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S. Sharai[1], M. Oliskevych[2], V. Sakhno[3], M. Roi[4], V. Poliakov[5], V. Stelmashchuk[6]
[1] *National Transport University, Kyiv, Ukraine*
[2]*National University of Nature Management, Dubliany, Ukraine*
[3]*National Transport University, Kyiv, Ukraine*
[3]*National Transport University, Kyiv, Ukraine*
[5]*National Transport University, Kyiv, Ukraine*
[6]*Lutsk National Technical University, Lutsk, Ukraine*

OPTIMIZATION OF CARGO DELIVERY VOLUMES BY ROAD CARRIES IN THE SYSTEM OF PROVIDING TRANSPORT SERVICES

The work considers the formulation of the problem of optimizing the transport process in transport service supply chains and the method of its solution.

The study of the transport process of servicing incoming flows of cargo transportation orders showed that in the conditions of competition, motor transport companies try to optimize their activities. However, such optimization leads to the fact that carriers unreasonably refuse obviously promising orders, if the properties of the relevant transport processes are taken into account. It becomes quite difficult to achieve further improvement of the execution of a set of orders at the individual level. This means that transport processes for servicing a single incoming flow of orders should be based on new principles of synthesis. Despite the random nature of the orders, organizational relationships can be established between them, which can serve as signs for building an optimally structured integrated transport process.

In order to solve the problem of optimization of the transport process, from the point of view of satisfaction the need for fulfilling orders for the transportation of goods, in transport service supply chains the use of structural modeling is proposed, which makes it possible to carry out the distribution of own vehicles of enterprises that interact with each other, to determine the need for their rental and in the amount of necessary information that, in aggregate, leads to the maximum profit of the enterprise.

The initial data and conditions of the formulated task of order fulfillment planning were performed according to the criterion of the maximum profit of the motor vehicle enterprise.

The purpose of these studies was the development of methodological bases for optimizing the volume of truck transportation of transport companies, taking into account the potential of their interaction at various levels.

Keywords: transportation process, motor vehicle enterprise, supply chain, transportation order, optimization, profit.

INTRODUCTION

The modern market of road freight transportation is characterized by high competition level. Both small carriers with a fleet of up to 10 rolling stock and large corporations do business in this market. However, regardless of the size of the enterprises, all truck fleets suffer from competition, since such a service market depends, first of all, on well-established logistics both within the enterprises and with the environment. Secondly, freight transportation services are sensitive to the allowable time of their execution, i.e. time windows. Because of this, transport companies must take into account not only the price of their services, but also the efficiency of their provision. Due to increased competitive pressure, motor transport companies try to optimize their activities, taking into account the conflicting criteria of transportation conditions. However, such optimization leads to the fact that carriers unreasonably refuse orders that are known to be promising, if one takes into account the properties of the corresponding transport processes. It becomes quite difficult to achieve further improvement of the execution of a set of orders at the individual level. This means that transport processes for servicing a single incoming flow of orders should be based on new principles of synthesis. When developing integrated processes, they have a synergistic effect. To achieve such an effect, it is important to develop scientific and methodological support and specific organizational and technological recommendations for the management of production activities of motor transport enterprises (MTE) using the principles of their partners interaction. The activity of motor transport enterprises that cooperate with each other does not necessarily lead to an increase in the efficiency of the execution of orders for transport services. After all, there must be signs of organizational and technological compatibility of processes that are performed in a package of single tasks. The rapid development of communication technologies allows the participants of the transport process to join their forces in interaction and further integration to achieve a joint effect in the provision of transport services, if such signs exist. Only thanks to this, modern transport processes become even more integrated, and their information support is one of the key factors in achieving the desired result.

ANALYSIS OF LITERATURE DATA AND FORMULATION OF THE PROBLEM

The internal potential of effective management of motor transport enterprises (MTE), as well as the level of their competitiveness, can be increased by establishing organizational and technological cooperation with partners in the sector of providing transport services.

