, 10) that the longer the transportation distance, the bigger the difference of the economic profit while using rail transport, compared to road transport. For instance, if the transportation distance equals 1800 km, using rail transport is 44 per cent more efficient, while if this distance equals 2100 km, rail transport is 90 per cent more efficient.

If the receiver does not own rail sidings, the economic profit of the logistics system while using rail transport is 3 per cent higher than that of using road transport if the distance equals 900 km (Fig. 9).

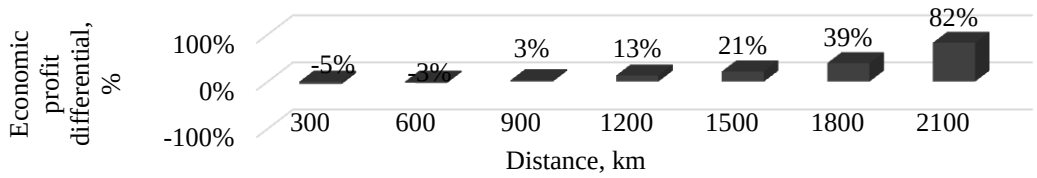

Fig. 9. Economic profit differential if the receiver uses rail transport and does not have their own rail siding

If the freight needs to be transported over the distance of 1200 km, the economic profit of the system will increase by 13 per cent, and if the distance equals 2100 km, the profit will increase by 82 per cent. If the distance is 300 km, the economic profit of the system is increased by 5 per cent while using road transport (by 3 per cent if the distance is 600 km). It has been established that the economic profit of the system while using rail transport is increased compared with using road transport with linear dependency.

8. CONCLUSIONS

With the help of the questionnaire conducted among the experts, it has been established that the issue of transport mode choice for trunk transportation in Ukraine is most important for packed (palletized) freight and freight transported in containers. The study allowed to determine the most crucial factors that influence the choice of road and rail transportation in Ukraine: transportation time, cargo amount, distance, cargo safety, being on time. It has been determined that the difference in highway and railway mileage has a slight deviation of about 2%.

The study looked at the situation when all the participants of the transportation process (shipper, carrier, receiver) are interested in maximizing other participants' profit, which can be observed in B2B cooperation. The model of determining the economic profit of the 'shipper – carrier – receiver' logistics model has been built. It allows to determine the suitable transport mode while transporting packed perishable freight in Ukraine. The fact of the receiver having or not having their own rail siding is also taken into account. Using the economic profit as an efficiency criterion allows taking into account the invisible costs, which occur while transporting freight within the logistics system (including the costs of immobilization of funds during the transportation). This happens due to the significant time difference of transporting the freight by road and rail, so various expenses stem out of funds immobilization. For instance, in Ukraine using rail transport has a disadvantage of requiring a lot of paperwork. Besides, it may take a long time to deliver freight by rail. Therefore, the suggested approach allows for more precise evaluation of every logistics system participants' profit while using the road or rail transport.

As a result of the calculations conducted, it has been determined that if the transportation distance equals 600 km and the receiver has their own rail sidings, using road and rail is equally efficient, as the economic profit is the same. It should be noted that the road is mostly used for distances shorter than 600 km. However, it is necessary to note the fact that not all the information was taken into account while determining the efficiency of using road and rail, which leads to the situation when there may be several decisions, each of which may turn out to be correct under certain conditions and with various combinations of factors. This problem was solved with the help of using the zones of equal economic decisions. This allowed to extend the range of sensible transportation distance. Using the graphic method, it was determined that the zone of the equal economic decisions lies in the range from 500 to 700 km (the difference of economic profit while using road or rail makes about 2 per cent). Therefore, if it is necessary to transport perishable freight over the distance of 500 – 700 km within Ukraine, using both road and rail is almost equal if judged by the economic profit of the system (under the condition that both the shipper and the receiver own the rail sidings).

Somewhat different values were obtained in the situation when the receiver does not have their own rail sidings. In this case, the equal expenses distance is about 750 km and the zone of equal economic decisions is within the 600 – 900 km range (the difference of the economic profit of the system while using road and rail makes about 1 per cent).

The application of the revealed laws will improve the efficiency of the logistics system by optimizing the transportation process. These laws will be particularly valuable for transport process planning at transport enterprises, for shippers and receivers. Besides, the suggested model allows to analyse the profit and expenditures of both every system participant and the logistics system as a whole, however, this topic is to be covered in the next thesis. Using the logistics system's maximum economic profit criteria provides more ample possibilities compared with the use of the expenditures criteria or separate participants' economic profit. These criteria should be used while analyzing the activity of separate firms. When it comes to regulating logistics systems, supply chains (especially at the strategic level), using the economic profit of the system seems to be more efficient, although it is still possible to control every system participant individually.

In the further study, it is necessary to add the ecological factor and inventory costs to the suggested mode choice method. Above all, it is considered necessary to analyse the comparative criteria of the road and rail, namely, saving of fuel, fuel cost saving, saving of CO_2 emission and road mileage saved. Including inventory costs into the model will allow to obtain a bit more effectively outputs for receiver. Taking into account the fact that the government of Ukraine conducts the policy aimed at Ukraine becoming a member of the European Union, it is necessary to implement contemporary methods while planning and organising the transportation process, particularly the ones concerning the environmental impact of the transportation process. Taking this criterion into account may significantly influence further results.

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