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METHODOLOGY OF IMPLEMENTING THE PRINCIPLES OF SYSTEM ANALYSIS IN STRATEGIES FOR IMPLEMENTING MULTI-STAGE CUSTOMS AND LOGISTICS PROCESSES

The article analyzes the technological features of the transport service of foreign trade cargo flows. The necessity of conducting research using the theoretical provisions of system analysis is substantiated, and the prospects for improving the infrastructure of customs and logistics systems are determined using the example of consolidation of export consignments of grain cargoes. The peculiarities of the implementation of technological and production processes in transport hubs with the participation of elevator and warehouse enterprises are considered. The peculiarities of conducting a system analysis for the formation of a strategy for the implementation of multi-stage customs and logistics processes have been analyzed.

It is noted that the development of a harmonized legal framework and the creation of the necessary digital infrastructure modules for the implementation of national paperless trade systems require the use of innovative infrastructure. Attention is focused on the fact that, taking into account the reorganization of business processes in the system of international trade, proposals for the optimization of new customs and logistics processes should be developed, taking into account national legislation. And prioritizing the application of international standards regarding the exchange of electronic documents in cross-border relations will contribute to the development of trade relations on the basis of economic integration.

Using the example of creating a methodology for finding the optimal solution to production problems, the generalized total costs for servicing foreign trade cargo flows and the hourly profit from the functioning of customs and logistics systems are calculated. It is noted that for import and export cargo flows, the proposed indicators comprehensively take into account the quality of infrastructural support of production systems under the condition of their integration into the global economic network.

With the use of the fundamental provisions of the theory of mass service by conducting complex calculations, the rational structure of customs and logistics systems of international direction is substantiated in the work. By using mathematical models to substantiate management decisions, new results were obtained regarding the infrastructural support of multi-stage customs and logistics processes.

Key words: *transport and technological systems, customs and logistics processes, system analysis, technological characteristics, infrastructural support, consolidated consignment of goods.*

Formulation of the problem. The development of trade relations on the basis of economic integration requires economic entities to form a rational structure of competitive transport and logistics systems. In this case, effective maintenance of foreign trade cargo flows allows improving the economic indicators of economic entities and introducing promising innovative technologies due to the reduction of general logistics costs. With the use of the main theoretical provisions of system analysis, technological and organizational principles for the improvement of transportation, it becomes possible to study the operational response of production structures to changes in the nomenclature of goods, volumes of supply and the quality of transport and logistics services. Therefore, the relevance of the introduction of promising transport and information technologies under the condition of the development of integration processes becomes important for improving the production activity of integrated production structures. The use of powerful transport hubs and import-export enterprises as infrastructural units allows storing, processing and transshipment of large volumes of foreign trade goods. In this case, a significant expansion of the range of transport and logistics services in integrated structures for a wide range of goods requires a complex solution of production tasks in multi-stage customs and logistics processes. And the systematic and documented development of market relations contributes to the intensive use of the existing infrastructure by a significantly larger number of business entities.

The creation of an integrated information system to ensure the smooth movement of goods and services on the transport market requires ensuring the interoperability of data exchange between national systems of electronic interaction. The use of the specified integration platform creates conditions for mutual recognition of electronic identifiers, digital signatures and transport documents by different countries and ensures the necessary protection and security of information for cross-border transfer. Thus, the implementation of the principles of system analysis for the formation of a strategy for the implementation of multi-stage customs and logistics processes requires conducting structural studies of the activity of complex production systems with the use of modern information technologies and innovative software.

Analysis of recent research and publications. The methodology for the implementation of multi-stage customs and logistics processes in the structures of international production formations is based on the use of the main theoretical provisions of system analysis [1, p. 181]. In accordance with the specified prerequisites, the creation of a new and improvement of the existing infrastructure of transport and logistics systems is carried out based on the results of the analysis of production entities with the use of modern information technologies and software [2, p. 4]. Under such conditions, the task of optimizing customs and logistics processes when designing promising production systems takes into account the possibilities of operational management of the entire complex of organizational solutions and is carried out according to the principles of system integration [3, p. 46].