Modern studies show that cooperation between partners, or even between competitors, can lead to significant savings of resources under the condition of technological compatibility of the processes being performed [1]. All participants in the logistics chain, including suppliers, manufacturers, distributors and customers, can be involved in such cooperation. However, the effectiveness of cooperation in the market of road freight transport does not always increase with the interaction of transport enterprises [2]. The losses of one of the enterprises may be too great if the subject of interaction is incompatible for all parties of the transport and logistics chain. Therefore, there is always a need to assess the likely benefit from the interaction of the subjects of transport and logistics activities. Ways to solve such a task are a preliminary assessment of the properties of transport tasks, which constitute a stochastic flow and are characterized by indicators of suitability for their joint implementation by different subjects of the transport and logistics process [3].

Interaction of enterprises operating in the market of transport services with different methods of interaction is considered by scientists as horizontal cooperation, if it involves the cooperation of subjects in the same supply chains [4-8]. The term "logistics cooperation" suggests considering mechanisms of joint decision-making, in which a group of participants jointly makes decisions that are optimal from the point of view of the entire group [9]. Within the framework of logistics cooperation, several enterprises combine orders for the execution of transportation that have come to them, with the aim of more efficient redistribution and execution. Since the goal of logistics cooperation is to increase the efficiency of carriers' activity schedules, the task is to form the structure of such logistics. A large amount of scientific literature on the issues of joint logistics devotes its attention to the identification of effective distribution schemes, since cooperation often leads to additional profits or reduced costs [10-14]. The fair distribution of costs or profits between the enterprises that interact with each other is a key criterion, because the proposed distribution mechanism should encourage partners to behave according to common goals and can improve the stability of cooperation. Cooperation among carriers can lead to an increase in the level of productivity of transport operations, an increase in the use of potential and, thus, the production of economic benefits for participants involved as partners in the implementation of the transport process [15-18].

THE PURPOSE OF THE WORK PURPOSE AND OBJECTIVES OF THE STUDY

The purpose of these studies was to develop methodical bases for the optimization of the volume of truck transportation in transport companies, taking into account the potential of their mutual cooperation at different levels. To achieve this goal, the following research tasks were formulated and performed:

1) Formulate the task of optimizing the transportation of an individual carrier, taking into account possible operational decisions regarding the distribution of a stochastic flow of orders.

2) Investigate optimal solutions in the range of real values of transportation conditions.

RESEARCH RESULT

A set of orders $Z = \{z_1, z_2, \dots z_N\}$ is given, which is forecast for a some period T. Orders arise arbitrarily and independently. In addition, each order is characterized by the points of departure and destination of the cargo, which will be denoted as q_v and q_y, where v, y =1..M. Delivery distance $l_{v.y}$ is known. With a sufficient degree of accuracy, it is possible to provide an estimate of the time spent on transporting cargo between points q_v and q_y. However, for the conditions of this problem, we will use the value $a^m_{i.j}$ – this is the time of m vehicle movement during the execution of order j, which is executed after the execution of order i. This time is more generalized than the time required to drive the distance $l_{v.y}$. The $a^m_{i.j}$ time depends significantly on the completion of the previous order and, since the point of the last unloading may not coincide with the point of the next load, and an empty run may also be performed. Formalized, if $a^m_{i.j} = \infty$, this means that order j cannot be executed after order i. There is also time spent on simple vehicle at the points of departure and destination of cargo $a^s_{i.j}$, which arise as a result of non-coordination of operations during the execution of the transport process. Time delays $a^s_{i.j}$ arise because the allowed time limits of orders i,j may not coincide and due to the irregularity of the process [5-8].

To do this, consider such a parameter as a time window [9]. Each Z_i order is characterized by a time window W_i, which determines the allowed order execution period, i.e.:

$$W_i = t_i^e - t_i^b, \quad (1)$$

where t_i^e – the most possible late order completion time, t_i^b is the earliest possible start time for order execution.

