UDC 656.135.073.42:63 DOI https://doi.org/10.33082/td.2023.2-17.10

INFRASTRUCTURE PROVISION OF COMMERCIAL ACTIVITIES OF PRODUCTION SYSTEMS OF INTERNATIONAL FORWARDING TO THE MARKET OF TRANSPORT SERVICES

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Summary

Introduction. *The analysis of literary sources regarding the directions of commercial activity of production systems of an international orientation indicates the presence of promising trends of stable development of integration processes. The development of trade relations on the basis of economic integration between individual countries requires the creation of innovative and economically feasible production formations with appropriate infrastructural support. Therefore, the development of unified production processes for servicing import-export and transit cargo flows is one of the main tasks in the commercial services market.* ***Purpose.*** *The development of integration relationships in the international freight flow service system requires the creation and intensive use of competitive transport and technological processes with appropriate infrastructural support. Powerful transport hubs with modern specialized terminals correspond to such opportunities. And the rational use of the existing state-of-the-art infrastructure of business entities requires the development of structural foundations for improving technical and economic indicators. The article examines the methodology of infrastructural support for the commercial activity of production systems of international orientation in the market of transport services.* ***Results.*** *The peculiarities of conducting foreign trade operations were analyzed, and the problems related to resource provision of transport terminals in existing production structures were systematized. It is noted that the peculiarities of service of import-export and transit goods flows in transport hubs should take into account the specifics of the preliminary creation of a consolidated batch of goods. By carrying out multivariate calculations using the main provisions of the theory of mass service, the work determined the optimal number of vehicles for the effective implementation of commercial services. In the process of summarizing the obtained results, economically justified measures are proposed for infrastructural* *support of commercial activity of production systems of international direction in the market of transport services.* ***Conclusions.*** *In the process of conducting the research, new results were obtained for improving the methodology of infrastructural support of commercial activity of production systems of international direction in the market of transport services. Based on the results of simulation modeling using the main theoretical provisions of mass service systems, integral economic indicators of quality provision of transport services were calculated using the example of export cargo flows. The conducted research can be useful for improving the efficiency of transport services in international production structures.*

Key words: *international communication, foreign trade cargo flows, transport service, infrastructural support, cargo consolidation, optimization of logistics costs, optimization of operational indicators.*

ІНФРАСТРУКТУРНЕ ЗАБЕЗПЕЧЕННЯ КОМЕРЦІЙНОЇ ДІЯЛЬНОСТІ ВИРОБНИЧИХ СИСТЕМ МІЖНАРОДНОГО СПРЯМУВАННЯ НА РИНКУ ТРАНСПОРТНИХ ПОСЛУГ

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Анотація

Вступ. *Аналіз літературних джерел стосовно напрямів комерційної діяльності виробничих систем міжнародного спрямування свідчить про наявність перспективних тенденцій стабільного розвитку інтеграційних процесів. Розвиток торгівельних відносин на засадах економічної інтеграції між окремими країнами вимагає створення інноваційних та економічно доцільних виробничих формувань із відповідним інфраструктурним забезпеченням. Тому розробка уніфікованих виробничих процесів для обслуговування імпортно-експортних та транзитних вантажопотоків є одним з головних завдань на ринку реалізації комерційних послуг.* ***Мета.*** *Розвиток інтеграційних взаємовідносин в системі обслуговування вантажопотоків міжнародного спрямування вимагає створення та інтенсивного використання конкурентоздатних транспортно-технологічних процесів із відповідним інфраструктурним забезпеченням. Таким можливостям відповідають потужні транспортні вузли з сучасними спеціалізованими терміналами. А раціональне використання існуючої новітньої інфраструктури суб'єктів господарської діяльності вимагає розробки структурних засад для покращення техніко-економічних* *показників. У статті досліджується методологія інфраструктурного забезпечення комерційної діяльності виробничих систем міжнародного спрямування на ринку транспортних послуг.* ***Результати.*** *Проаналізовано особливості проведення зовнішньоторговельних операцій, систематизовані задачі щодо ресурсного забезпечення транспортних терміналів в існуючих виробничих структурах. Зазначено, що особливості обслуговування імпортно-експортних та транзитних товаропотоків в транспортних вузлах повинні враховувати специфіку попереднього створення консолідованої партії вантажів. Шляхом проведення багатоваріантних розрахунків з використанням основних положень теорії масового обслуговування в роботі визначена оптимальна кількість транспортних засобів для ефективної реалізації комерційних послуг. В процесі узагальнення отриманих результатів запропоновані економічно обґрунтовані заходи щодо інфраструктурного забезпечення комерційної діяльності виробничих систем міжнародного спрямування на ринку транспортних послуг.* ***Висновки.*** *В процесі проведення дослідження отримано нові результати для удосконалення методології інфраструктурного забезпечення комерційної діяльності виробничих систем міжнародного спрямування на ринку транспортних послуг. За результатами імітаційного моделювання із використанням основних теоретичних положень систем масового обслуговування розраховані інтегральні економічні показники якісного надання транспортних послуг на прикладі експортних вантажопотоків. Проведене дослідження може бути корисним для підвищення ефективності транспортного обслуговування у виробничих структурах міжнародного спрямування.*