In a number of scientific works, the implementation of the principles of system analysis for the selection of optimality criteria and limitations in mathematical models and methods is illustrated on the example of servicing foreign trade cargo flows [4, p. 28]. Under the conditions of involvement for the transportation of various types of transport, the methodology for determining the main factors that affect the development of customs and logistics processes is shown [5, p. 407]. Numerical values of individual components of production processes in transport and logistics entities are determined on the basis of goal achievement criteria for structured problems [6, p. 78]. And the involvement of mathematical and informational resources in the system analysis allows substantiating the numerical values of indicators characteristic of integrated production formations [7, p. 57].

The determination of integrated system indicators by creating mathematically correct models of static and dynamic customs logistics processes allows us to draw a conclusion about the efficiency of the production system as a whole [8, p. 76]. The development of trade relations between individual subjects of economic activity requires the use of innovative software for conducting mathematical and methodological studies of the efficiency of transport services [9, p. 2398]. Therefore, an important component of the system analysis of customs and logistics processes is the computer implementation of mathematical models for integrated production structures [10, p. 54].

System studies, as a modern interdisciplinary methodology for optimizing information processing and intellectual analysis of the obtained results, became the basis of the approach to the creation of promising transport and logistics systems [11, p. 20]. The wide application of logistics management methods is based on solving a wide range of problems of synthesis of complex customs and logistics processes [12, p. 94]. Therefore, a fundamentally new approach to the development of innovative processes involves the definition of organic mutual relations for the maintenance of material, financial and information flows in a single integrated system. [13, p. 1209].

Presenting main material. A feature of the operation of transport and logistics systems in integrated production structures of an international orientation is significant volumes of cargo flows, the need for regular updating of the material and technical base, as well as limited access to financial resources [14, 224]. The impact of a large number of random factors on the final results of transport service in some cases does not always allow to fully use the planned performance of infrastructure equipment and design features of rolling stock. This situation is particularly relevant to the transportation of grain cargoes in international traffic. And a wide range of types of the specified products requires improvement of the existing infrastructure of transport and logistics systems and intensive use of a sufficient number of service mechanisms. Therefore, in order to ensure the reliability of timely performance of transport operations with an acceptable level of economic indicators, it will be appropriate to create mathematical models for making informed decisions at individual stages of structured problems. And the methodology for determining the rational ratio of quantitative and value parameters requires the implementation of the principles of system analysis in the strategy of implementing multi-stage customs and logistics processes (Table 1).

In the process of analyzing the effectiveness of the functioning of customs and logistics processes of an international direction, the features of the infrastructural service of the specified cargo flows are taken into account, namely the market mechanism of economic regulation of the circulation of goods between individual countries and the tariff regulation of transportation of certain types of cargo. The conducted scientific studies on the development and implementation of appropriate measures for the creation and modernization of transport infrastructure and the formation of an effective export strategy indicate that it may be appropriate to use system analysis for mathematical modeling of customs and logistics processes. And in the absence of a reliable forecast of the future situation in the global grain sector, an increase in the volume of exports of these goods may lead to unpredictable economic consequences. Therefore, one of the directions of

Table 1

The technology of applying system analysis in the strategy of implementing multi-stage customs and logistics processes

The main stages of decision-making for the implementation of customs and logistics processes	Content of reasoned solutions at separate stages of structured problems
1. Formulation of a problem situation in multi-stage processes	• formalization of the problem using system analysis for mathematical modeling of customs and logistics processes; • analysis of production activity of complex systems using modern information technologies and software; • setting the task of optimizing customs and logistics processes when designing production systems.
2. Determination of goal achievement criteria for structured problems	• implementation of the principles of system analysis for the selection of optimality criteria and limitations in mathematical models and methods; • determination of the main factors that influence the development of customs and logistics processes and the separation of stochastic and uncertain factors in them; • the use of mathematical and informational resources in the systematic analysis of transport and technological processes of an international direction.
3. Construction of mathematical models to substantiate management decisions	• creation of mathematically correct models of static and dynamic customs and logistics processes, taking into account the uncertainty of external and internal factors; • use of innovative software for conducting mathematical and methodological studies of the effectiveness of customs and logistics service of foreign trade cargo flows; • computer implementation of mathematical models for integrated systems and customs logistics processes.
4. Search for the optimal solution using methods of system analysis	• the use of systematic research as a modern interdisciplinary methodology to optimize information processing and intellectual analysis of the obtained results; • solving a wide range of synthesis problems of complex customs and logistics processes by using methods of system analysis; • development and implementation of models and decision support systems using computer programming.
5. Systematization of conclusions and preparation of a set of measures for implementation	• formulation of conclusions for complex management tasks in integrated production systems; • generalization of experimental and empirical studies with the aim of creating proposals for the implementation of customs and logistics processes; • use of the obtained results for promising developments in modern transport and information technologies.