The carrier has R vehicles in stock. With these vehicles, it is necessary to fulfill a specified set of orders Z. However, the available number of vehicle may not be enough, i.e. $R < R_z$, or their number may be excessive, i.e. $R > R_z$, where R_z is the number of vehicles actually required to fulfill a given set of known orders. It is assumed that for the transportation of cargo it is possible to use the R_o vehicles of motor transport companies-partners with lease rights. The tenant can get the main benefit from this rental. In the presence of information about the set of orders, which is known only to him, the carrier makes a decision on the possibility of their fulfillment. At the same time, such actions are possible.

1. Lease own rolling stock. The action is accepted as permissible if there are not enough profitable orders at $R > R_z$. The cost of renting a unit of motor vehicle P_r is taken for the entire period T. Thus, the income from renting out all vehicles can be determined by the expression:

2. Rent additional vehicles that are missing, i.e. if $R < R_z$. The action is executed if there are more profitable orders than free trucks. In this case, it is assumed that the expenses for renting vehicles of the carrier C_r are included in the cost price for the entire period T. Rental expenses are determined from the expression:

$$D_1 = (R - R_z) \cdot P_r . \tag{2}$$

$$D_2 = (R_z - R) \cdot C_r . \tag{3}$$

3. Buy information about orders unknown to the carrier. This action is performed when $R > R_z$. Cost of information about one order – C_z. Actually, the purchase of additional information occurs if there are not enough orders from the carrier, and this action is an alternative to renting out one's own trucks. However, there is a risk that the purchased and accepted order may not be profitable.

4. Sell information about available, but not accepted orders. Selling price – P_z. This decision is made when the number of available orders is larger, i.e. $R < R_z$, and they are unprofitable for the carrier.

5. Fulfill the order with own vehicles. In this case, MTE costs are spent on the movement of vehicles C_m and on their idle time C_s. To perform this action, it is necessary that the carrier has enough vehicles to fulfill the orders, and that such orders are profitable. As a result, the carrier receives funds from the performed transportations P_m, the amount of which depends on the mileage of the vehicles with the cargo during the execution of this order l_z. Actions 1-5 are taken for each order in particular so that the total profit from transportation is maximized. It is obvious that actions 1–5 are mutually contradictory. Therefore, the problem of profit maximization is multivariate, optimization. As a result of its solution, we will get the structure of such an integrated transport process (ITP), which will allow us to achieve the desired criterion. To solve it, we introduce the variable $x_{i.j} = \{0, 1\}$. The variable $x_{i.j}$ takes the value "0" if the order z is not fulfilled by own vehicles, and takes the value "1" if the order is fulfilled. The expression for finding the maximum profit will look like this:

$$\begin{aligned} П = {} & (R - R_z) \cdot P_r - (R_z - R) \cdot C_r - (R_z - R) \cdot C_z + \\ & + \sum_{i=1}^{N} \sum_{j=1}^{N} a_{i.j}^{m} \cdot (1 - x_{i.j}) \cdot P_z + \sum_{i=1}^{N} \sum_{j=1}^{N} a_{i.j}^{m} \cdot x_{i.j} \cdot P_m - \sum_{i=1}^{N} \sum_{j=1}^{N} a_{i.j}^{m} \cdot x_{i.j} \cdot C_m - \cdot \\ & - \sum_{i=1}^{N} \sum_{j=1}^{N} a_{i.j}^{s} \cdot x_{i.j} \cdot C_s \Rightarrow \max \end{aligned} \tag{4}$$

The first to fourth terms in the expression (4) correspond to the described actions 1–4. The fifth member is the receipt of funds from the execution of transportation orders by vehicles. The sixth member is the cost of transportation according to the orders of trucks itself when carrying out trips with cargo. The seventh member is the costs associated with downtime and delays of vehicles in the execution of orders.

