This study's object is the process that organizes and plans the work of a transport enterprise when transporting general, dangerous, and oversized cargo along international roads.

The task addressed is the need to compile recommendations for determining the required number of personnel and the duration of rendering transport services depending on the type of cargo received for service.

A simulation model of the work of a transport enterprise when organizing international road transportation has been built and implemented in the GPSS World simulation modeling automation package. The model involves determining the duration of transport service and planning the personnel support for a transport enterprise according to the functional division of labor.

When building the model, the duration of the types of work provided by specialists of the transport enterprise when transporting general, dangerous, and oversized cargo was taken into account.

In addition, the model takes into account the probability of errors and delays at each stage of service. The average duration of the delay in the event of errors is also determined, which could make it possible to set additional time for engaging a separate specialist to eliminate them.

The application of the devised model in practice would allow owners of transport enterprises to organize business processes depending on the available type of rolling stock. It could also make it possible to determine the optimal number of specialists of various profiles required for organizing transport services for the customer.

At the same time, the duration of transport services for the delivery of various types of cargo will be reduced by 8–14% while the number of specialists of the transport enterprise – by 10–15%; in turn, the throughput will increase by 7–16%

Keywords: transport enterprise, international transportation, simulation model, motor vehicle

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DEVELOPMENT OF A SIMULATION MODEL OF TRANSPORT ENTERPRISE OPERATION WHEN CARRYING VARIOUS TYPES OF CARGO ALONG INTERNATIONAL ROUTES

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1. Introduction

The effectiveness of foreign trade operations largely depends on the implementation of organizational, managerial, technical, and technological measures related to the transportation of goods. The key characteristics of the transport process are provided by the main and auxiliary personnel of the transport enterprise, which must perform all types of work in a timely and high-quality manner. Most employers in this field of activity are faced with a shortage of qualified specialists in the labor market. Lack of experience or narrow specialization of the employee can cause delays or errors in the provision of services to the customer, which will negatively affect the reputation of the enterprise. Since the issue of staffing transport enterprises is quite relevant under the conditions of competition among business entities, it is advisable to use modern approaches to study it with the aim of improvement.

Practical experience of transport enterprises shows that the service of different types of cargo may differ in terms of efficiency indicators for both the contractor and the customer. The main differences in transport service are in documentary support, preparation of rolling stock, and transportation technology. On the part of the contractor, the key characteristics of the work are the available type of rolling stock, which limits

the range of goods that it can transport. The qualification of the company's management personnel is confirmed by the ability to promptly process the customer's request without significant differences in the duration of the work and the absence of errors in the service. In turn, the performance of auxiliary work requires the necessary number of specialists who will provide timely and high-quality services.

When forming a request for service to transport companies, customers are interested in cooperation with the organization of delivery of goods in compliance with the requirements for transportation, the performance of all types of work in the shortest possible time at an acceptable cost of services. Therefore, the establishment of long-term partnerships depends on the efficiency of the carrier's work in comparison with competing organizations. An individual transport company, organizing its activities, independently forms the number of staff, its qualitative and quantitative composition, the type and number of vehicles, its carrying capacity and chooses the main directions of transportation. Depending on the demand by regular customers, management may choose different strategies for making management decisions regarding changes in personnel and material and technical support.

Scientific research on improving organizational and managerial measures in the activities of transport enterprises when transporting various types of cargo is relevant when planning all stages of service. Companies can achieve competitive advantages in the international transportation market by optimizing production processes using modern software packages capable of performing current analysis of performance indicators for all types of work.

Practical implementation of such results will make it possible to plan the work of transport enterprises taking into account the demand for transportation of individual categories of cargo, the duration of their service, and the availability of a sufficient number of personnel for work. In addition, it will be possible to determine the required number of specialists and vehicles for servicing various categories of cargo. Research on the current state of the enterprise will provide the opportunity to identify shortcomings in the activities and eliminate them to improve service for future periods.

2. Literature review and problem statement

In [1] it is noted that conducting economic activities in the field of transport requires the coordination of many factors at the same time. Planning and implementation of transport processes require extensive knowledge of the stages and procedures associated with the movement of goods along international routes. The results of the research make it possible to reduce delivery time and decrease transport costs when transporting goods along international routes. At the same time, the study does not use simulation modeling and does not consider the process of preparing the carrier for the trip.

In [2], it is also indicated that the transport process consists of many stages, at which many obstacles and problems may arise, therefore, persons responsible for various stages must closely monitor them. Therefore, to ensure the efficiency of the transport process, it must be properly coordinated. The work identified the main problems that arise in the organization of transport processes, developed schemes for organizing the transport process when transporting goods along international routes. However, the study does not use simulation modeling and does not consider the processes that occur at a transport enterprise during the organization of cargo transportation.

In work [3], attention focuses on the fact that road transport enterprises should constantly pay attention to increasing the efficiency of providing transport services, in accordance with the requirements and expectations of consumers. The enterprise should devise a system for assessing the quality and efficiency of the functioning of the transport system and present a procedure for improving production processes. The paper gives a mathematical model for a comprehensive assessment of the transport service production process. This model does not apply to simulation models, in addition, the cited paper does not consider the organization of the work of a transport enterprise when transporting various types of cargo along international routes.

In [4], a study was carried out, the purpose of which was to evaluate the operation process and determine the impact of important technical and operational variables on the economic efficiency of vehicle operation process. To this end, the indicator method and a multifactor regression model were used. The paper is relevant since the problems of vehicle operation efficiency are important for transport companies. In it, the authors focus on local networks, which are important for the last mile of delivery. Thus, the method and model developed in the paper cannot be used to build a simulation model of the operation of a transport enterprise when transporting various types of cargo along international routes.

Transportation of each type of cargo (dangerous, oversized, perishable) requires different types of preparatory work. For example, in [5] it is noted that the transportation of dangerous goods requires careful planning, strict rules, and special processing procedures for analyzing potential hazards and assessing the level of transportation risk. In the work, a method for assessing the risk of transporting dangerous goods using a multi-agent system was proposed and simulated, which displays the location, trajectory of the truck, and the impact zone in the event of an accident during simulation. The presented model does not make it possible to simulate and study the processes that occur in the transport company during the carrier's preparatory work.