research in the multi-stage processes of customs and logistics service is the analysis of the production activity of complex systems with the use of modern information technologies and software.

Transport and logistics service of integrated enterprises requires a differentiated approach to its mathematical modeling. In such a formulation of the question, when designing new and improving existing production systems, it becomes necessary to solve the problems of optimizing customs and logistics processes. This issue becomes especially relevant when introducing new technologies for the movement of grain cargoes, which are based on the need to take into account the cost mechanism for internal transportation, as well as international trade in export goods.

The formation of the export-import policy in the road and transport complex of Ukraine shows that the products of agro-industrial production and the food industry make up a significant part of foreign trade cargo. Under such circumstances, specialized terminals in transport hubs are an important factor in infrastructural support for the export of agricultural products and food.

As a result of the analysis, it can be stated that significant liberalization of the export policy in relation to agro-industrial products significantly simplifies the organization of cargo transportation in international traffic. However, the introduction of an effective export promotion policy requires increasing the competitiveness of customs and logistics processes. As a result of the measures taken, the integration of the Ukrainian agricultural sector into the world trade and economic system is strengthened.

On the basis of previously conducted research, the change in generalized costs in various variants of customs and logistics processes indicates a significant influence of the level of infrastructure support. Therefore, in these circumstances, the development of mathematical models and methods of systematic analysis of influencing factors for the adoption of agreed management decisions is relevant. Taking into account the influence of the production conditions of the formation and movement of the combined export batch of goods, these models can be applied to implement the principles of system analysis for the purpose of choosing optimization criteria, limitations and analyzing the functional capabilities of individual components.

The main criterion for the competitiveness of customs logistics services under the condition of the formation of a combined batch of grain is the general logistics costs *B(n)* calculated per one ton of cargo, as a function of the optimal value of vehicles *n* in the system. In these integrated structures, the increase in the total cost of logistics operations due to the increase in non-productive costs associated with rolling stock downtime at the end points of the route is explained by the increase in the total number of vehicles in the system, and accordingly, the number of cars in the queue. At the same time, when the productivity of service posts increases, the idle time of vehicles in the queue decreases. Therefore, under the condition of an unchanged number of road vehicles in the system, the number of free unloading mechanisms increases, which also affects the increase in the numerical value *B(n)* of the total logistics costs.

Under such circumstances, the calculation of the optimal technological parameters of the system infrastructure in transport nodes is considered taking into account the separation of stochastic and uncertain factors in them and the use of new approaches to interaction between economic entities in conditions of intensive use of intelligent information technologies. Therefore, it is advisable to carry out a mathematical analysis of the change in logistics costs *B(n)* using information resources on the example of the functioning of a multi-channel dynamic mass service system with two nodes.

The input flow λ_1 of demands to the first node is the arrival of empty cars for loading. At the same time, the intensity μ_1 of servicing the total flow of requirements by each mechanism is determined by the average number of loaded cars per unit of time.

For the second node, the input flow of demands λ_2 is the arrival to service cars with grain loads. By analogy with the first node, the intensity of servicing the demand flow μ_2 in the opposite point of the system is characterized by the average number of cars unloaded per unit of time. Taking into account the fact that such a transport system is closed, the numerical values of the input flows λ_1 and λ_2 are equalized, therefore, in the following statements, they are denoted by the total intensity of the demand flow λ, as a value inversely proportional to the car's turnover time on the route, i.e. $\lambda = f(\mu_1, \mu_2)$.

In the specified system, when servicing *n* cars with *m* grain loading machines and unloading them at elevator and warehouse enterprises, the states of the closed system S_k $(k = 0, 1,..., m_1, m_2,..., n)$ will be associated with the number of k cars, which alternately arrive for service.