Two more fictitious orders are introduced to solve the problem: Z_0 is the formal start of the integrated transport process (ITP) in the order execution sequence, Z_F is the formal end of the ITP at the end of the term T.

The variable $x_{0.j}$, as well as the value $a^m_{0.j}$, means the execution of order Z_j without any previous order being executed. Thus, these are the variables that determine the "pure" execution of the order. In this case, the organization of the process does not affect the duration of orders.

When drawing up a transportation plan, restrictions on variables must be met:

$$\sum_{j=1}^{N} x_{i.j} - \sum_{i=1}^{N} x_{i.j} = 0\,, \tag{5}$$

$$\sum_{j=1}^{N+F} x_{i.j} - \sum_{j=0}^{N} x_{i.F} = -R_z\,, \tag{6}$$

$$\sum_{j=1}^{N+F} x_{i.j} - \sum_{j=0}^{N} x_{j.F} = R_z\,, \tag{7}$$

$$\sum_{j=1}^{N} x_{i.j} \le 1\,, \tag{8}$$

$$\sum_{i=1}^{N} x_{i.j} \le 1\,, \tag{9}$$

$$\sum_{i=1}^{N} \left(\left| x_{0.i} - x_{i.F} \right| \right) = R_z\,, \tag{10}$$

where $x_{i.F}$, $x_{j.F}$ is a formal variable that corresponds to the completion of orders Z_i, Z_j, respectively, $x_{0.i}$, $x_{0.j}$ is a formal variable that corresponds to the start of execution of orders Z_i, Z_j, respectively, R_z is a predetermined number of trucks used in the process of transportation. This value is used because at each modeling step it is initially unknown at which R_z value the numerical value of criterion (4) will be maximum. Therefore, the value of R_z varies within the limits of $1 \le R_z \le R$, where R is the maximum number of vehicles (own and leased) that can be involved in transportation. It is obvious that $R < N$.

Constraint (5) means that the number of outgoing vehicles flows to fulfill the j-th order should not exceed the number of incoming ones. This restriction is valid for all variables $x_{i.j}$, i, j=1..N and does not apply to fictitious ones.

Limitation (6) means that the number of outgoing trucks flows from the formal start of the ITP does not exceed the predetermined value R_z. The same number of vehicles flows should be included in the formal completion of the ITP, which is evidenced by constraint (7).

Since the orders in this problem are unitary, i.e. each of them is executed in one trip with a load, the constraint (8) is applied, which means that the number of outgoing trucks flows for the execution of the j-th order does not exceed one. For the same reason, constraint (9) means that the number of incoming trucks flows to fulfill the j-th order does not exceed one.

In order to get rid of cyclic traffic flows that do not start at the formal start time of the ITP Z_0 and do not end at the formal time Z_F as a result of solving the optimization problem, constraint (10) was introduced. This limitation means that the number of routes from the formal start to the formal end of the process as a whole should be equal to the number of vehicles involved, which actually excludes the possibility of cycles, and therefore ambiguous simulation results. Constraint (10) actually brings the optimization problem to a non-linear form, since the module of the difference of variables is used in its expression.

When performing the optimization, it is not known in advance at what number of necessary vehicles the profit from the implementation of the transportation plan will be maximum. Therefore, iterative modeling was applied when changing the number of trucks involved. As a result of the optimization of the integrated transport process with the number of necessary vehicles, R=1, 2, 3, 4, 5, respectively.

DISCUSSION OF THE STUDY RESULTS

As can be seen from Fig. 1, and the optimal option is to execute only two orders No. 10 and 1 in the specified order. The profit received at the same time is UAH 10,418. At the same time, part of the profit is obtained: a) 71.7% - fulfillment of two orders; b) 16.8% - from the sale of information on 8 other known orders; c) 11.5% - from the lease of idle trucks. At the same time, 4 vehicles are rented out. The total number of own vehicles is 5.