Ключові слова: *міжнародне сполучення, зовнішньоторговельні вантажопотоки, транспортне обслуговування, інфраструктурне забезпечення, консолідація вантажів, оптимізація логістичних витрат, оптимізація експлуатаційних показників.*

Introduction. The development of trade relations between individual countries is based on the principles of economic integration and mutually beneficial cooperation. in relation to the areas of commercial activity of production systems of an international orientation, it indicates the presence of promising trends of stable development of integration processes. The development of trade relations on the basis of economic integration between individual countries requires the creation of innovative and economically feasible production formations with appropriate infrastructural support. Therefore, the development of unified production processes for servicing import-export and transit cargo flows is one of the main tasks in the commercial services market.

Formulation of the problem. The rapid development of trade relations between individual countries indicates the need to accelerate integration processes on the basis of economic expediency. To a large extent, this situation is explained by the fact that qualitative changes are taking place in interstate economic relations, the volume of export-import operations with goods is increasing, and production structures of an international orientation are purposefully created.

The movement of the growing volume of cargo is carried out, as a rule, with the close interaction of the main types of transport (water, rail, road). The transportation of goods in international communication by the specified modes of transport has its own characteristics, which affect the infrastructural support of the commercial activity of production systems in the market of transport services. One of the conditions for ensuring the competitiveness of logistics systems in transport hubs is the technological process of creating a consolidated batch of cargo. And the preliminary accumulation of export goods at the expense of consolidating cargo spaces and shortening the service terms of vessels in the sea trade port significantly improves the technological and economic indicators of transport and logistics systems.

A comprehensive approach in researching the peculiarities of commercial service of foreign trade cargo flows in existing transport and logistics systems involves taking into account the specifics of the interaction of different types of transport. Thus, the optimization of technical and technological parameters in the specified systems requires high-quality infrastructural support of commercial vehicles that move foreign trade goods in international traffic.

Analysis of recent research and publications. A detailed analysis of modern literature testifies to meaningful studies of the technology and sequence of commercial service of international cargo flows by various types of transport [1, 2]. The content of such services is determined by the export potential of the country and individual regions, means of infrastructural service, methods of carrying out cargo operations [3, 4]. And in each individual case, the characteristics of transport and technological systems and the conditions for compliance with contractual obligations should be taken into account [5, 6]. Under such circumstances, the deepening of economic integration between individual countries comprehensively takes into account the need to improve the structural and economic indicators of production systems of an international orientation [7, 8].

The existing approved regulatory documents and standard schemes for the movement of goods in international traffic contain fundamental provisions regulating the procedure for the accumulation of export consignments of goods in specialized terminals [9, 10]. Separate departmental documents regulate the sequence of customs control and customs clearance of vehicles and cargo moving across the customs border of Ukraine [11]. The sequence of actions of officials and the list of commercial services during the implementation of customs control and customs clearance of foreign trade supplies of goods allows determining the cost system as the basis of the legal mechanism for calculating economic indicators [12].

As a result, as the transport and logistics systems become more complicated, the infrastructural provision of international connections and the assessment of the cost-effectiveness of their operation become more responsible [13]. Complex indicators of the functioning of individual integrated structures are insufficient because, focusing only on the transportation process, they do not take into account the impact of the results of operational changes in the structure and the numerical characteristics of individual components on the final result of their production activity [14].

Formulation of the goals of the article. The existing trends in the development of integration relationships in the international freight flow service system outlined the scientific prospects for the creation and intensive use of competitive transport and technological processes with appropriate infrastructure support. The specificity of international foreign trade operations involves the creation and intensive use of powerful transport hubs with modern specialized terminals. The rational use of innovative infrastructure to create a consolidated batch of foreign trade cargo requires the development of theoretical provisions and practical recommendations to improve technical and economic indicators. Therefore, special attention should be paid to the development and improvement of the methodology of infrastructural support for the commercial activity of production systems of international orientation in the market of transport services.