The creation of mathematically correct models of static and dynamic customs and logistics processes, taking into account the uncertainty of external and internal factors, was carried out using a diagram of the intensity of transitions of a closed mass service system.

In practical activities, when using own or hired fleet of cars for the accumulation of combined cargo in the terminal, the priority criterion for determining the complex of strategic solutions is the minimum logistics costs $B(n) = B_1(n) + B_2(n)$ of the entire set of transport and transshipment works, as a function of the total number of rolling stock in the system

$$B_1(n) = \frac{P_{k1}S_{k1}}{\mu_1 q} + S_m + \frac{1}{K_{z1}\mu_1 q}\left(C_1 K_{n1} + C_2 A_{n1}\right)$$
$$B_2(n) = \frac{P_{k2}S_{k2}}{\mu_2 q} + \frac{1}{K_{z2}\mu_2 q}\left(C_3 K_{n2} + C_2 A_{n2}\right) \quad (1)$$

where P_{k1}, P_{k2} – hourly productivity of loading and unloading posts of motor vehicles, respectively, tons/hour;

S_{k1}, S_{k2} – the cost of carrying out loading and unloading works, respectively, €/ton;

K_{z1}, K_{z2} – the number of occupied posts, respectively, for loading and unloading motor vehicles;

K_{n1}, K_{n2} – the number of idle posts for servicing cars, respectively, at loading and unloading points;

A_{n1}, A_{n2} – the average number of cars waiting for service at the loading and unloading stations, respectively;

C_1, C_2 – hourly cost of downtime of service mechanisms, respectively, at loading and unloading points, €/hour;

C_3 – the cost of vehicle downtime, €/hour.

The use of innovative software for conducting mathematical and methodological studies of the effectiveness of customs and logistics service of foreign trade cargo flows shows that the value of the indicator $B(n)$ largely depends on the number of service mechanisms m_1, m_2, and the productivity P_{k1}, P_{k2} of each of them.

The results of mathematical modeling carried out under the conditions of transportation of grain cargoes by road trains with a carrying capacity of q = 20 tons over a distance of l_m = 90 km convincingly show that the minimum value of the total logistics costs $B(n)$ is achieved under the condition of synchronous operation of the service mechanisms in the grain sending and receiving enterprises cultures (Table 2).

The computer implementation of mathematical models for integrated systems and customs logistics processes shows that the feature of the operation of the transport system with two service nodes with the synchronous growth of the productivity of technological mechanisms P_{k1}, P_{k2} is that the resulting value of the total logistics costs $B(n)$ decreases. For example, a simultaneous increase in the hourly productivity of mechanisms P_{k1} and P_{k2} in the range of numerical values from 10 tons/hour to 50 tons/hour leads to a decrease in the total logistics costs $B(n)$ from 7,13 €/ton to 5,38 €/ton. And the change of the specified indicators P_{k1} and P_{k2} in the range from 50 tons/hour to 90 tons/hour reduces the total logistics costs $B(n)$ by 1,13 €/ton (from 5,38 €/ton to 4,25 €/ton). The determined trend is explained by the increase in the capacity of the transport system and, accordingly, the reduction of the idle time of rolling stock at service points. And a slight decrease in the rate of change in the logistics cost of transportation $B(n)$ with the growth of indicators P_{k1} and P_{k2} is the result of a slight saving of time due to the idleness of motor vehicles.

A reliable generalization of the patterns of transport and logistics service of export cargo flows is important when using systematic research as a modern interdisciplinary methodology for optimizing information processing and intellectual analysis of the obtained results. The formation of a rational infrastructure of relevant transport systems involves

Table 2

Total logistics costs for the transportation of grain cargo by road trains with a carrying capacity of q = 20 tons for a distance of l_m = 90 km in a system with two service nodes, €/ton