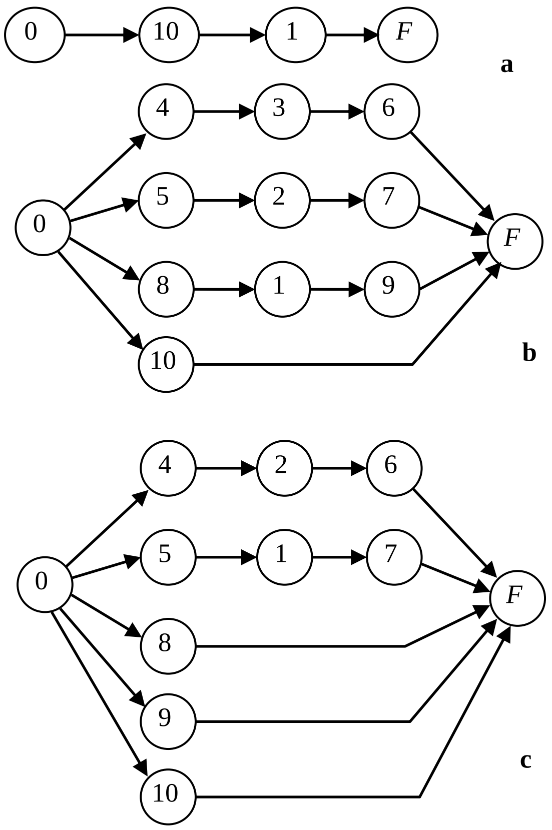

Figure 1. Optimal order fulfillment schemes: a) R=1, b) R=4; c) R=5

The Fig. 1, b shows the optimal order fulfillment option, with the number of free trucks that can be used - R=4. The profit received at the same time is UAH 20,624. Parts of the profit are obtained by: a) 98.5% - fulfilling of nine orders; b) 1.5% - the rental of trucks. At the same time, 1 vehicle is leased.

The optimal order fulfillment option shows in fig. 1, c, with the number of free vehicles that can be used - R=5. The profit received at the same time is UAH 20,624. Parts of the profit are obtained by: a) 98.5% - fulfilling of nine orders; b) 1.2% - the sale of information about one other known order. At the same time, no vehicle is rented out.

Thus, the simulation results obtained with constant parameters of the incoming flow of orders and a variable number of involved trucks can be displayed in Fig. 2.

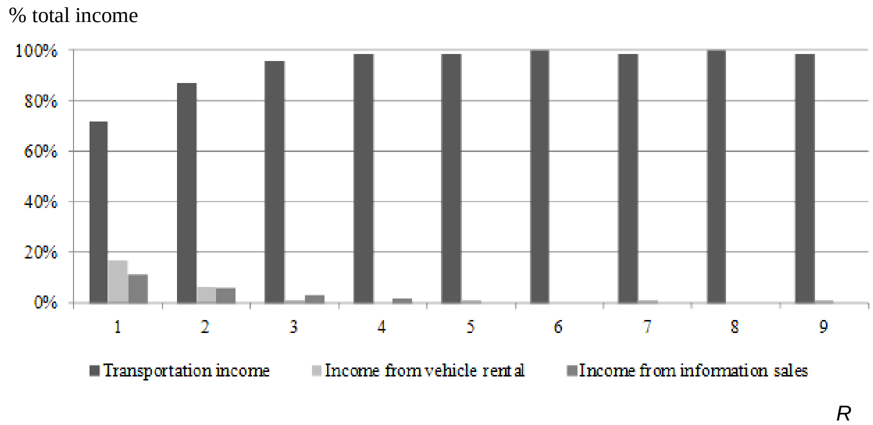

Figure 2. The structure of the carrier's income with different number of involved trucks