Simulation models (SMs) are the most effective tool for analyzing transport processes and systems, which makes it possible to solve a wide range of tasks in the field of their management. As noted in [6], simulation modeling provides an opportunity to study logistics technologies. Using IM to model the existing process, it is possible to choose the optimal logistics technology that meets all the requirements necessary for the organization of freight transportation. At the same time, in the presented SM, the authors did not take into account the impact of specificity in the preparation of different types of cargo on the organization of transportation along international routes.

In work [7], several models were built that optimize delivery routes based on time, distance, and total cost. However, these models are constructed for local networks and for optimizing the delivery of the "last mile" and cannot be used in modeling freight transportation along international routes. In addition, the devised models do not provide an opportunity to study the work of a transport enterprise in organizing the transportation process.

In [8], attention is drawn to the fact that in transport companies, vehicle route planning and vehicle loading are managed separately, despite the fact that these actions are interconnected. This forces routes or loading plans to be changed quite often to allow for their coordination. The authors

propose a certain algorithm that jointly solves the problem and automates the delivery process, which significantly increases the efficiency of logistics operations. However, this algorithm does not provide for its application for organizing international transportation and does not take into account the need to perform certain preparatory operations for different types of cargo.

In [9], a combination of simulation modeling and optimization is proposed, which makes it possible to take into account both planned and unforeseen events when managing multimodal transportation. The work focuses on the European transport network and does not consider the specificity of international transportation. In addition, the simulation model built does not allow for the specificity of transporting different types of cargo.

In [10], a simulation of transport processes in a transport company was performed using business process modeling tools and methodology. Specialized software was used to simulate the transport process in order to identify the main problems that arise during the organization of cargo transportation. This approach cannot be used for simulation modeling due to the impossibility of taking into account the specificity of organizing transportation along international routes.

In [11], a comprehensive model for assessing the effectiveness of the functioning of logistics activities of road transport enterprises was constructed. This model can be used in the operational management of logistics activities of road transport enterprises to assess the effectiveness of decisions made. This model cannot be used to study the work of a transport enterprise when transporting various types of cargo because it does not take into account the specificity of the implementation of preparatory operations.

In [12], a SM of the work of a freight forwarding company in organizing multimodal cargo transportation was built. The model makes it possible to study and optimize individual parameters of a transport company, such as the duration of service provision and the number of specialists in the transportation department. At the same time, in the presented SM, the authors did not take into account the specificity of organizing preparatory work for transporting different types of cargo.

Organizing the transportation of different types of cargo (dangerous, oversized, perishable, general, groupage) requires the implementation of certain specific organizational, managerial, technical, and technological measures in preparation for the trip. The duration of these activities can significantly affect the efficiency of organizing the transport process, especially in international transportation. Therefore, there is a need to build a SM of the work of a transport company, which would make it possible to perform such studies.

Our review of related literature shows that existing studies cover individual aspects of organizing transport processes but do not take into account the key factors necessary for modeling the work of a transport company under international transportation conditions. In particular, there are no models that would simultaneously combine modeling of internal processes of the enterprise, the specificity of preparation for the trip depending on the type of cargo, requirements for technical and technological support. Some works are focused on optimizing certain stages but do not provide a holistic reflection of the process of organizing transportation along international routes. Thus, the problem of constructing a SM that would make it possible to optimize the work of a transport enterprise taking into account the types of cargo, necessary preparatory operations, as well as the impact of these factors on the efficiency of transportation, remains unresolved. This is the problem that predetermines the expediency of conducting further research.

3. The aim and objectives of the study

The purpose of our work is to build a simulation model of the process of rendering transport services when organizing international transportation of hazardous, oversized, and general cargoes, taking into account the time characteristics of the studied stages of work by transport enterprise specialists. This would make it possible:

– to provide recommendations to the management of transport enterprises on the effectiveness of customer service when organizing transportation of hazardous, oversized, and general cargoes;

– to plan the duration of organizational measures by transport enterprise specialists depending on the type of cargo to be transported;

– to plan the staff number of transport enterprise specialists necessary for organizing transportation of hazardous, oversized, and general cargoes.

To achieve this aim, the following objectives were accomplished:

– to formalize the model of the transport enterprise's work when organizing transportation of hazardous, oversized, and general cargoes;

– to develop an algorithm for the functioning of a transport enterprise that takes into account the transportation of various types of cargo along international routes;

– to conduct a study of the work of a transport enterprise when organizing transportation of various types of cargo and evaluate the results of modeling.

4. The study materials and methods

The object of our study is the process of organizing and planning the work of a transport enterprise when transporting general, hazard, and oversized cargoes by road along international routes.

The hypothesis of the study assumes that the use of a simulation model of the work of a transport enterprise when transporting hazardous, oversized, and general cargoes would allow for the optimization of organizational, managerial, and production processes.

It would allow for planning the duration of rendering transport services, taking into account the probability of errors and delays at a separate stage of service.

When preparing for an international trip, a transport enterprise performs a number of activities related to the fulfillment of documentary formalities and preparing a vehicle for the trip. Depending on the type of cargo, transport enterprise managers must prepare a package of transport and permit documents that would ensure the unhindered movement of the driver, vehicle, and goods across the customs border. The practical experience of transport enterprises indicates significant differences in the implementation of these processes when transporting hazardous, oversized, and general cargoes.

Modern transport companies have a different structure of the fleet of vehicles. Some of them have the same brands and models of vehicles, which characterizes the organization as highly specialized. Others, on the contrary, prefer to purchase

vehicles capable of transporting various types of cargo. However, preparation for the transport process requires the company's managers to have professional competencies that meet the regulatory requirements for the transportation of a given cargo and service technology in accordance with the individual needs of the customer.

First of all, for the effective operation of a transport enterprise, management team needs to plan the number and employment of managers taking into account influencing factors. Such factors are the available fleet of vehicles; the number of applications for the transportation of a particular type of cargo; the duration of a particular stage of service; the probability of errors and delays at the stage; the duration of the delay.

Given the need to optimize the processes occurring at different enterprises depending on their specialization, the following basic assumptions regarding the differences in organizing the transportation of general, hazard, and oversized cargoes were taken into account:

– list of types of work required for execution at each stage;

– number of specialists providing service in a particular area of activity;

– duration of work at each stage, min;

– probability of errors at each stage, %;

– probability of delays at each stage, %;

– average delay time when errors occur, min;

– the number of vehicles capable of transporting a particular type of cargo by specialization;

– the movement of MVs in the return connection with or without cargo;

– the presence or absence of service errors at each stage.