Productivity of P_{k1} mechanisms at the point of departure, tons/hour	Hourly productivity of service post P_{k2} in the transport terminal, tons/hour								
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
10	**7,13**	7,58	8,08	8,63	9,23	9,88	10,58	11,33	12,10
20	7,54	**6,62**	7,20	7,79	8,39	9,00	9,60	10,25	10,86
30	8,00	7,16	**6,16**	6,71	7,28	7,85	8,44	9,04	9,68
40	8,51	7,71	6,68	**5,75**	6,29	6,84	7,40	7,98	8,56
50	9,08	8,28	7,20	6,25	**5,38**	5,90	6,44	6,99	7,55
60	9,69	8,85	7,74	6,76	5,86	**5,04**	5,55	6,08	6,61
70	10,35	9,41	8,29	7,29	6,36	5,51	**4,75**	5,25	5,75
80	11,06	10,03	8,85	7,83	6,88	6,00	5,21	**4,51**	4,96
90	11,83	10,60	9,45	8,38	7,40	6,50	5,68	4,93	4,25

solving a wide range of problems of synthesis of complex customs and logistics processes by using methods of system analysis. And the forms and technologies of servicing various cargo flows are determined by the dominant types of foreign trade cargo, volumes of deliveries and an adapted expert system for making organizational decisions in conditions of reputational risks.

Taking into account the specified theoretical prerequisites, it becomes possible to develop and implement models and decision support systems using computer programming. The reliability of the proposed mathematical models was confirmed by field observations of the functioning of transport and logistics systems in the conditions of servicing foreign trade cargo flows. The search for the optimal option for the implementation of multi-stage customs and logistics processes using the methods of system analysis is considered on the example of the creation of a consolidated batch of international grain cargoes. With the application of innovative approaches to the interaction between individual subjects of economic activity, the prerequisites for evaluating the activities of integrated production structures on the market of international transportation have been developed.

With this 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 economic entities in the provision of commercial services. Using the basic provisions of the theory of mass service systems, the optimal value of n_{opt} is determined by maximizing the profit function $G(n)$ per hour of operation of the transport and logistics complex as

$$G(n) = (T_k - S_k) q \mu K_z + (T_m - S_m) q \mu A_z - C_k K_n - C_a A_n, \quad (2)$$

where T_k, – tariff for cargo flow maintenance when creating a consolidated batch of cargo in a specialized terminal, €/ton;

A_z – the average number of cars that are simultaneously serviced by m posts in the transport and logistics system;

S_m – tariff for the transportation of 1 ton of a consolidated batch of goods for a specified lm distance, €/ton;

$C_к$, C_a – costs related to downtimes of service posts and road vehicles, respectively, €/hour.

Other components of dependence (2) are similar in content to the components of mathematical model (1) with the difference that when determining $G(n)$ in some of them, due to the presence of only one service point, there is no digital numbering in subscript symbols. For specialized terminals, the difference between revenues T_k from the provision of commercial services in transport terminals and current costs S_k for the creation of a consolidated batch of export cargoes is interpreted as a profit from the completed full cycle of works. The numerical values of these values are closely related to each other by market relationships and depend on the quality of the available range of transport and logistics services in the system and the conditions for their performance.

Stochastic and uncertain factors include such as the possibility of attracting additional third-party organizations to perform certain types of work, the amount of payment of existing taxes and fees, etc. The numerical value of the variable component of the S_k indicator includes the wages of workers, the cost of using energy resources, the costs of maintenance and current repairs, and depreciation charges for the restoration of the main production assets.

The permanent component of the S_k indicator includes charges for using credit, lessor and bank insurance services, as well as general household expenses. The need to use advanced innovative technologies in transport and logistics systems confirms the well-known theses about the feasibility of using high-performance infrastructure in transport hubs and specialized terminals.

The methodology for determining the profit $G(n)$ in integrated structures from the use of terminal infrastructure and road vehicles for 1 hour of operation of the transport and logistics system involves the use of existing tariffs for servicing foreign trade cargo flows. The results of prospective calculations based on the proposed mathematical dependencies should take into account the change in tariffs and costs compared to the base period.

With the use of mathematical dependence (2), it became possible to determine both the optimal values of the technical and technological parameters of transport and logistics systems, as well as the results of the function $G(n)$ from the change in infrastructure characteristics. For example, when creating a consolidated batch of export goods, an important factor in the organizational structure of the system is the hourly productivity of the elevator-warehouse facility P_k for loading cars and the number of service posts m in a specialized terminal. The special influence of these factors is manifested by the fact that 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.