As can be seen from the histogram, the largest part of the company's income comes from transportation. Only when the company has 5 of its own vehicles, and uses 1-2 for transportation, the income from truck rental barely exceeds 10% of the total. Income from the sale of information for the enterprise means that out of 10 known orders, 10−R will be sold to partners, where *R* is the number of involved vehicles, including leased ones. The maximum (100%) revenues from transportation are obtained when 6 vehicles are involved: 5 - own + 1 leased and with 8 vehicles involved: 5 own + 3 leased. As can be seen from the results, the carrier's income increases with the use of leased vehicles. This is due to the use of more orders. However, the carrier's profit does not increase. This can be seen from Fig. 3.

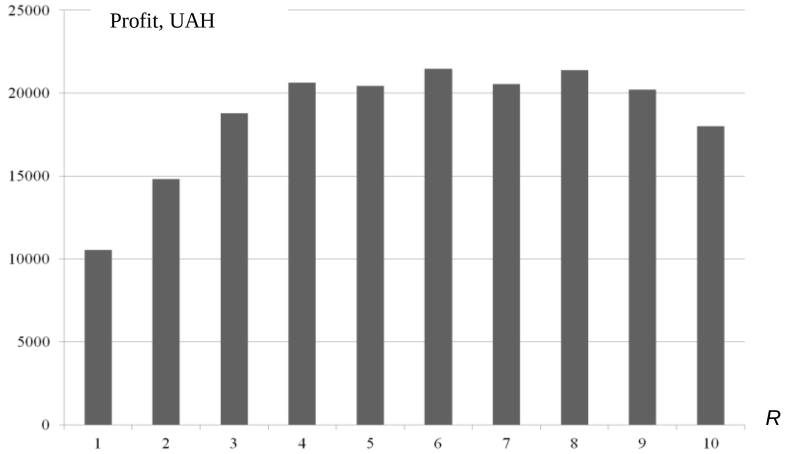

Figure 3. Dependence of the carrier’s profit on the number of used own and leased vehicles with a maximum number of 10 known orders

So, if the number of leased trucks exceeds 3, or more than 60% of the used own, then the profit of the carrier decreases, which is associated with the increase in rent and inefficient use of trucks, which are at its own disposal.

CONCLUSIONS

Based on the method of non-linear structural optimization of the transport process, based on the criterion of the maximum profit obtained from freight transportation and activities in cooperation with partners, it was established that the involvement of additional motor vehicles with an increase in the number of orders leads to the opposite effect, namely an increase in the number of refusals. This is observed up to a certain limit (approximately 80% of orders), after which the incoming flow of higher intensity is served stably. When applying the joint activity of motor transport enterprises, the difference in maximum profit for the optimal structure of the process can exceed other options for cooperation with 10 known orders, 5 available motor vehicles, which is 71-73% of the total income.

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С. Шарай, М. Оліскевич, В. Сахно, М. Рой, В. Поляков, В. Стельмащук. **Оптимізація обсягів доставки вантажів автомобільними перевізниками в системі надання транспортних послуг**.

У роботі розглядається постановка задачі оптимізації транспортного процесу в ланцюгах поставок транспортних послуг та методика її вирішення.

Дослідження транспортного процесу обслуговування вхідних потоків замовлень на перевезення вантажів показало, що в умовах конкуренції автотранспортні підприємства намагаються оптимізувати свою діяльність. Однак, така оптимізація приводить до того, що перевізники необґрунтовано відмовляються від завідомо перспективних замовлень, якщо брати до уваги властивості відповідних транспортних процесів. Досягти подальшого удосконалення виконання сукупності замовлень на індивідуальному рівні стає доволі складно. Це означає, що транспортні процеси при обслуговуванні єдиного вхідного потоку замовлень повинні базуватись на нових принципах синтезу. Незважаючи на випадковий характер замовлень, між ними можуть встановлюватися організаційні зв'язки, які і можуть служити ознаками для побудови оптимально структурованого комплексного транспортного процесу.