Presentation of the main material. Infrastructural support of production systems in the market of transport services is carried out during the entire period of movement of goods in the logistics chain. The process of creating a consolidated batch of goods and customs clearance of commercial goods and vehicles used to move goods across the customs border of Ukraine are of a unified nature. That is, the process of providing transport and logistics services does not depend on the business entity, the place of registration or the country of the owner of the vehicle. The specificity of a wide range of transport services for the transportation of grain cargoes in international traffic requires a differentiated analysis of their provision (Table 1).

Table 1

Classification of transport services in customs and logistics systems

Transport services	The content of the main transport services under the condition of creating a consolidated batch of grain cargoes
Technological – those related to the technology of transport service of the grain cargo flow	– organization of loading and unloading operations at transport hubs and specialized terminals; – transfer operations between different modes of transport; – temporary storage of grain cargoes at elevator and warehouse enterprises; – sorting of goods according to consumer properties and directions of transportation; – maintenance and control of physical and chemical properties of cargo.
Informational – those related to the informational support of the transport flow	– notification of the recipient about the shipment or arrival of the cargo; – record keeping and analysis of data on transport activity of consumers; – informing consumers about the location of the cargo; – selection and justification of an effective method of cargo delivery; – informing consumers about the types and cost of transport services.
Commercial - related to transportation technology, production organization and financial reporting	– execution of financial settlements with cargo owners, transport operators and transport organizations on behalf of the transport customer; – registration of the cargo delivery process (customs registration, sanitary control, veterinary control, radiation control, etc.); – conclusion of commercial and other acts on shortages and surpluses, deterioration or damage of cargo or vehicles; – organization of cargo protection in the process of transportation and storage; – performance of insurance operations and search for undelivered goods.
Forwarding – those related to the forwarding of goods and cargo	– selection of technologies for cargo movement; – advising customers of transport services on terms of delivery; – preparation of necessary documents and conclusion of transportation contract; – transfer of cargo to the transport company or its agent; – collecting small shipments and combining them according to transportation directions.

Based on the results of the analysis, it became possible to determine the main areas of commercial activity of the integrated enterprise. For example, participation in the formation of the tariff policy of production formations is as follows:

- substantiation of proposals for determining the real level of tariffs and fees for new and existing categories of cargo flows;
- systematization of proposals for granting preferences to certain groups of consumers of transport services;
- provision of proposals and relevant calculations regarding the introduction of end-to-end tariffs for servicing foreign trade cargo flows.

The conclusion of contracts for transport services for consumers of commercial services is characterized by the following tasks:

- determination of the basic conditions for the transport service of grain cargo flows;
- definition of a differentiated list of types of transport services for possible outsourcing;
- determination and calculation of possible risks in case of force majeure.

Commercial provision of the execution of concluded contracts involves the following type of works:

- execution of freight transport documentation;
- execution of mutual settlements between participants of the transport market;
- consideration of mutual commercial claims.

Thus, depending on the specialization of the integrated production structure, the following areas of work are distinguished in the commercial service:

– sale of transport services and organization of transport services;
– studying the state and forecasting the prospects for the development of the transport services market;
– marketing activities and strategic planning of infrastructure development.

In the theory of optimal management of production processes, in general, such transport and logistics systems are considered, the behavior of which can be influenced or which can be controlled by changing the control parameters. The latter are selected taking into account the technical and technological characteristics for reasonable restriction systems. Therefore, the goal of creating mathematical models based on the theory of optimal management of material resources is the development of methods for choosing numerical values of input parameters, provided that the optimum is achieved by the specified functional.

Problems of this direction arise not only in the study of modern transport and logistics systems, which contain complicated processes of cargo movement, and therefore have not yet been developed in detail, but also in the study of the production processes of providing traditional commercial services related to the maintenance of foreign trade cargo flows. Naturally, the proposed mathematical models for these systems should take into account the influence of a large number of constantly existing and random factors. The first group includes, for example, the length of the cargo transportation route, the productivity of service channels, the planned idle time of the vehicle under loading and unloading, etc. A characteristic feature of these factors is their relative stability due to the fact that their numerical characteristics are selected in advance by customers of commercial services or determined by regulatory documents.

Random factors in the process of creating a consolidated batch of export goods are characterized by the speed of movement of cars on the route, the generalized average carrying capacity of road vehicles, structural features of the rolling stock. The nature of changes in certain factors in the process of providing commercial services is largely influenced by the conditions of the organization of the transport and technological process.