The example of involving cars with a carrying capacity of q = 22 tons for the transportation of grain for a distance of l_m = 30 km shows the possibility of ensuring the competitiveness of the transport and technological process of cargo consolidation (Table 3).

Thus, if the number of service posts m is doubled (from m = 2 to m = 4), the optimal number of road vehicles n_{opt} increases accordingly by 69,2% (from n_{opt} = 26 to n_{opt} = 44) for elevator productivity-warehouse P_k = 60 tons/hour and by 90,6% (from n_{opt} = 53 to n_{opt} = 101) for productivity P_k = 160 tons/hour. A slightly more intense increase in the optimal value of the rolling stock for the elevator and warehouse economy of higher productivity is explained by a significant reduction in the idle time of cars under loading, and, accordingly, an increase in the transport capacity of vehicles. The specified trend is preserved also under the condition of a three-fold increase in the productivity of P_k elevators.

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 a productivity of P_k = 60 tons/hour increases by 2,18 times (from *G(n)* = 296,58 €/hour for m = 2 to *G(n)* = 649,49 €/hour for m = 4). Under similar conditions, for a system with a productivity of P_k = 160 tons/hour, the increase in the specified result is 2,06 times (from *G(n)* = 1115,09 €/hour for m = 2 to *G(n)* = 2300,67 €/hour for m = 4).

A slightly more intensive growth of the *G(n)* indicator for cars with a lower system performance P_k is explained by the fact that with low-power shipping mechanisms, the profitability of transport and logistics service is somewhat lower than in the case of using high-performance service posts. Therefore, at the initial stage of the analysis (m = 2), the throughput of the system is relatively low due to a significant increase in the number of cars in the queue to service stations A_n of the terminal. The obtained results confirm the well-known thesis about the need to provide specialized terminals with high-performance service mechanisms...

The increase in the average productivity P_k of the elevator and warehouse economy has a positive effect on the change in structural n_{opt} and economic *G(n)* indicators in transport and logistics systems during the consolidation of the export batch of cargo.

An example of such an influence can be the numerical value of relative profit $G_{(l)}$ – hourly profit *G(n)* per car. According to the results of the calculations, the proposed indicator $G_{(l)}$ increases by 1,89 times under the condition m = 2 (from $G_{(l)}$ = 11,41 €/hour for the hourly productivity of the elevator and warehouse facility P_k = 60 tons/hour to $G_{(l)}$ = 21,03 €/hour for P_k = 160 tons/hour). When the number of service posts is doubled (m = 4), the $G_{(l)}$ indicator in the specified P_k range increases by 1,54 times (from $G_{(l)}$ = 14,76 €/hour for the productivity of elevators P_k = 60 tons/hour to $G_{(l)}$ = 22,78 €/hour for P_k = 160 tons/hour) (Fig. 1). A similar trend of the change in the $G_{(l)}$ indicator is observed in the case of the equipment of the specialized terminal with three (m = 3) unloading mechanisms (Fig. 2).

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 high-performance infrastructure equipment.

Based on the results of the generalization of the main theoretical provisions of the system analysis for integration processes in international production structures, it became possible to determine a set of measures for the unification of customs and logistics processes (Table 4).

Implementation of the proposed innovative procedures makes it possible to use the obtained results for promising developments in modern transport and information technologies. And in order to implement measures to ensure cross-border electronic interaction in customs affairs, appropriate subprograms should be implemented to reorganize business processes for paperless trade in international relations.

Table 3

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

Parameters of infrastructure support		The number of service stations in the specialized terminal					
Hourly elevator productivity, tons/hour	Terminal costs, €/ €/ton	*m* = 2		*m* = 3		*m* = 4	
		n_{opt}	G(n), €/hour	n_{opt}	G(n), €/hour	n_{opt}	G(n), €/hour
P_k = 60	6,50	26	296,58	34	475,95	44	649,49
P_k = 80	6,35	29	441,61	42	684,12	56	929,85
P_k = 100	6,20	35	591,19	51	911,67	67	1235,43
P_k = 120	6,05	41	753,38	60	1157,80	78	1565,72
P_k = 140	5,90	47	928,04	68	1422,44	90	1920,96
P_k = 160	5,75	53	1115,09	77	1705,80	101	2300,67

