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INTERACTION OF TRANSPORT ENTERPRISES IN THE SECTOR OF ROAD FREIGHT TRANSPORTATION

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The article addresses the issues of interaction among transport enterprises based on the distribution of orders for freight transportation through the calculation of proposed indicators that determine the degree of order compatibility. In the context of increasing demand for road freight transportation and limited production capacities of individual carriers, cooperation between motor transport enterprises becomes an important tool for improving the efficiency of transport processes. The study substantiates the feasibility of organizing such interaction by taking into account organizational and technological compatibility of transportation orders.

It has been established that the compatibility of freight transportation orders depends on the sequence of their execution within the transport process and on their concentration within a given transport network. The article proposes analytical indicators that make it possible to quantitatively assess the degree of compatibility and concentration of orders, which allows transport enterprises to form rational priorities for order execution. These indicators can be used to determine the expediency and level of interaction among motor transport enterprises, including the redistribution of orders and the joint use of vehicle fleets.

The proposed methodology for distributing freight transportation orders makes it possible not only to solve the problem of planning the transport process under conditions of a large volume of incoming transportation orders, but also to ensure a reduction in unproductive mileage, downtime, and inefficient use of vehicles. As a result, interaction among motor transport enterprises contributes to an increase in the overall efficiency of freight transportation and to the achievement of a higher total profit for all cooperation partners.

The object of the research is the process of interaction among motor transport enterprises in the execution of freight transportation orders. The aim of the study is to determine the criteria that form the basis for planning and distributing freight road transportation orders among cooperating road transport enterprises. The research method is analytical and is based on the analysis of time parameters of order execution and spatial characteristics of transportation networks.

The practical significance of the research lies in the possibility of applying the proposed approach in the operational planning of freight transportation by motor transport enterprises, especially under conditions of limited resources and high market competition.

Keywords: road transport enterprise, interaction, order for executing the transportation of cargo, coefficient of compatibility of orders, coefficient of concentration of orders.

Statement of the problem

Since the transportation of goods by air and water transport has faced significant operational, infrastructural, and security limitations during the period of military operations in Ukraine, the domestic market of transport services has increasingly prioritized road transport for freight movement. Disruptions of maritime corridors, restrictions in airspace usage, damage to port and airport infrastructure, and increased insurance risks have substantially reduced the reliability and predictability of alternative transport modes. Under such conditions, shippers and carriers were compelled to urgently restructure their logistics chains, revise established delivery routes, reconsider supply chain configurations, and adapt to a new risk environment characterized by uncertainty and volatility.

Motor transport enterprises operating in the freight road transportation sector, seeking to strengthen their competitive advantages in a rapidly changing market environment, are actively implementing measures aimed at improving service quality, expanding the range of logistics services provided, increasing the level of customer orientation, and enhancing operational flexibility. These measures include the integration of digital dispatching systems, implementation of route optimization technologies, diversification of vehicle fleets, and development of partnership agreements with other carriers. At the same time, enterprises are forced to operate under conditions of rising fuel prices, fluctuating demand, limited access to financial resources, and increased wear and tear of vehicles due to intensified usage.

Taking into account the contradictory nature of the criteria that determine transportation conditions – such as cost minimization, delivery time reduction, reliability, safety, and vehicle utilization efficiency – motor transport enterprises attempt to optimize their operating costs. However, excessive cost optimization or rigid

capacity planning may result in unintended consequences. In particular, carriers are sometimes compelled to refuse potentially profitable and promising orders due to insufficient production capacities, imbalance in fleet allocation, or incompatibility of new transportation requests with existing commitments. Such refusals negatively affect market share, long-term competitiveness, and overall profitability.

These trends stimulate the development of interaction and cooperation between transport enterprises in their production activities. Cooperative arrangements may take the form of subcontracting, joint planning of routes, shared use of vehicle fleets, information exchange platforms, or creation of transport alliances. The purpose of such interaction is to increase the efficiency of the use of motor vehicles performing freight transportation, improve load factors, reduce empty mileage, and ensure better coverage of fluctuating demand. Nevertheless, the mere fact of interaction does not automatically guarantee efficiency gains.