In mathematical models, the influence of the specified factors is determined by the numerical values of the car's rotation time on the route, the intensity of requests and the duration of their service. In addition, in order to determine the economic indicators of the functioning of transport systems, the developed mathematical models must take into account the numerical values of the cost of carrying out transport and loading and unloading operations and the costs associated with unproductive downtime of individual technological mechanisms.

Taking into account the specified theoretical prerequisites, it becomes possible to check the reliability of the created mathematical models through experimental studies and field observations of the functioning of transport and logistics systems in production conditions. The calculation of the economic indicators of the service of international cargo flows is considered on the example of the creation of a consolidated batch of grain cargoes with the application of innovative approaches to the interaction between individual entities of economic activity. Such prerequisites are designed to evaluate the activities of integrated economic structures and production entities in the market of international transportation.

With such a formulation of the question, the number of cars n is considered as a control variable in the objective function of optimizing the structure of integrated systems for the provision of commercial services. Its optimal value n_{opt} is determined by maximizing the profit function $G(n)$ per hour of operation of the transport and logistics complex

$$G(n) = (T_k - S_k)q\mu K_z + (T_m - S_m)q\mu A_z - C_k K_n - C_a A_n, \quad (1)$$

where T_k, S_k – respectively, the tariff and costs for cargo flow maintenance when creating a consolidated batch of cargo in a specialized terminal, €/ton;
μ – intensity of service of road vehicles of load capacity q in the transport node, cars/hour;
K_z, A_z – respectively, the average number of working service posts and the average number of cars serviced by m posts in the transport and logistics system;
T_m, S_m – respectively, the tariff and the cost of transportation of 1 ton of a consolidated batch of goods for the specified l_m distance, €/ton;
K_n – the average number of idle service posts waiting for cars to be serviced;
A_n – the average number of cars waiting for service in a specialized terminal;
$C_к$, C_a – costs related to downtimes of service posts and road vehicles, respectively, €/hour.

The difference $(T_k - S_k)$ between the income T_k from the provision of commercial services in transport terminals and the current costs S_k for the creation of a consolidated batch of export goods is the profit from the completed full cycle of works. The numerical values of these values are closely related to each other and depend on such factors as the available range of commercial services in the system, the conditions for their performance, the possibility of involving additional third-party organizations to perform certain types of work, and the need to pay existing taxes and fees. The variable component value of the S_k indicator includes workers' wages with accruals, costs for the use of energy resources, the cost of technical maintenance and additional commercial services of a specialized terminal, and current repairs and depreciation charges for the restoration of the main production assets.

The constant component of the S_k indicator includes the amount of charges for using the loan, the services of the lesser and the insurance bank, deductions to the innovation fund, as well as general economic expenses. In addition, the numerical value of the first component of the mathematical expression (1) depends on the conditions of the transport-technological process and the scope of the use of advanced innovative technologies. The specified limitations indicate the need to use high-performance infrastructural support in transport hubs and specialized terminals.

The method of determining the profit from the use of terminal infrastructure and road vehicles for 1 hour of operation of the transport and logistics system involves the use of currently existing tariffs for cargo flow maintenance. The results of calculations based on known mathematical dependencies should take into account the change in tariffs and costs compared to the base period.

Using the general solution of known mathematical dependencies in terms of mass service theory for the process of commercial service in a closed system, the numerical value of the indicator $K_z = A_z$ is determined as

$$K_z = \sum_{k=1}^{m-1} kp_k + m\sum_{k=m}^{n} p_k = \sum_{k=1}^{m-1} kp_k + m(1 - \sum_{k=0}^{m-1} p_k) \quad (2)$$

The number of service stations waiting for cars in the specialized terminal Kn, using the main theoretical provisions for stochastic processes, is calculated as

$$K_n = \sum_{k=0}^{m-1} (m-k)p_k \quad (3)$$

The average number of road vehicles that are in the queue for service is

$$A_n = \sum_{k=m}^{n} (k-m)p_k \quad (4)$$

The costs associated with the downtimes of service posts Sk and road vehicles Ca should be interpreted as the sum of fixed costs to determine the cost price, respectively, of technological operations and transportation of consolidated cargoes and lost profit from forced non-productive downtimes of infrastructure components.

Graphical interpretation of the mathematical dependence G(n) = f(n) for the case of creating a consolidated batch of grain cargo with the involvement of road trains with a carrying capacity of q = 20 t to a specialized terminal with two m = 2 service stations is presented in Fig. 1.