In the process of conducting the study, the following simplifications were adopted regarding the work of transport enterprises:

– the condition is accepted that the organizational structure and staffing are generalized for all types of transport enterprises by specialization;

– the duration of customs formalities is carried out in accordance with the current legislation of the country of departure, destination, and transit (if any);

– the speed of movement of MVs along specified routes is regulated by the traffic rules of the countries of destination on individual sections of the routes;

– all involved specialists provide service within the scope of job descriptions.

The choice of methods and procedures for conducting the study is significantly influenced by the following features of the work of a transport enterprise:

– a significant number of business processes, which are difficult to predict for long periods;

– indicators of the efficiency of the work of an individual specialist and his/her interaction with other employees;

– the probability of unforeseen circumstances at each stage of service;

– most technical, technological, and organizational processes are random in nature.

When modeling the work of a transport enterprise, it is necessary to take into account a number of random factors that cannot be described analytically. To build the model, the method of statistical testing (Monte Carlo method) was used. Its essence is that instead of describing random phenomena by analytical dependences, multiple repetition of realizations of some random event is carried out. By performing such a draw repeatedly, statistical material is accumulated, which is then processed by known statistical methods.

The simulation model of the transport enterprise is implemented in the GPSS World simulation modeling automation package [13]. The GPSS World environment is a machine implementation of the statistical testing method and makes it possible to automatically acquire information about the modeling results – modeling statistics.

5. Determining the optimal number of managers at a transport enterprise using a simulation model

5. 1. Formalizing the model of transport enterprise operation

The process of functioning of a transport enterprise in the organization of international road transportation is influenced by a certain set of factors. Let us divide the input parameters of the model of the operation of a transport enterprise into known $A=\{a_1, a_2, \ldots, a_m\}$, which cannot be influenced, and controlled $X=\{x_1, x_2, \ldots, x_k\}$.

The output parameters, which in some way depend on vectors A and X, are denoted as $Y=\{y_1, y_2, \ldots, y_n\}$, i.e., $Y=\Phi(A; X)$.

In general, the model of functioning of the activities of a transport enterprise in the organization of international road transportation of goods can be represented by the following structure

$$Y=\begin{Bmatrix} a_1, a_2, \ldots, a_m \\ x_1, x_2, \ldots, x_k \end{Bmatrix}. \quad (1)$$

When formalizing the model of the transport enterprise, the presence of controllable factors X was noted, which include:

– the intensity of orders received by the carrier when delivering hazardous, oversized, and general cargoes λ_j, s/month;

– options for returning the vehicle in the opposite direction (movement with cargo, movement without cargo).

The uncontrollable factors A of the model are:

– the estimate of the average time for performing the i-th operation W_i at each stage of service when delivering hazardous, oversized, and general cargoes $m_{ij} \pm \sigma_{ij}$, min.;

– the delay in performing the i-th operation W_i at each stage of service when delivering hazardous, oversized, and general cargoes β_{ij};

– the probability of making errors in service when performing the i-th operation W_i at each stage of service when delivering hazardous, oversized, and general cargoes γ_{ij};

– the number of specialists at the transport enterprise required to organize the transportation of hazardous, oversized, and general cargoes M_{lj};

– the number of vehicles on the balance sheet of the enterprise for the delivery of hazardous, oversized, and general cargoes V_j.

The processing of an application by a transport enterprise is the execution of certain stages of work (Tables 1–3), which must be completed before it leaves the service. The duration of each work is considered as a random variable with a given distribution law. The parameters necessary for modeling the random variable are established as a result of statistical processing of field research data. The FIFO order (first in, first out) is adopted as the main order for servicing applications.

Two options for returning a motor vehicle (MV) in the reverse direction are considered:

– movement with cargo;

– movement without cargo.

Table 1

Types of activities by a transport company when organizing the transportation of hazardous goods

Activity ID	Activity essence	Performer (job title)
ST_1	**Step 1. Acceptance of the application from the Customer**	
W_{11}	Acceptance of the Customer's initial request	Logistics Manager
W_{12}	Determination of the cargo hazard class (class 1–9)	Logistics Manager
W_{13}	Checking the availability of appropriate transport for transporting cargo of this class	Logistics Manager
W_{14}	Preliminary calculation of the cost of transportation	Logistics Manager
W_{15}	Agreement of preliminary transportation conditions with the Customer	Logistics Manager
ST_2	**Step 2. Preparation for transportation**	
W_{21}	Drawing up a detailed route taking into account prohibitions and restrictions on movement for dangerous goods	Logistician
W_{22}	Coordination of the route with the relevant authorities (police, local administrations)	Logistician, lawyer
W_{23}	Issuance of permits for the transportation of dangerous goods	Lawyer
W_{24}	Checking the completeness of the vehicle for transporting goods (ADR cards, fire extinguishing equipment, etc.)	Logistician
W_{25}	Checking the driver's availability of documents for the transportation of dangerous goods of this class (ADR certificate)	Logistician, logistics manager
ST_3	**Step 3. Paperwork**	
W_{31}	Conclusion of a contract with the Customer	Logistics Manager
W_{32}	Preparation of accompanying documents (CMR, invoices, permits, ADR documents)	Logistics Manager
W_{33}	Checking the compliance of documents with the requirements for the transportation of dangerous goods	Lawyer
ST_4	**Step 4. First stage of transportation**	
W_{41}	Loading the vehicle with safety requirements in mind	Driver, loader
W_{42}	Securing the cargo in accordance with the standards for the transport of dangerous goods	Mechanic, driver
W_{43}	Final inspection of the vehicle and cargo	Logistics manager
W_{44}	Cargo transportation	Driver
ST_5	**Step 5. Completion of transportation at destination**	
W_{51}	Unloading of cargo at the destination in compliance with safety regulations	Driver, loader
W_{52}	Transfer of documents to the cargo owner (invoice, original CMR)	Logistics manager
ST_6	**Step 6. Return to the transport company and final document flow**	
W_{61}	Search for cargo for reverse loading	Logistics Manager
W_{62}	Cargo transportation	Driver
W_{63}	Return of the vehicle to the base (TC)	Driver
W_{64}	Transfer of documents to the company's accounting department (CMR register, driver's reports)	Driver, Accountant
W_{65}	Preparation of an invoice for payment for the client (taking into account the actual transportation)	Accountant
W_{66}	Providing the client with original documents (invoice, CMR, acts)	Accountant
W_{67}	Sending invoices and accompanying documents to the client for payment	Accountant
W_{68}	Receiving confirmation of payment from the client (bank details, invoice)	Accountant
W_{69}	Verifying the crediting of funds to the company's account and closing the application	Accountant
$W_{6\,10}$	Archiving documents in the company	Logistics Manager