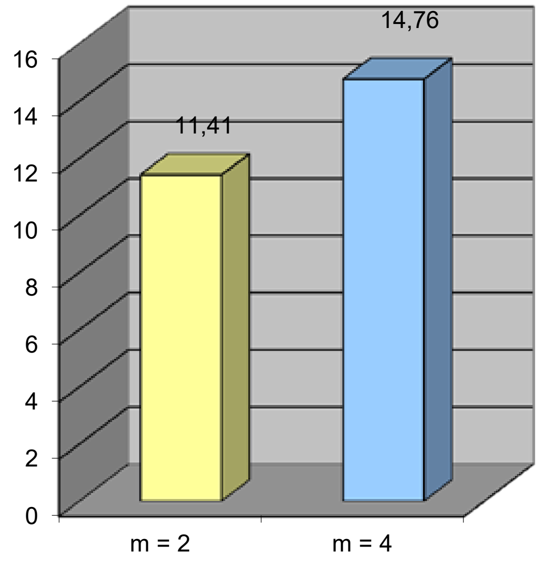

Fig. 1. Relative profit in the transport and logistics system $G_{(1)}$ under the condition of elevator productivity P_k = 60 tons/hour

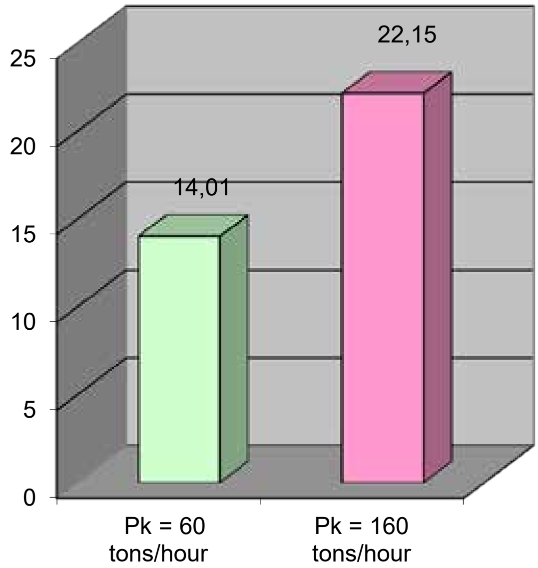

Fig. 2. Change in relative profit in the transport and logistics system $G_{(1)}$ under the condition m = 3 in a specialized terminal

Table 4

Application of the principles of system analysis for the implementation of cross-border business processes in transport and logistics systems

Creation of cross-border networks for integrated processes	Implementation of measures in the environment of digital infrastructure	The result of the creation and implementation of integration platforms in the system of international transportation
Interoperable platforms to ensure cross-border electronic interaction in customs affairs	– implementation of cross-border paperless trade transactions using electronic identification; – the ability to work with electronic documents according to international standards; – provision of various access channels for the formation of electronic payment documents; – creation of a unified catalog of goods and services (SCGS) in accordance with GS1 international standards; – synchronization of SCGS with national banks of general products and services in each country; – adaptation and synchronization of SCGS language versions.	– a solution for an integration platform with a mechanism for cross-border exchange of data and documents; – unified catalog of goods and services (SCGS), synchronized with national data banks; – individual deployment planning in partner countries.
Control units in the electronic logistics system: – digital infrastructure of electronic invoicing; – electronic delivery; – electronic identification; – electronic signature; – automated transfer in each country.	– systematic analysis of all relevant EU directives and requirements; – certification of the secure data and document exchange infrastructure (eDelivery) with compliance checks in accordance with e-SENS AS4; – coordination with EU standards (Directive 2014/55/EU) of information messages of state bodies and exchange protocols; – a technical solution for processing electronic signatures in accordance with EU Regulation № 910/2014 for electronic transactions (eIDAS Regulation); – development of a mechanism for automated translation of various documents.	– the main solution for the digital platform of data and document exchange (eDelivery access point) with eID and eSignature functions; – adapted eInvoicing modules for exchanging standardized information messages with government bodies in partner countries; – implemented eTranslation modules; – certified national infrastructures.