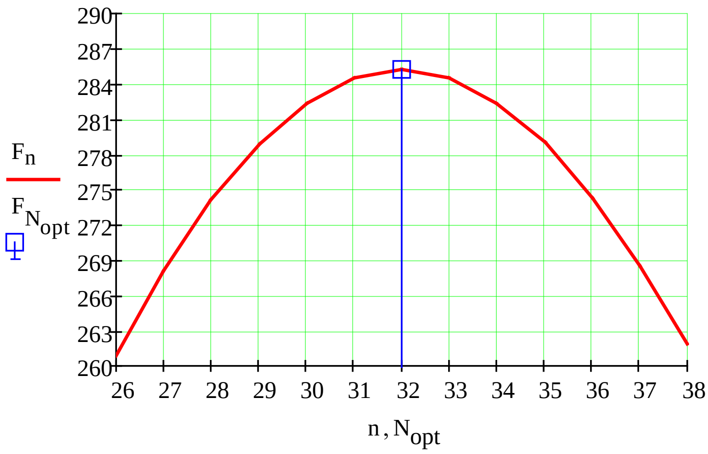

Fig. 1. Hourly profit in the transport and logistics system under the condition of creating a consolidated batch of grain cargo with the involvement of road trains with a carrying capacity of q = 20,0 tons to a specialized terminal with two m = 2 service stations

The task of analyzing the effectiveness of the transport and technological system in relation to the final result is to determine the existing possibilities of achieving the set goal by the specified system in conditions of uncertainty of the parameters of the external environment.

When studying the indicators of the reliability and cost-effectiveness of the functioning of transport and logistics systems in the process of commercial service of foreign trade cargo flows, conditions arise that are characterized by the influence of various random factors: changes in the demand for transport services, the possibility of attracting additional vehicles, changes in the numerical value of operational costs, etc.

The decrease in the hourly profit of the transport and logistics system in the absence of a sufficient number of vehicles is explained by the increase in the Kn indicator of the average number of non-working service posts waiting for cars and, accordingly, the decrease in Kz of working mechanisms. And since the product Kzm is represented in the mathematical relationship (1) with a "plus" sign, and the product CkKn with a "minus" sign, the resulting indicator F(n) decreases significantly.

The trend of decreasing hourly profit G(n) with an excessive number of vehicles in the transport and logistics system indicates the emergence of forced downtime of cars waiting for service. In mathematical expression (1), the change in the indicator G(n) is explained by the influence of the increase in the average number of An cars in the expected service. Moreover, under the condition n > nopt, the rate of growth of the CaAn component is slightly ahead of the rate of decrease of the CkKn component in the system.

With the use of mathematical dependencies (1–4) it became possible to determine both the optimal values of the technical and technological parameters of transport and logistics systems, and the results of the change in the function G(n) due to the change in influencing factors. When creating a consolidated batch of export cargo, an important factor in the organizational structure of the system is the number of service stations for loaded cars m in a specialized terminal. The special influence of the mentioned factor is manifested because the creation of export consignments of grain with subsequent loading onto a sea merchant ship takes place in fairly significant volumes within a limited time frame. Therefore, compliance with the planned indicators of reliability and economy of transport service allows ensuring the competitiveness of the transport and technological process of international direction (Table 2).

Table 2

The optimal value of the number of road vehicles and the maximum hourly profit in the transport and logistics system

Cars		The number of service posts in the terminal					
Load capacity, tons	Costs, €/ton	$m = 1$		$m = 2$		$m = 3$	
		n_{opt}	G(n), €/год	n_{opt}	G(n), €/год	n_{opt}	G(n), €/год
$q = 12{,}0$	4,00	27	69,73	46	186,85	69	300,82
$q = 14{,}0$	3,71	21	95,26	41	221,03	62	352,41
$q = 16{,}0$	3,50	19	107,97	38	246,49	56	390,68
$q = 18{,}0$	3,33	18	118,46	35	267,50	51	422,08
$q = 20{,}0$	3,20	17	126,68	32	284,04	48	446,49
$q = 22{,}0$	3,09	16	133,88	30	298,17	44	467,53

Yes, if the number of service stations is doubled (from $m = 1$ to $m = 2$), the optimal number of road vehicles increases by 70,4% (from $n_{opt} = 27$ to $n_{opt} = 46$) for vehicles with a carrying capacity $q = 12$ t and by 87,5% (from $n_{opt} = 16$ cars to $n_{opt} = 30$ cars) for cars with a carrying capacity of $q = 22$ tons. A slightly more intensive increase in the optimal value of vehicles with a larger carrying capacity is explained by a significant decrease in the time the cars are idle, and accordingly, the possibility of increasing productivity. The specified trend is also preserved under the condition of a three-fold increase ($m = 3$) in the throughput of the system.