Table 2

Types of activities by a transport company when organizing the transportation of oversized cargo

Activity ID	Activity essence	Performer (job title)
1	2	3
ST_1	**Step 1. Acceptance of the application from the Customer**	
W_{11}	Acceptance of the Customer's initial request (phone, email, platform)	Logistics manager
W_{12}	Clarification of cargo parameters (dimensions, weight, special requirements)	Logistics manager
W_{13}	Checking the availability of available transport	Logistician
W_{14}	Preliminary calculation of the cost of transportation	Logistics manager
W_{15}	Agreement of preliminary transportation conditions with the Customer	Logistics manager
ST_2	**Step 2. Preparation for transportation**	
W_{21}	Drawing up a detailed route taking into account road restrictions	Logistician
W_{22}	Coordination of the route with local authorities (police, road services)	Logistician, lawyer
W_{23}	Issuance of permits for the transportation of oversized cargo	Lawyer
W_{24}	Organization of escort (special transport, traffic police)	Logistician
W_{25}	Verification of vehicle compliance with transportation requirements	Mechanic
W_{26}	Conducting briefing for the driver and escort team	Logistician

Continuation of Table 2

1	2	3
ST_3	**Step 3. Paperwork**	
W_{31}	Conclusion of a contract with the Customer	Logistics Manager
W_{32}	Preparation of accompanying documents (CMR, invoices, permits)	Logistics Manager
W_{33}	Checking the compliance of documents with the requirements of road services	Lawyer
W_{34}	Agreement on the time of departure and arrival at the destination with the Customer	Logistician
ST_4	**Step 4. First stage of transportation**	
W_{41}	Loading the vehicle taking into account safety requirements	Driver, loader
W_{42}	Securing the cargo in accordance with transportation standards	Mechanic, driver
W_{43}	Conducting a final inspection of the vehicle and cargo	Logistics manager
W_{44}	Receiving documents from the cargo owner (CMR, invoices, permits)	Logistics manager
W_{45}	Cargo transportation	Driver
ST_5	**Step 5. Completion of transportation at destination**	
W_{51}	Unloading of cargo at the destination in compliance with safety regulations	Driver, loader
W_{52}	Transfer of documents to the cargo owner (invoice, original CMR)	Logistics manager
ST_6	**Step 6. Return to the transport company**	
W_{61}	Search for cargo for reverse loading	Logistics Manager
W_{62}	Cargo transportation	Driver
W_{63}	Return of the vehicle to the base (TC)	Driver
W_{64}	Transfer of documents to the company's accounting department (CMR register, driver reports)	Driver, Accountant

Table 3

Types of activities by a transport company when organizing the transportation of general cargo

Activity ID	Activity essence	Performer (job title)
ST_1	**Step 1. Acceptance of the application from the Customer**	
W_{11}	Acceptance of the Customer's initial request (phone, email, platform)	Logistics manager
W_{12}	Clarification of cargo parameters (dimensions, weight, type of packaging, special requirements)	Logistics manager
W_{13}	Checking the availability of appropriate transport for transportation	Logistician
W_{14}	Preliminary calculation of the cost of transportation	Logistics manager
W_{15}	Agreement of preliminary transportation conditions with the Customer	Logistics manager
ST_2	**Step 2. Preparation for transportation**	
W_{21}	Drawing up a detailed route taking into account road infrastructure	Logistician
W_{22}	Agreement on departure time with the Customer	Logistics Manager
W_{23}	Checking the vehicle's compliance with cargo requirements (carrying capacity, volume)	Mechanic
W_{24}	Preparation of equipment for loading/unloading (if necessary)	Logistician
ST_3	**Step 3. Paperwork**	
W_{31}	Conclusion of a contract with the Customer	Logistics Manager
W_{32}	Preparation of accompanying documents (CMR, invoices)	Logistics Manager
W_{33}	Verification of compliance of documents with the requirements for the transportation of general cargo	Lawyer
ST_4	**Step 4. First stage of transportation**	
W_{41}	Loading the vehicle in accordance with the requirements	Driver, loader
W_{42}	Securing the cargo in accordance with safety standards	Mechanic, driver
W_{43}	Conducting a final inspection of the vehicle and cargo	Logistics manager
W_{44}	Handing over to the driver documents for the carriage of cargo (CMR, invoices, route)	Logistics manager
W_{45}	Cargo transportation	Driver
ST_5	**Step 5. Completion of transportation at destination**	
W_{51}	Unloading cargo at the destination	Driver, loader
W_{52}	Transfer of documents to the cargo owner (invoice, original CMR)	Driver, Logistics Manager
ST_6	**Step 6. Return to the transport company and final document flow**	
W_{61}	Search for cargo for reverse loading	Logistics Manager
W_{62}	Cargo transportation	Driver
W_{63}	Return of the vehicle to the base (TC)	Driver
W_{64}	Transfer of documents to the company's accounting department (CMR register, driver's reports)	Driver, Accountant
W_{65}	Preparation of an invoice for payment for the client	Accountant
W_{66}	Providing the client with original documents (invoice, CMR, acts)	Accountant
W_{67}	Receive confirmation from the client of payment	Accountant
W_{68}	Verification of funds credited to the company's account and closing the application	Accountant
W_{69}	Archiving documents in the company	Logistics Manager

Service can be carried out:
– in the presence of errors in service;
– without errors in service.
Each of the studied stages is characterized by:
– duration of execution of a separate stage of service;
– probability of errors at a stage;
– probability of delays at a stage;
– average delay time when errors occur.