The development of a harmonized legal framework and the creation of the necessary digital infrastructure modules for the implementation of national paperless trade systems (NPTS) involve the use of innovative infrastructure in the strategy of implementing multi-stage customs and logistics processes. On the basis of the reorganization of business processes in the international trade system, proposals for optimizing import-export procedures and new future processes should be developed, taking into account national legislation. The priority of applying EU standards with an emphasis on the exchange of electronic documents in cross-border relations will contribute to the development of international trade relations on the basis of economic integration.

According to the results of the generalization of experimental and empirical studies with the aim of creating proposals for the implementation of customs and logistics processes, one of the promising directions is the intensive use of the "single window" platform. The integration of existing elements of the national digital infrastructure and information systems in the "single window" portal allows performing the functions of an integrator of information flows for foreign economic operations.

Conclusions. The generalization of the results of the research on the infrastructural support of transport and logistics systems indicates the need for technical and organizational improvement of the specified production structures. Using the main theoretical provisions of system analysis, new results were obtained for the creation and implementation of innovative infrastructure in specialized terminals. Based on the main provisions of the theory of mass service, the main technological and structural characteristics of multi-stage customs and logistics processes were calculated.

The need to create an integrated information system to ensure the interoperability of data exchange between national e-commerce systems is substantiated. Attention is focused on the fact that such an integration platform will create conditions for mutual recognition of electronic identifiers, electronic signatures and transport documents in different countries. The specified platform will provide the necessary protection and security of information for cross-border transmission, and its components will be interconnected using existing telecommunication networks.

The conducted research can be useful for improving the transportation of goods in international communication by implementing the principles of system analysis in the strategy of implementing multi-stage customs and logistics processes.

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Грищук О.К., Петрик А.В., Літус Т.М. МЕТОДОЛОГІЯ ВПРОВАДЖЕННЯ ПРИНЦИПІВ СИСТЕМНОГО АНАЛІЗУ В СТРАТЕГІЯХ РЕАЛІЗАЦІЇ БАГАТОЕТАПНИХ МИТНО-ЛОГІСТИЧНИХ ПРОЦЕСІВ

У статті проведено аналіз технологічних особливостей транспортного обслуговування зовнішньоторговельних вантажопотоків. Обґрунтовано необхідність проведення досліджень із використанням теоретичних положень системного аналізу та визначено перспективи удосконалення інфраструктури митно-логістичних систем на прикладі консолідації експортних партій зернових вантажів. Розглянуто особливості виконання технологічно-виробничих процесів в транспортних вузлах за участю підприємств елеваторно-складського господарства. Проаналізовано особливості проведення системного аналізу для формування стратегії реалізації багатоетапних митно-логістичних процесів.

Зазначено, що розроблення гармонізованої законодавчої бази та створення необхідних модулів цифрової інфраструктури для впровадження національних безпаперових торговельних систем передбачають використання інноваційної інфраструктури. Акцентовано увагу на тому, що з урахуванням реорганізації бізнес-процесів в системі міжнародної торгівлі мають бути розроблені пропозиції щодо оптимізації нових митно-логістичних процесів з урахуванням національного законодавства. А пріоритетність застосування міжнародних стандартів щодо обміну електронними документами у транскордонних відносинах сприятиме розвитку торговельних відносин на засадах економічної інтеграції.

На прикладі створення методології пошуку оптимального варіанту рішення виробничих проблем розраховано узагальнені сумарні витрати на обслуговування зовнішньоторговельних вантажопотоків та годинний прибуток від функціонування митно-логістичних систем. Зазначено, що для імпортних та експортних вантажопотоків запропоновані показники комплексно враховують якість інфраструктурного забезпечення виробничих систем за умови їх інтеграції у світову економічну мережу.

З використанням фундаментальних положень теорії масового обслуговування шляхом проведення комплексних розрахунків в роботі обґрунтована раціональна структура митно-логістичних систем міжнародного спрямування. Шляхом використання математичних моделей для обґрунтування управлінських рішень отримано нові результати щодо інфраструктурного забезпечення багатоетапних митно-логістичних процесів.

Ключові слова: *транспортно-технологічні системи, митно-логістичні процеси, системний аналіз, технологічні характеристики, інфраструктурне забезпечення, консолідована партія вантажів.*