Для вирішення задачі оптимізації транспортного процесу, з точки зору задоволення потреби у виконанні замовлень на перевезення вантажів, в ланцюгах поставок транспортних послуг запропоновано застосування структурного моделювання, що дає змогу здійснити розподіл власних транспортних засобів підприємств, які взаємодіють між собою, визначити потребу в їх оренді та кількості необхідної інформації, що, в сукупності, приводить до максимального прибутку підприємства.

Вихідні дані та умови сформульованого завдання планування виконання замовлення виконано за критерієм максимального прибутку автотранспортного підприємства.

Метою цих досліджень була розробка методичних основ оптимізації обсягів автомобільних перевезень транспортних компаній з урахуванням потенціалу їх взаємодії на різних рівнях.

Ключові слова: транспортний процес, автотранспортне підприємство, ланцюг постачань, замовлення на перевезення, оптимізація, прибуток.

ШАРАЙ Світлана Михайлівна, кандидат технічних наук, доцент, професор кафедри міжнародних перевезень та митного контролю, Національний транспортний університет, e-mail: Svetasharai@gmail.com. http://orcid.org/0000-0001-6568-4990.

ОЛІСКЕВИЧ Мирослав Стефанович, доктор технічних наук, професор, професор кафедри агроінженерії та технічного сервісу, Львівський національний університет природокористування, e-mail: myroslav@3g.ua. http://orcid.org/0000-0001-6237-0785.

САХНО Володимир Прохорович, доктор технічних наук, професор, завідувач кафедри автомобілів, Національний транспортний університет, e-mail: sakhno@ntu.edu.ua. http://orcid.org/0000-0002-5144-7131.

РОЙ Максим Петрович, доктор філософії, доцент кафедри міжнародних перевезень та митного контролю, Національний транспортний університет, e-mail: 7569027@ukr.net. http://orcid.org/0000-0001-5788-4220.

ПОЛЯКОВ Віктор Михайлович, кандидат технічних наук, доцент, професор кафедри автомобілів, Національний транспортний університет, e-mail: poljakov_2006@ukr.net. http://orcid.org/0000-0001-7042-3066.

СТЕЛЬМАЩУК Валерій Віталійович, кандидат технічних наук, доцент, доцент кафедри автомобілів і транспортних технологій, Луцький національний технічний університет, e-mail: Val.stelmashchuk@gmail.com. https://orcid.org/0000-0003-3813-3143.

Svitlana SHARAI, Ph.D in Engeneering, Associate Professor, Professor of the Department of International Transportation and Customs Control, National Transport University, e-mail: svetasharai@gmail.com. http://orcid.org/0000-0001-6568-4990.

Myroslav OLISKEVYCH, Doctor of Technical Sciences, Professor, Professor of the Department of of agricultural engineering and technical service, Lviv National University of Nature Management, e-mail: myroslav@3g.ua. http://orcid.org/0000-0001-6237-0785.

Volodymyr SAKHNO, Doctor of Technical Sciences, Professor, Head of the Department of Automobiles, National Transport University, e-mail: sakhno@ntu.edu.ua. http://orcid.org/0000-0002-5144-7131.

Maksym ROI, Doctor of Philosophy, Associate Professor of the Department of International Transportation and Customs Control, National Transport University, e-mail: 7569027@ukr.net. http://orcid.org/0000-0001-5788-4220.

Victor POLIAKOV, Ph.D in Engeneering, Associate Professor, Professor of the Department of Automobiles, National Transport University, e-mail: poljakov_2006@ukr.net/ http://orcid.org/0000-0001-7042-3066.

Valery STELMASHCHUK, Ph.D in Engeneering, Associate Professor, Associate Professor of the Department of Automobiles and Transport Technologies, Lutsk National Technical University, e-mail: Val.stelmashchuk@gmail.com. https://orcid.org/0000-0003-3813-3143.

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