The activities of road transport enterprises that cooperate with each other do not necessarily lead to improved effectiveness in the execution of transport service orders if there are no clear signs of organizational, technological, and operational compatibility of the transport processes being carried out. Incompatibility may arise due to differences in fleet structure, technical characteristics of vehicles, information systems, management approaches, contractual obligations, or service standards. Lack of synchronization in scheduling, route planning, and cargo handling procedures may generate additional transaction costs and operational inefficiencies.

Therefore, the problem of increasing the efficiency of organizing freight road transportation based on structured and economically justified interaction between road transport enterprises is highly relevant. It requires the development of scientifically grounded methodological approaches to the coordination of transport processes and rational distribution of orders among cooperation participants.

Analysis of recent publications on the problem. The issue of interaction between transport enterprises in the execution of cargo transportation has been examined in the works of domestic and foreign scholars, including Gorbachov P.F., Mospan M.V., Oliskevych M.S., Prokudin G.S., Rudrazhit Pal, Kruyssen F., Gansterer M., Hartl R., and others. Their studies address various aspects of cooperative logistics, vehicle routing problems, collaborative transportation planning, and profit-sharing mechanisms within transport alliances. Particular attention has been paid to mathematical modeling of vehicle routing problems with cooperation elements, optimization of fleet utilization, and development of decision-support systems for dispatching operations.

However, despite significant scientific contributions, insufficient attention has been devoted to the issues of compatibility of transportation orders executed by cooperation participants within their operational activities. In particular, the criteria for assessing technological and organizational compatibility of orders, as well as methods for their formalization in the process of order distribution among interacting enterprises, remain underdeveloped. The absence of clearly defined compatibility indicators limits the practical applicability of existing models in real conditions of the Ukrainian transport market.

Formulation of research objectives (task statement). The purpose of this study is to determine and substantiate the criteria that form the basis for planning and distributing orders for freight road transportation between interacting road transport enterprises. The research aims to develop an improved methodological approach to the allocation of transportation orders among cooperating motor transport enterprises, taking into account economic efficiency, production capacities, technological compatibility, and risk factors.

Solving the research task is based on improving the mechanism for distributing orders for the transportation of goods between interacting motor transport enterprises in order to obtain the maximum total profit from the execution of the transportation process for all cooperation partners. This implies the development of a decision-making model that ensures balanced workload distribution, reduction of idle mileage, rational use of fleet resources, and equitable sharing of economic benefits among participants in cooperation.

Presentation of the main research material. The interaction of motor transport enterprises operating in the transport services market can occur in different organizational and economic forms depending on the structure of the logistics system, the type of transportation orders, and the operational capabilities of the enterprises involved. In modern market conditions, such interaction is increasingly becoming an important instrument for improving the efficiency of freight transportation processes and strengthening the competitiveness of transport companies. Depending on the objectives of cooperation, the interaction between carriers may involve joint planning of transportation routes, sharing of vehicle fleets, exchange of operational information, subcontracting of transportation tasks, or the formation of strategic alliances between enterprises.

Accordingly, different forms of interaction between road transport enterprises lead to different financial and operational consequences. If such interaction involves cooperation between enterprises operating within the same supply chains, it is commonly considered horizontal cooperation [1–4]. Horizontal cooperation is characterized by the collaboration of enterprises operating at the same level of the logistics system, which

jointly coordinate their transportation activities while maintaining their economic independence. Such cooperation allows enterprises to combine their resources, synchronize transportation schedules, and increase the utilization rate of their vehicle fleets.

The interaction of several road transport enterprises typically involves the consolidation of transportation orders with the purpose of their more efficient redistribution and execution. Through such consolidation, enterprises can achieve a more rational allocation of transportation tasks among available vehicles and ensure more efficient use of both their own and leased transport resources. This approach makes it possible to reduce empty mileage, increase vehicle load factors, optimize transportation routes, and improve the overall performance of freight transportation systems.