The results of changing the influence of the number of service posts in the terminal on the numerical value of the hourly profit *G(n)* in the system are slightly different from the previous analysis. For example, if the indicator m doubles, the hourly profit of the *G(n)* system with cars with a carrying capacity of $q = 12$ tons increases by 2,67 times (from *G(n)* = 69,73 €/hour for $m = 1$ to *G(n)* = 186,85 €/hour for $m = 2$). Under similar conditions, for a system with cars with a carrying capacity of $q = 22$ tons, the increase in the specified result is 2,23 times (from *G(n)* = 133,73 €/hour for $m = 1$ to *G(n)* = 298,17 €/hour for $m = 2$). A somewhat more intensive growth of the *G(n)* indicator for cars with a smaller carrying capacity is due to the fact that the profitability of transportation by these cars is much lower than in the case of using heavy-duty road trains. And at the initial stage of the analysis ($m = 1$), the available bandwidth of the system significantly increases the numerical value of the indicator A_n in the terminal.

For the next increase in the capacity of the transport and logistics system to $m = 3$, the change in hourly profit in the transport and logistics system looks like *G(n)* = 300,82 €/hour for $q = 12$ t and *G(n)* = 467,53 €/hour for $q = 22$ tons. The obtained results confirm the previous thesis about the need to provide specialized terminals with high-performance service mechanisms.

A positive effect on the change of structural n_{opt} and economic *G(n)* indicators in transport and logistics systems is observed when the average carrying capacity of road vehicles increases. The calculated numerical values of the resulting indicators for $q = 12$ tons are within the range of *G(n)* = 69,73 €/hour under the condition $n_{opt} = 27$ cars for $m = 1$ to *G(n)* = 300,82 €/hour under the condition $n_{opt} = 69$ cars for $m = 3$. And increasing the carrying capacity of road vehicles to $q = 22$ tons gives the following results: *G(n)* = 133,88 €/hour under the condition $n_{opt} = 16$ cars for $m = 1$ and *G(n)* = 467,53 €/hour under the condition $n_{opt} = 44$ cars for $m = 3$.

The conducted calculations indicate that in order to significantly improve technological and economic indicators for the creation of a consolidated batch of grain cargoes, there is a need to equip the specified transport and logistics systems with heavy-duty vehicles and road trains.

The requirements for compliance with a certain level of competitiveness of transport and logistics processes in the world market of commercial services are the basis for recommendations in relation to the interaction of individual components of the relevant industrial associations. And one of the elements of optimizing the structure of such integrated entities in the system of international trade can be high-quality and economical infrastructural equipment with a certain number of road vehicles. However, in a number of production situations, the consolidation of export goods requires a forced increase in the productivity of the system to the detriment of economic indicators, or on the contrary, the system may be understaffed with vehicles due to their physical absence. In addition, the nature of the change in the dependence *G(n) = f(n)* indicates a different degree of influence of the indicator n on the cost-effectiveness of transport services.

Using the stated theoretical prerequisites for optimizing the production structure of transport and logistics systems, it became possible to analyze the influence of the average distance of cargo delivery to a specialized terminal on the resulting indicator *G(n)* of hourly profit (table 3).

Table 3

Change in the hourly profit of the operation of the transport and logistics system when creating a consolidated batch of grain under the condition of different average distances of cargo delivery

Number of vehicles in the system	The average distance of delivery of grain cargoes to a specialized terminal, km					
	l_m = 60 km		l_m = 80 km		l_m = 100 km	
	G(n), €/hour	ΔG(n), €/hour	G(n), €/hour	ΔG(n), €/hour	G(n), €/hour	ΔG(n), €/hour
n_{opt}	284,04	–	308,81	–	334,18	–
$n_{opt} – 2$	280,61	3,46	305,26	3,55	332,69	1,49
$n_{opt} – 4$	271,63	12,41	296,99	11,82	327,00	7,18
$n_{opt} – 6$	257,37	26,67	284,53	24,28	317,49	16,69
$n_{opt} – 8$	238,88	45,16	268,47	40,34	304,64	29,54
$n_{opt} – 10$	216,98	67,06	249,45	59,36	288,96	45,22
$n_{opt} + 2$	281,67	2,37	307,41	1,40	331,30	2,88
$n_{opt} + 4$	273,89	10,15	301,17	7,64	324,17	10,01
$n_{opt} + 6$	261,61	22,43	290,61	18,20	313,23	20,95
$n_{opt} + 8$	246,01	38,03	276,57	32,24	299,16	35,02
$n_{opt} + 10$	228,27	55,77	260,01	48,80	282,76	51,42

The results of the comparison of the hourly profit in the *G(n)* system for three variants of the numerical value of the transportation distance l_m show that with the increase of the indicated indicator lm, the optimal value of the indicator *G(n)* tends to increase from *G(n)* = 284,04 €/hour for l_m = 60 km to *G(n)* = 334,18 €/hour for l_m = 100 km. This situation is explained by the fact that with the growth of lm, the productivity of vehicles in ton-kilometers increases, and accordingly, the revenues and profits of the transport and logistics system increase.