Accordingly, the management team of the enterprise is faced with the task of planning personnel support capable of organizing transport service in the shortest possible time in the absence of errors and delays at all stages and with minimal refusals in the provision of services.

We accept the condition: execution of an international trip along the Kyiv-Warsaw route for all types of research since here it is necessary to represent the employment of managers in organizational activities.

The main indicators of modeling Y, which determine the goals of modeling – optimization of the work of a transport enterprise in organizing the transportation of various types of cargo, are:
– average service time t_j, min.;
– average downtime in the queue to the manager for service w_k, min.;
– average queue length to the manager, η_k, s.p.;
– share of applications that were serviced without downtime in the queue to the manager, ν_k, %;
– number of managers to service a separate flow of applications, n_k;
– manager load factor, ψ_k;
– average number of employed managers, ρ_k;
– probability of service failure, q_k;
– throughput, A_k, s.p./month.

SM restrictions are related to the conditions imposed on the incoming flow of applications when delivering hazardous, oversized, and general cargoes. It is assumed that the incoming flow is the simplest, that is, it has three main properties: ordinariness, stationarity, and absence of aftereffects. There are also no phenomena that change the regularities of service time (failures and equipment failures, etc.).

5. 2. Development of an algorithm for the operation of a transport enterprise that takes into account the transportation of various types of cargo along international routes

To build a SM of a transport enterprise in organizing international road transportation of hazardous, oversized, and general cargoes, it is proposed to use the theory of mass service.

Unlike the SM reported in [14], additional modules are proposed for the SM being built, which make it possible:
– to take into account different types of cargo and the specificity of organizing their transportation, including the involvement of additional specialists;
– to determine the duration of delays and assess their probability when performing different types of work;
– to take into account errors that were detected during the execution of work and the time required to eliminate them;
– to determine the probabilities of refusals when accepting applications for the transportation of cargo at a given length of the queue of unprocessed applications or exceeding the service waiting time.

The block diagram of the algorithm and the relationship among the built SM modules is shown in Fig. 1.

An example of the SM of the transport enterprise activity in GPSS World is shown in Fig. 2.

5. 3. Research on the work of a transport enterprise in organizing the transportation of various types of cargo

SM should accurately reflect the work of a transport enterprise in organizing the transportation of cargo and the consistency of the work of organization specialists at each stage. Therefore, for its further use, a check of the adequacy of the modeling to a real transport enterprise was performed.

To check the adequacy of the model, the hypothesis of the proximity of the average values of the service time and the idle time in the queue was tested according to the data of the transport enterprise and the results obtained during the simulation experiment on the constructed SM was tested.

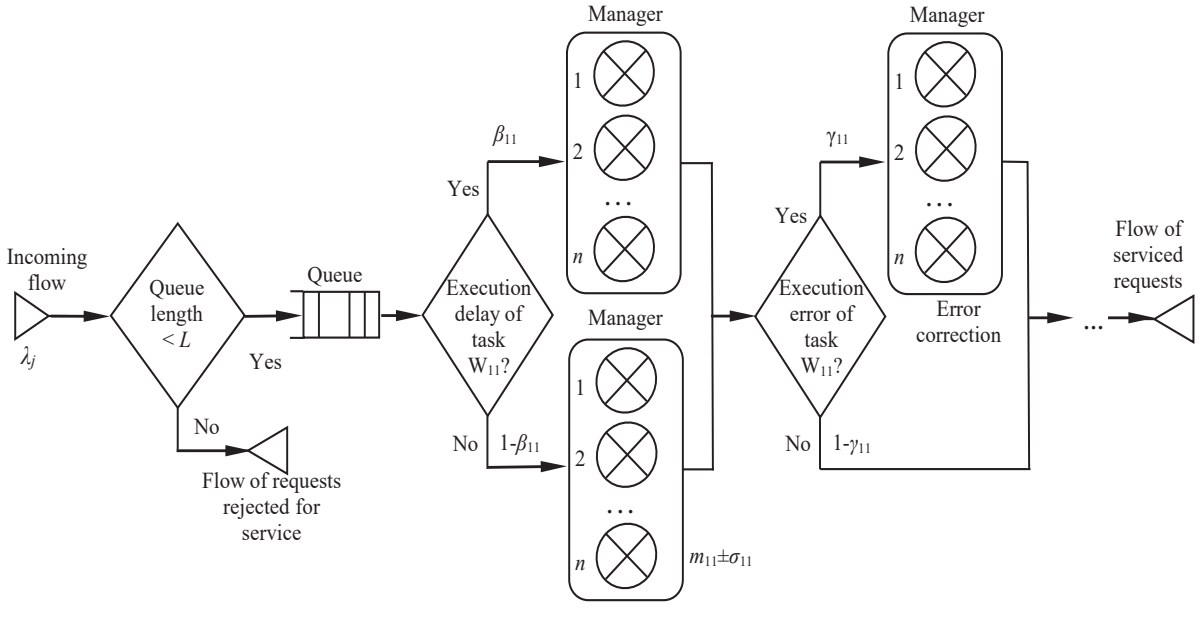

Fig. 1. Flowchart of the modeling process of work W_{11} execution at stage ST_1

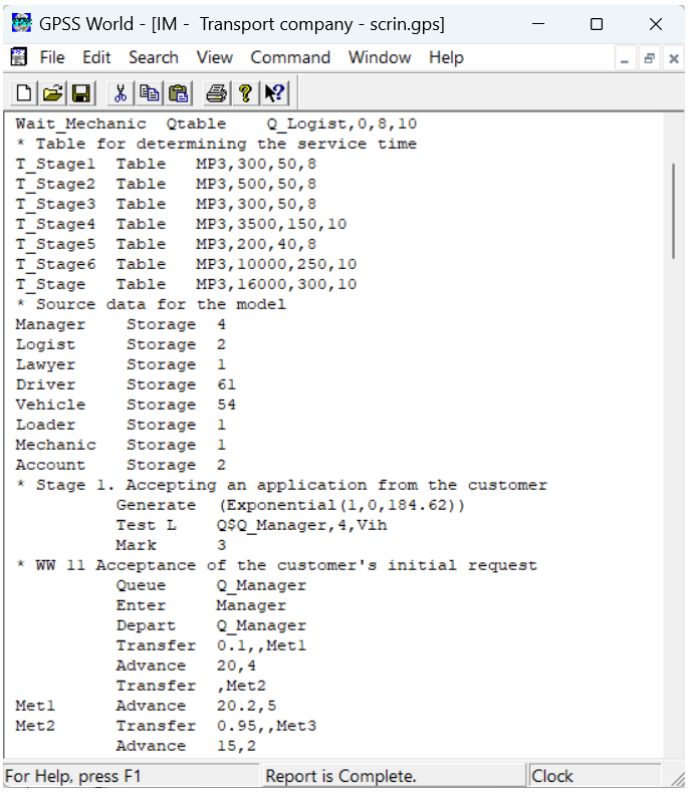

Fig. 2. Partial program listing of the simulation model (SM) implemented in GPSS World