In many cases, such interaction between road transport enterprises leads to additional financial benefits in the form of increased revenues or reduced operational costs. At the same time, cooperative transportation activities require the development of mechanisms for the fair distribution of both costs and profits among cooperation participants [5–7]. Ensuring fairness in the distribution of economic results is an important prerequisite for maintaining stable long-term cooperation between transport enterprises.

The calculation of the criteria that form the basis for planning and distributing orders for freight road transportation between interacting road transport enterprises can be carried out taking into account the temporal relationships between the execution of transportation orders. These relationships are primarily determined by time windows within which cargo must be delivered to the designated destination points. The consideration of time windows allows not only satisfying the requirements of customers regarding delivery deadlines but also organizing transportation in such a way that the number of vehicles required for the execution of all orders is minimized.

Between orders for cargo transportation, certain relationships can be established that characterize the possibility and efficiency of their joint execution. These relationships include compatibility, concentration, unevenness, and orderliness of orders [8]. The analysis of such relationships allows determining the optimal sequence of order execution and selecting transportation routes that provide the highest level of operational efficiency.

At the same time, the orderliness of execution of transportation orders depends on their priorities, which are determined sequentially according to certain criteria. The alternation of order execution according to priorities allows transport enterprises to ensure the rational utilization of their vehicle fleets and minimize idle time and unproductive mileage.

The priority of order execution is determined according to the following conditions:

- the highest priority is determined by the coefficient of compatibility of transportation orders;
- in the case where several orders do not differ according to the value of the compatibility coefficient, the priority of execution is determined by the coefficient of order concentration. The order whose concentration coefficient approaches its maximum value is given priority.

Orders i and j will be considered compatible if they can be executed sequentially by one vehicle without taking into account zero mileage, empty mileage, or downtime while waiting for loading operations [8]. In other words, compatibility reflects the possibility of organizing transportation tasks in such a way that one order naturally follows another within the operational schedule of the same vehicle.

To evaluate the degree of order compatibility, it is proposed to use the order compatibility coefficient, which characterizes the compatibility of executing orders in the sequence $j \rightarrow i$:

$$K_c^{j,i} = \frac{a_{0,i}}{a_{j,i}}, \quad (1)$$

where $a_{0,i}$ – duration of execution the order Z_i without prior execution of any other orders and without zero mileage, loading wait, etc.; $a_{j,i}$ – duration of execution the order Z_i after execution of order Z_j .

The coefficient of order compatibility can have a maximum value equal to 1, which indicates that the orders are fully compatible and can be executed sequentially without additional time losses. A lower value of the coefficient indicates a lower degree of compatibility between transportation orders. Orders for which this coefficient is greater than 0 but less than 1 are considered partially compatible.

To evaluate the degree of compatibility of orders executed in the sequence $i \rightarrow j$, it is proposed to use the inverse indicator:

$$K_c^{i,j} = \frac{a_{0,j}}{a_{i,j}}, \quad (2)$$

where $a_{0,j}$ – duration of execution the order Z_j without prior execution of any other orders and without zero mileage, loading wait, etc.; $a_{i,j}$ – duration of execution the order Z_j after execution of order Z_i .

In order to evaluate the overall compatibility of all transportation orders within the planned set of orders, the average compatibility coefficient can be calculated:

$$K_c = \frac{\sum_{i=1}^N \sum_{j=1}^N K_c^{i,j}}{N}, \quad (3)$$

where N – number of orders.

The coefficient of compatibility of all orders shows the general level of compatibility among transportation tasks planned for execution within a certain order set. However, this indicator does not take into account the possibility of executing transportation orders by different road transport enterprises that interact with each other. Therefore, using only this coefficient to evaluate the effectiveness of cooperation between transport enterprises is insufficient [9].

To address this limitation, it is proposed to introduce an additional indicator that characterizes the territorial concentration of transportation orders. In order to assess the concentration of orders within a certain territory served by several motor transport enterprises that may cooperate with each other, the coefficient of order concentration is introduced:

$$K_k = \frac{N_z}{N_q}, \quad (4)$$

where N_z – the number of orders that need to be executed within a certain period of time T ; N_q – the number of points of departure and receipt of cargo (transport points) for which orders must be executed within a certain period of time T .