The mentioned circumstances also explain the "sensitivity" of transport and logistics structures to changes in the numerical value of cars in the system. For example, the absence or excess of four cars in the system reduces the hourly profit Δ*G(n)* in the transport and logistics system in the range from 4,36% for l_m = 60 km to 2,99% for l_m = 100 km. And if there are no or an excessive number of eight road vehicles, the *G(n)* indicator decreases from 15,90% for l_m = 60 km to 10.48% for l_m = 100 km.

The identified trends convincingly prove the need for the creation and intensive practical use of integrated production structures with a wide range of infrastructure support in the market of commercial services.

Conclusions. According to the results of the research on the infrastructural support of the commercial activity of integrated formations, new results were obtained regarding the effective use of material and financial resources. By creating mathematical models and corresponding software products based on the criterion of hourly profit *G(n)*, the work calculated the value of the optimal number of n_{opt} road vehicles of integrated production structures. Using the main provisions of the theory of mass service, the main principles of equipping production formations of international direction with technical means of service in specialized terminals are determined. It was established that the optimal value of the hourly profit *G(n)* of integrated transport and logistics systems increases with the total increase in the productivity of service stations. By carrying out multivariate calculations, the necessity of equipping production structures of the international direction with large-tonnage cars and road trains, which has a positive effect on the improvement of technological and economic indicators, is substantiated. The conducted research can be useful for the organization of rational infrastructural provision of commercial activities of integrated formations with the aim of competitive service of foreign trade cargo flows.

BIBLIOGRAPHY

1. Pourakbar M., Zuidwijk R.A. The role of customs in securing containerized global supply chains. *European Journal of Operational Research.* 2018. № 271(1). pp. 331-340. doi:10.1016/j.ejor.2018.05.012.
2. Vorkut T., Volynets L., Bilonog O., Sopotsko O., Levchenko I. The model to optimize deliveries of perishable food products in supply chains. *Eastern-European Journal of Enterprise Technologies.* 2019. № 5. pp. 43-50. doi:10.15587/1729-4061.2019.177903.
3. Kulbovskyi I., Bakalinsky O., Sorochynska O., Kharuta V., Holub H., Skok P. Implementation of innovative technology for evaluating high-speed rail passenger transportation. *EUREKA: Physics and Engineering.* 2019. № 6. pp. 63-72. doi:10.21303/2461-4262.2019.001006.
4. Apfelst A., Dashkovskiy S., Nieberding B. Modeling, optimization and solving strategies for matching problems in cooperative full truckload networks. *IFAC Papers On Line*. 2016. № 49. Issue 2. pp. 18-26. doi:10.1016/j.ifacol.2016.03.004.
5. Danchuk V., Bakulich O., Svatko V. Identifying optimal location and necessary quantity of warehouses in logistic system using a radiation therapy method. *Transport.* 2019. № 34. Issue 2. pp. 175-186. doi:10.3846/transport.2019.8546.
6. Prokudin G., Remekh I., Maidanyk K. The efficiency of the runsystem application in international freight transportation, *Politechnika Rzeszowska*. 2017. № 10. pp. 79-86.
7. Silantieva I., Katrushenko N., Kushym B. Ensuring effectiveness in handling the movement of goods and passengers by enhancing information and communication technologies. *Current Problems of Transport: Proceedings of the 1st International Scientific Conference*. 2019. pp. 75-83. doi:10.5281/zenodo.3387287.
8. Lashenyh A., Turpak S. Development of mathematical models for planning the duration of shunting operations. *Eastern-European Journal*

of Enterprise Technologies. 2016. № 5/3(83). pp. 40-46. doi:10.15587/1729-4061.2016.80752.