As a result of collecting and processing statistical data, the average service time in organizing all stages of cargo transportation, as well as the delay time in servicing (idle time in the queue for servicing) was obtained.

The check of adequacy of the SM to a real transport enterprise was carried out for the case when it is possible to determine the values of the system responses during full-scale tests.

To check the adequacy of the model, the hypothesis of the proximity of the average values of each model response $\overline{Y}$ to known average value of the response of a real object $\overline{Y}^*$ was tested. $N_1 = 5$ experiments were conducted at a real object, and a sample of values $\{Y_i^*\}$, $i = \overline{1,5}$. was formed. Using the simulation model, $N_2 = 5$ experiments were conducted; samples of values $\{Y_i\}$ were obtained from the model responses $i = \overline{1,5}$.

The results of our field and model experiments are given in Table 4.

Table 4

Verifying adequacy of the simulation model

Response	Value of components of the sample					$\overline{Y}_n, \overline{Y}_n^*$	$\overline{D}_n, \overline{D}_n^*$	D_{an}	t_n
	$J=1$	$J=2$	$J=3$	$J=4$	$J=5$				
t_{1j}	534	505	440	512	525	503	1374.7	2233.6	0.6959
t_{1j}^*	580	485	450	535	570	524	3092.5		
t_{2j}	786	675	752	804	790	761.4	2697.8	3140.15	1.0327
t_{2j}^*	820	710	765	855	840	798	3582.5		
t_{3j}	553	695	585	612	667	622.4	3395.8	5450.05	0.5740
t_{3j}^*	480	685	650	530	633	595.6	7504.3		
t_{4j}	4420	5240	4115	4560	5502	4767	338078	634279.4	0.8604
t_{4j}^*	3500	5500	3610	5260	3800	4334	930480		
t_{5j}	502	475	486	604	675	548.4	7638.3	6780.5	0.8026
t_{5j}^*	535	569	519	618	710	590.2	5922.7		
t_{6j}	11515	11488	15460	12450	11600	12503	2892109	20646169	0.7790
t_{6j}^*	10870	10300	18400	10800	950	10264	38400230		
w_{1j}	260	266	246	235	212	243.8	462.2	674.95	1.2781
w_{1j}^*	270	290	285	264	215	264.8	887.7		
w_{2j}	42	53	49	66	54	52.8	76.7	137.2	0.8639
w_{2j}^*	55	56	40	77	68	59.2	197.7		
w_{3j}	55	68	78	56	82	67.8	152.2	97.5	0.6725
w_{3j}^*	69	53	64	63	69	63.6	42.8		

Estimates of the mathematical expectation and variance of the model and system responses were determined from the samples (Table 4) using the following relationships:

$$\bar{Y}^*_{Q_n} = \frac{1}{N_1}\sum_{k=1}^{N_1} Y^*_{Q_{nk}};$$

$$D^*_n = \frac{1}{N_1 - 1}\sum_{k=1}^{N_1}\left(Y^*_{Q_{nk}} - \bar{Y}^*_{Q_n}\right)^2;$$

$$\bar{Y}_n = \frac{1}{N_2}\sum_{k=1}^{N_2} Y_{nk};$$

$$D_n = \frac{1}{N_2 - 1}\sum_{k=1}^{N_2}\left(Y_{nk} - \bar{Y}_n\right)^2. \quad (2)$$

The basis for testing the hypothesis is the difference $E_n = \left(\bar{Y}_n - \bar{Y}^*_{Q_n}\right)$, the variance estimate of which is

$$D_{an} = \frac{\left(N_1 - 1\right)D_n + \left(N_2 - 1\right)D^*_n}{N_1 + N_2 - 2}. \quad (3)$$

The calculated estimates of variance D_{an} are given in Table 2.

The quantities E_n and D_{an} are independent statistics, so the t-statistic can be used

$$t_n = \left(\bar{Y}_n - \bar{Y}^*_{Q_n}\right)\sqrt{\frac{N_1 N_2}{D_{an}\left(N_1 + N_2\right)}}. \quad (4)$$

With the number of degrees of freedom $n = N_1 + N_2 - 2 = 8$ and the significance level $\alpha = 0.05$, the critical value ($t_{cr} = 1.85$) was determined according to the Student distribution tables. Comparing each of the values of the t-statistics in Table 4 with t_{cr} ($t_n \le t_{cr}$), the hypothesis about the closeness of the average values of the model responses and the real object is accepted. Thus, we can speak about the adequacy of the SM and the real object.

The study simulated the process of rendering transport services for organizing international transportation of hazardous, oversized, and general cargoes along the Kyiv-Warsaw route. Screening of the results of SM simulation is shown in Fig. 3.

To simulate the operation of a transport enterprise when delivering goods in the presence of service errors and without errors, the Kyiv-Warsaw route was chosen. The simulation results, taking into account the movement of MVs with and without cargo in the reverse direction, are given in Tables 5–7.