The coefficient of order concentration is a dynamic indicator whose value depends on the size of the territory under consideration, the number of transportation points located within this territory, and the duration of the planning period for transportation orders. Its maximum value is limited to two transport points regardless of how many transportation orders are planned within the territory. Its minimum value corresponds to the situation where each transportation order is associated with two completely independent transport points.

Therefore, the numerical value of the concentration coefficient K_k may vary within a certain range depending on the spatial distribution of transport points and the number of transportation requests. This coefficient reflects the degree to which transportation routes overlap spatially and temporally and indirectly characterizes the time required to perform trips with or without cargo. Deviation of this coefficient from the value of 1 indicates the level of favorable conditions for organizing and implementing freight transportation processes by road transport enterprises during their interaction.

The level of interaction between road transport enterprises also significantly influences their financial results from executing transportation orders. In practice, carriers often receive more transportation requests than they are able to execute using their own vehicle fleets. One carrier may lack a sufficient number of vehicles to fulfill all orders received from customers.

In such situations, after determining the compatibility coefficient of transportation orders and the concentration coefficient of orders, the transport enterprise may transfer part of the orders to its cooperation partner for execution or rent vehicles from that partner to perform the transportation itself. Such mechanisms of cooperation allow enterprises to maintain service reliability and avoid the rejection of profitable transportation orders.

Calculations of the potential planned profit of a motor transport enterprise depending on the required number of vehicles (both own and leased) necessary to execute a certain number of transportation orders at different values of the compatibility coefficient were carried out using the proposed methodology for determining order execution priorities. The results of the calculations showed that when the value of the compatibility coefficient approaches 1, the motor transport enterprise can achieve maximum profit due to the efficient sequential execution of transportation orders.

At the same time, not all transportation orders can always be executed by a single enterprise. In such cases, some of the orders may be transferred within the framework of cooperation to another road transport enterprise acting as a cooperation partner. Conversely, when the compatibility coefficient approaches lower values (for example, about 0.2), the motor transport enterprise may need to use additional vehicles or leased transport resources in order to execute all transportation orders (Fig. 1).

When the coefficient of compatibility of orders for cargo transportation decreases, the conditions for sequential execution of transportation tasks by the same vehicle become less favorable. In such circumstances, the efficiency of transportation planning within a single motor transport enterprise is reduced due to the increase in additional mileage, waiting time for loading operations, and other operational losses. As a result,

the enterprise may need to involve additional transport resources in order to ensure the timely execution of transportation orders received from customers.