9. Shin S., Roh H-S, Hur S. Characteristics Analysis of Freight Mode Choice Model According to the Introduction of a New Freight Transport System. *Sustainability.* 2019. № 11(4). 1209 p.
10. Lebid I., Luzhanska N., Kotsiuk O. Technical Support for Freight Customs Complex Operation. *Bulletin of the Eastern Ukrainian National University named after Volodymyr Dahl: Scientific journal.* 2019. № 2(250). pp. 7-11.
11. Singh S., Dubey G.C., Shrivastava R. Various method to solve the optimality for the transportation problem. *Statistical Mechanics and its Applications*. 2016. № 12. pp. 161-169.
12. Gryshchuk O., Petryk A., Yerko Y. Development of methods for formation of infrastructure of transport units for maintenance of transit and export freight flows. *Technology Audit and Production Reserves*. 2022. № 1. Issue (2(63)). pp. 26-30. doi:10.15587/2706-5448.2022.251505.
13. Crainic T., Perboli G., Rosano M. Simulation of intermodal freight transportation systems: a taxonomy. *European Journal of Operational Research.* 2018. № 270. Issue 2. pp. 401-418. doi:10.1016/j.ejor.2017.11.061.
14. Naumov V., Kholeva O. Studying Demand for Freight Forwarding Services in Ukraine on the Base of Logistics Portals Data. *Procedia Engineering.* 2017. № 187. pp. 317-323. doi:10.1016/j.proeng.2017.04.381.

REFERENCES

1. Pourakbar M. & Zuidwijk R.A. (2018) The role of customs in securing containerized global supply chains. European Journal of Operational Research. 271(1), 331-340. doi:10.1016/j.ejor.2018.05.012.
2. Vorkut T., Volynets L., Bilonog O., Sopotsko O. & Levchenko I. (2019) The model to optimize deliveries of perishable food products in supply chains. Eastern-European Journal of Enterprise Technologies. 5, 43-50. doi:10.15587/1729-4061.2019.177903.
3. Kulbovskyi I., Bakalinsky O., Sorochynska O., Kharuta V., Holub H. & Skok P. (2019) Implementation of innovative technology for evaluating high-speed rail passenger transportation. EUREKA: Physics and Engineering. 6, 63-72. doi:10.21303/2461-4262.2019.001006.
4. Apfelst A., Dashkovskiy S. & Nieberding B. (2016) Modeling, optimization and solving strategies for matching problems in cooperative full truckload networks. IFAC Papers On Line. 49. Issue 2, 18-26. doi:10.1016/j.ifacol.2016.03.004.
5. Danchuk V., Bakulich O. & Svatko V. (2019) Identifying optimal location and necessary quantity of warehouses in logistic system using a radiation therapy method. Transport. 34. Issue 2, 175-186. doi:10.3846/transport.2019.8546.
6. Prokudin G., Remekh I. & Maidanyk K. (2017) The efficiency of the runsystem application in international freight transportation, Politechnika Rzeszowska. 10, 79-86.

7. Silantieva I., Katrushenko N. & Kushym B. (2019) Ensuring effectiveness in handling the movement of goods and passengers by enhancing information and communication technologies. Current Problems of Transport: Proceedings of the 1st International Scientific Conference. 75-83. doi:10.5281/zenodo.3387287.
8. Lashenyh A. & Turpak S. (2016) Development of mathematical models for planning the duration of shunting operations. Eastern-European Journal of Enterprise Technologies. 5/3(83), 40-46. doi:10.15587/1729-4061.2016.80752.
9. Shin S., Roh H-S & Hur S. (2019) Characteristics Analysis of Freight Mode Choice Model According to the Introduction of a New Freight Transport System. Sustainability. 11(4), 1209 p.
10. Lebid I., Luzhanska N. & Kotsiuk O. (2019) Technical Support for Freight Customs Complex Operation. Bulletin of the Eastern Ukrainian National University named after Volodymyr Dahl: Scientific journal. 2(250), 7-11.
11. Singh S., Dubey G.C. & Shrivastava R. (2016) Various method to solve the optimality for the transportation problem. Statistical Mechanics and its Applications. 12, 161-169.
12. Gryshchuk O., Petryk A. & Yerko Y. (2022) Development of methods for formation of infrastructure of transport units for maintenance of transit and export freight flows. Technology Audit and Production Reserves. 1. Issue (2(63)), 26-30. doi:10.15587/2706-5448.2022.251505.
13. Crainic T., Perboli G. & Rosano M. (2018) Simulation of intermodal freight transportation systems: a taxonomy. European Journal of Operational Research. 270. Issue 2, 401-418. doi:10.1016/j.ejor.2017.11.061.
14. Naumov V. & Kholeva O. (2017) Studying Demand for Freight Forwarding Services in Ukraine on the Base of Logistics Portals Data. Procedia Engineering. 187, 317-323. doi:10.1016/j.proeng.2017.04.381.