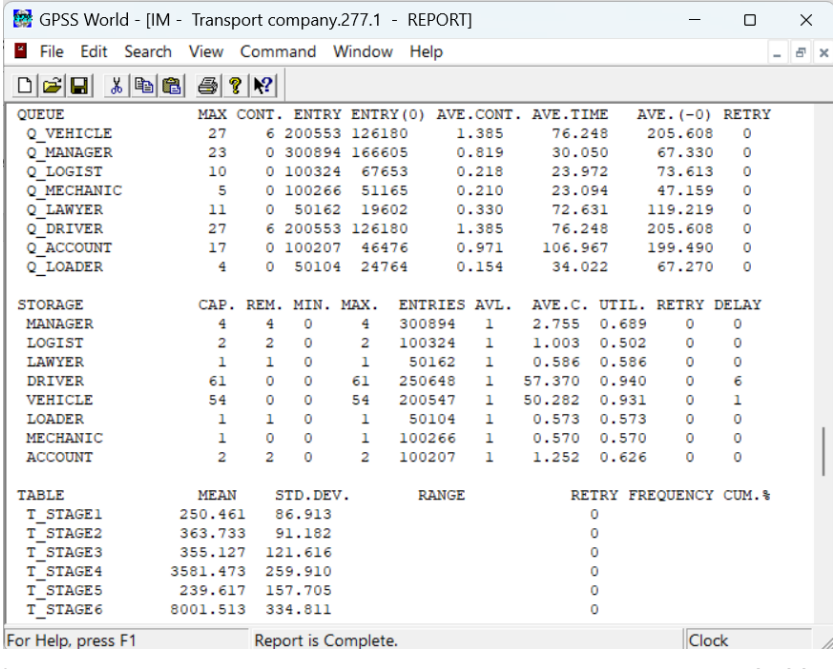

Fig. 3. Example of results based on modeling a transport enterprise activity in GPSS World

Table 5

Results of assessing the average delivery time of hazardous goods along the Kyiv-Warsaw route

Stages of service	Average service time, min.			
	Presence of errors		Error-free	
	Movement of MVs with cargo	Movement of MVs without cargo	Movement of MVs with cargo	Movement of MVs without cargo
Stage 1. Acceptance of the application from the customer, t_{11}	534	457	522	399
Stage 2. Preparation for transportation, t_{12}	786	1029	711	813
Stage 3. Preparation of documents, t_{13}	553	877	520	643
Stage 4. The first stage of transportation, t_{14}	4420	4409	4430	4352
Stage 5. Completion of transportation at the destination, t_{15}	302	395	308	354
Stage 6. Return to the transport company and final document flow, t_{16}	11515	4414	11511	4318
Stage 1 – Stage 6. Delivery of hazardous goods, t_1	18110	11581	18002	10879

Table 6

Results of assessing the average delivery time of oversized cargo along the Kyiv-Warsaw route

Stages of service	Average value of service time, min.			
	Presence of errors		Error-free	
	Movement of MVs with cargo	Movement of MVs without cargo	Movement of MVs with cargo	Movement of MVs without cargo
Stage 1. Acceptance of the application from the customer, t_{11}	272	264	259	248
Stage 2. Preparation for transportation, t_{12}	925	918	829	836
Stage 3. Preparation of documents, t_{13}	430	435	382	392
Stage 4. The first stage of transportation, t_{14}	5022	4761	4980	4713
Stage 5. Completion of transportation at the destination, t_{15}	522	368	498	326
Stage 6. Return to the transport company and final document flow, t_{16}	15607	4153	15584	3852
Stage 1 – Stage 6. Delivery of oversized goods, t_1	22778	10899	22532	10367

Table 7

Results of assessing the average delivery time of general cargo along the Kyiv-Warsaw route

Stages of service	Average value of service time, min.			
	Presence of errors		Error-free	
	Movement of MVs with cargo	Movement of MVs without cargo	Movement of MVs with cargo	Movement of MVs without cargo
Stage 1. Acceptance of the application from the customer, t_{11}	250	244	241	246
Stage 2. Preparation for transportation, t_{12}	364	358	350	361
Stage 3. Preparation of documents, t_{13}	355	347	328	351
Stage 4. The first stage of transportation, t_{14}	3581	3586	3564	3577
Stage 5. Completion of transportation at the destination, t_{15}	240	258	228	246
Stage 6. Return to the transport company and final document flow, t_{16}	8002	3677	7838	3422
Stage 1 – Stage 6. Delivery of general cargo goods, t_1	12792	8470	12549	8203

According to the reports compiled as a result of modeling the work of the enterprise in servicing customers, the main indicators of the modeling results were determined and the duration of downtime in service queues was calculated, which are given in Tables 8–14.

The results given in Tables 5–7 reflect the time characteristics of all types of work required for the delivery of hazardous, oversized, and general cargoes. This will allow both the customer and the specialists of the transport enterprise to plan production processes. The results of our studies given in Tables 8–13 make it possible to assess the efficiency of the work of various specialists at a transport enterprise. The data in Table 14 allow us to assess the efficiency of the work of the transport enterprise when transporting hazardous, oversized, and general cargoes. The modeling results will allow the owners of transport enterprises and their specialists to carry out organizational and managerial measures regarding personnel policy and material and technical support, taking into account the specificity of rendering their services.

Table 8

Results of modeling the delivery of hazardous goods in the presence of errors in the work of transport company specialists

Performer	Presence of errors											
	Movement of MVs with cargo						Movement of MVs without cargo					
	w_k	η_k	ν_k	n_k	ψ_k	ρ_k	w_k	η_k	ν_k	n_k	ψ_k	ρ_k
Logistics Manager	260	3.01	31.3	2	0.75	1.50	238	2.24	26.4	1	0.71	0.71
Logistician	42	0.16	75.2	2	0.44	0.88	8.8	0.03	89.6	2	0.43	0.86
Lawyer	55	0.32	74	3	0.55	1.63	330	1.86	25.7	2	0.80	1.59
Driver	206	1.19	56.1	43	0.74	31.8	259	1.46	53.3	20	0.86	17
MVs	206	1.19	56.1	30	0.90	27.1	259	1.46	53.3	17	0.83	14
Truck Driver	23	0.05	95.2	1	0.25	0.25	9.38	0.02	86.7	1	0.24	0.24
Mechanic	0	0.0	100	1	0.12	0.12	0	0.0	100	1	0.12	0.12
Accountant	104	0.40	49.2	1	0.48	0.48	132	0.49	51.6	1	0.46	0.46

Table 9

Results of modeling the delivery of hazardous goods without errors in the work of transport company specialists