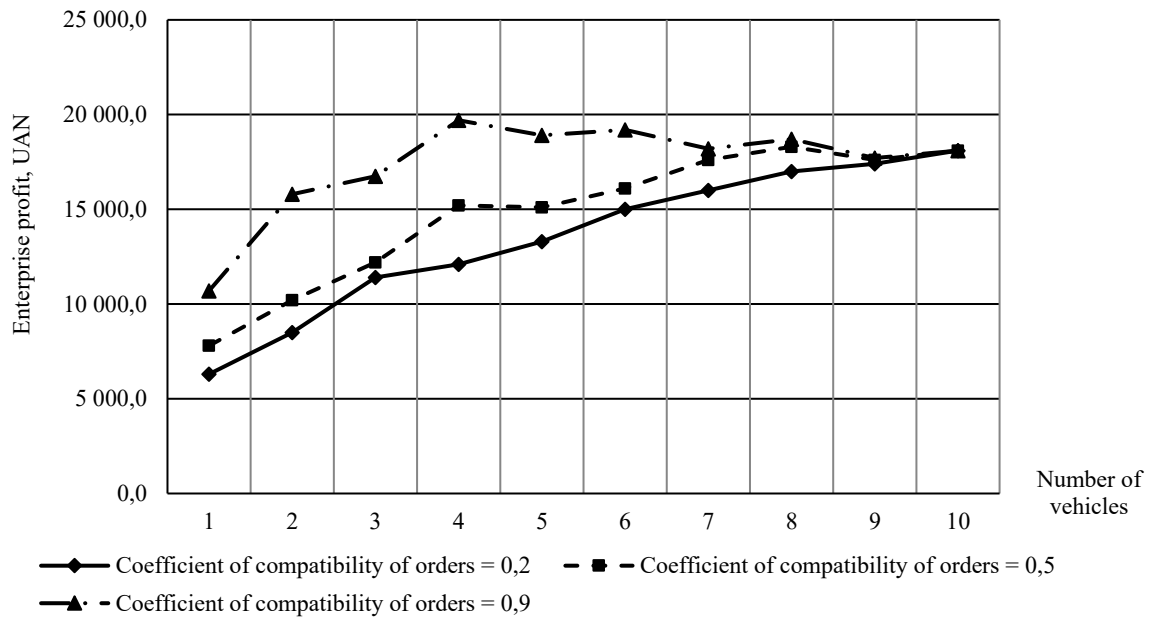


Fig. 1. Dependence of the profit of a motor transport enterprises on the executing of orders for cargo transportation at different values of the coefficient of compatibility of orders for different numbers of vehicles involved

At the same time, the results of the performed calculations show that the maximum possible profit under such conditions can be achieved when the motor transport enterprise increases the utilization of both its own and rented vehicles. The involvement of additional vehicles allows maintaining the required level of service reliability and avoiding delays in cargo delivery even when transportation orders have low compatibility with each other. However, the use of leased vehicles may also lead to an increase in operational costs, which requires careful planning and economic justification.

In this context, the interaction between road transport enterprises becomes an effective organizational mechanism for increasing the efficiency of freight transportation processes. Cooperative interaction between carriers allows redistributing transportation orders among enterprises according to their available production capacities, fleet structure, and operational schedules. As a result, enterprises that participate in such cooperation are able to use their transport resources more efficiently and reduce unproductive losses associated with idle vehicles or empty mileage.

The conducted research confirms that the interaction of motor transport enterprises leads to an increase in total profits for all partners participating in the cooperation process. The redistribution of transportation orders within a cooperative network allows each enterprise to focus on those transportation tasks that correspond most closely to its operational capabilities and current workload. This approach ensures a more balanced utilization of vehicle fleets and reduces the probability of rejecting profitable transportation orders.

An additional advantage of such interaction is the possibility of executing all transportation orders received from customers of transport services. In many cases, a single motor transport enterprise may not possess sufficient production capacities to fulfill the entire volume of transportation requests within the required time limits. However, through cooperation with other carriers, it becomes possible to distribute orders among several enterprises and thus guarantee the fulfillment of all contractual obligations to customers.

Consequently, the development of effective mechanisms for coordinating the interaction of road transport enterprises becomes an important factor in improving the efficiency and reliability of freight transportation systems. The use of scientifically grounded criteria for evaluating the compatibility and concentration of transportation orders allows enterprises to make rational decisions regarding the allocation of orders and the selection of cooperation partners.

Conclusions

For the possibility of evaluating the compatibility of orders for the execution of cargo transportation within a transport process performed either by a single road transport enterprise or by several enterprises interacting with each other, a system of indicators has been proposed. These indicators include the coefficient of

compatibility of transportation orders and the coefficient of order concentration, which together characterize the technological and organizational conditions for executing transportation tasks within the transport network.

The proposed compatibility coefficient allows determining the degree to which different transportation orders can be executed sequentially by the same vehicle without significant losses in time or operational efficiency. This coefficient reflects the temporal and spatial interrelation between transportation tasks and provides an opportunity to determine the most rational sequence of their execution.

At the same time, the coefficient of order concentration characterizes the spatial distribution of transportation requests within a certain territory and reflects the density of transportation tasks within the transport network. The joint use of these indicators allows evaluating not only the feasibility of executing transportation orders within a single enterprise but also the efficiency of cooperation between several road transport enterprises.

The results of the conducted research have shown that the compatibility of orders for cargo transportation largely depends on the sequence of their execution within the transportation process as well as on their territorial concentration within a given transport network. The higher the compatibility of orders and the greater their concentration within a certain area, the more favorable the conditions for organizing efficient transportation routes and minimizing transportation costs.

The proposed indicators can therefore be used as an analytical tool for determining the appropriate level of interaction between road transport enterprises. In particular, the coefficient of compatibility of transportation orders serves as an important indicator of the economic feasibility of cooperation between carriers, since the financial results of transport enterprises largely depend on its numerical value.

It has been established that when the compatibility coefficient approaches higher values, enterprises are able to organize transportation routes more efficiently and achieve higher profitability from transportation operations. Conversely, when this coefficient decreases, the need for additional vehicles and increased coordination between enterprises becomes more significant.

The proposed method for distributing orders for cargo transportation between interacting road transport enterprises makes it possible not only to solve the problem of planning the transportation process under conditions of a large number of incoming transportation requests but also to improve the overall economic results of transport enterprises. In particular, the implementation of the proposed method allows obtaining a greater total profit from the execution of freight transportation processes for all participants of cooperation.

Thus, the application of the developed methodological approach contributes to increasing the efficiency of freight road transportation, improving the utilization of vehicle fleets, reducing unproductive operational losses, and strengthening the competitive position of motor transport enterprises operating in the transport services market.

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Взаємодія транспортних підприємств у секторі вантажних автомобільних перевезень

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У статті розглянуто питання взаємодії транспортних підприємств на основі розподілу замовлень на виконання вантажних перевезень шляхом розрахунку запропонованих показників, що визначають ступінь сумісності замовлень. В умовах зростання попиту на автомобільні вантажні перевезення та обмежених виробничих можливостей окремих перевізників співпраця між автотранспортними підприємствами стає важливим інструментом підвищення ефективності транспортних процесів. У роботі обґрунтовано доцільність організації такої взаємодії з урахуванням організаційно-технологічної сумісності замовлень на перевезення.

Встановлено, що сумісність замовлень на виконання вантажних перевезень залежить від послідовності їх виконання у транспортному процесі та від рівня їх концентрації на заданій транспортній мережі. Запропоновано аналітичні показники, які дають змогу кількісно оцінити ступінь сумісності та концентрації замовлень, що дозволяє автотранспортним підприємствам формувати раціональні пріоритети виконання перевезень. Зазначені показники можуть бути використані для визначення доцільності та рівня взаємодії автотранспортних підприємств, зокрема під час перерозподілу замовлень і спільного використання рухомого складу.

Запропонована методика розподілу замовлень на виконання вантажних перевезень дає змогу не лише розв'язати задачу планування транспортного процесу за умов значного обсягу вхідних замовлень на транспортні послуги, а й забезпечити скорочення непродуктивних пробігів, простоїв та неефективного використання транспортних засобів. У результаті взаємодії автотранспортних підприємств сприяє підвищенню загальної ефективності вантажних перевезень і отриманню більшого сумарного прибутку всіма учасниками співпраці.

Об'єктом дослідження є процес взаємодії автотранспортних підприємств під час виконання замовлень на вантажні перевезення. Метою роботи є визначення критеріїв, що формують основу планування та розподілу замовлень на автомобільні вантажні перевезення між автотранспортними підприємствами, які взаємодіють між собою. Метод дослідження – аналітичний, заснований на аналізі часових параметрів виконання замовлень і просторових характеристик транспортної мережі.

Практичне значення роботи полягає у можливості застосування запропонованого підходу в оперативному плануванні вантажних перевезень автотранспортними підприємствами, особливо в умовах обмежених ресурсів і високої конкуренції на ринку транспортних послуг.

Ключові слова: автотранспортне підприємство, взаємодія, замовлення на виконання перевезення вантажу, коефіцієнт сумісності замовлень, коефіцієнт концентрації замовлень.

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