Performer	Error-free											
	Movement of MVs with cargo						Movement of MVs without cargo					
	w_k	η_k	ν_k	n_k	ψ_k	ρ_k	w_k	η_k	ν_k	n_k	ψ_k	ρ_k
Logistics Manager	259	3.01	31.8	2	0.74	1.48	196	1.89	27.6	1	0.70	0.70
Logistician	37	0.15	74.8	2	0.42	0.83	7.2	0.03	90.9	2	0.41	0.83
Lawyer	45	0.26	68.8	3	0.51	1.54	181	1.05	36.9	2	0.74	1.47
Driver	218	1.27	68.2	43	0.74	32.0	234	1.35	51.0	20	0.88	18
MVs	218	1.27	68.2	30	0.91	27.2	234	1.35	51.0	17	0.85	14
Truck Driver	23	0.05	74.4	1	0.25	0.25	8.7	0.02	87.0	1	0.23	0.23
Mechanic	0	0.0	100.0	1	0.12	0.12	0	0.0	100.0	1	0.12	0.12
Accountant	102	0.40	49.5	1	0.47	0.47	123	0.48	51.8	1	0.47	0.47

Table 10

Results of modeling the delivery of oversized cargo in the presence of errors in the work of transport company specialists

Performer	Presence of errors											
	Movement of MVs with cargo						Movement of MVs without cargo					
	w_k	η_k	ν_k	n_k	ψ_k	ρ_k	w_k	η_k	ν_k	n_k	ψ_k	ρ_k
Logistics Manager	47	0.21	71.2	2	0.43	0.85	55	0.20	54.9	1	0.43	0.43
Logistician	22	0.04	84.1	2	0.31	0.62	12	0.04	87.9	2	0.33	0.66
Lawyer	82	0.28	64.5	2	0.51	1.01	85	0.28	62.0	2	0.54	1.09
Driver	425	1.43	52.4	35	0.72	25.2	252	0.92	56.6	15	0.82	12.3
MVs	425	1.43	52.4	23	0.95	21.7	252	0.92	56.6	12	0.84	10.1
Truck Driver	6	0.01	89.8	1	0.14	0.14	6	0.01	89.9	1	0.15	0.15
Mechanic	2	0.01	93.6	1	0.14	0.14	2	0.01	92.9	1	0.15	0.15
Accountant	0	0.0	100.0	1	0.05	0.05	0	0.0	100.0	1	0.04	0.04

Table 11

Results of modeling the delivery of oversized cargo without errors in the work of transport company specialists

Performer	Error-free											
	Movement of MVs with cargo						Movement of MVs without cargo					
	w_k	η_k	ν_k	n_k	ψ_k	ρ_k	w_k	η_k	ν_k	n_k	ψ_k	ρ_k
Logistics Manager	47	0.21	71.8	2	0.42	0.85	50	0.19	55.8	1	0.43	0.43
Logistician	17	0.04	86.1	2	0.29	0.62	9	0.03	89.9	2	0.32	0.65
Lawyer	56	0.28	64.9	2	0.46	1.01	70	0.26	65.7	2	0.51	1.03
Driver	404	1.36	53.8	35	0.72	25.2	220	0.82	59.8	15	0.82	12.3
MVs	404	1.36	53.8	23	0.94	21.7	220	0.82	59.8	12	0.84	10.1
Truck Driver	5	0.01	90.6	1	0.14	0.14	6	0.01	90.1	1	0.15	0.15
Mechanic	2	0.01	92.7	1	0.14	0.14	2	0.01	92.8	1	0.15	0.15
Accountant	0	0.0	100.0	1	0.03	0.05	0	0.0	100.0	1	0.04	0.04

Table 12

Results of modeling the delivery of general cargo in the presence of errors in the work of transport company specialists

Performer	Presence of errors											
	Movement of MVs with cargo						Movement of MVs without cargo					
	w_k	η_k	ν_k	n_k	ψ_k	ρ_k	w_k	η_k	ν_k	n_k	ψ_k	ρ_k
Logistics Manager	30	0.82	55.4	4	0.69	2.76	26	0.67	57.6	3	0.62	1.86
Logistician	23	0.22	67.4	2	0.50	1.01	22	0.20	68.3	2	0.51	1.01
Lawyer	73	0.33	39.1	1	0.59	0.59	68	0.31	39.8	1	0.59	0.59
Driver	76	1.39	62.9	61	0.94	57.4	94	1.29	53.6	41	0.93	38.0
MVs	76	1.39	62.9	54	0.93	50.3	94	1.29	53.6	34	0.91	30.9
Truck Driver	34	0.15	49.4	1	0.58	0.58	31	0.14	49.9	1	0.58	0.58
Mechanic	23	0.21	51.0	1	0.57	0.57	23	0.21	57.6	1	0.57	0.57
Accountant	107	0.97	46.4	2	0.63	1.25	116	1.07	46.6	2	0.63	1.28

Tabl e 13

Results of modeling the delivery of general cargo without errors in the work of transport company specialists

Performer	Error-free											
	Movement of MVs with cargo						Movement of MVs without cargo					
	w_k	η_k	ν_k	n_k	ψ_k	ρ_k	w_k	η_k	ν_k	n_k	ψ_k	ρ_k
Logistics Manager	29	0.81	56.3	4	0.68	2.73	29	0.68	56.3	3	0.64	1.91
Logistician	22	0.20	69.3	2	0.49	0.98	22	0.21	68.4	2	0.52	1.04
Lawyer	59	0.27	43.4	1	0.56	0.56	68	0.32	39.6	1	0.61	0.61
Driver	72	1.32	63.8	61	0.94	57.2	82	1.16	57.0	41	0.92	37.7
MVs	72	1.32	63.8	54	0.93	50.1	82	1.16	57.0	34	0.90	30.5
Truck Driver	31	0.14	52.5	1	0.56	0.56	33	0.16	48.8	1	0.59	0.59
Mechanic	22	0.20	52.4	1	0.56	0.56	24	0.22	49.7	1	0.59	0.59
Accountant	107	0.98	46.8	2	0.62	1.25	124	1.17	44.9	2	0.65	1.30

Table 14

Modeling indicators for the delivery of hazardous, oversized, and general cargoes with and without service errors

Indicator	Hazardous				Oversized				General			
	Presence of errors		Error-free		Presence of errors		Error-free		Presence of errors		Error-free	
	with cargo	without cargo	with cargo	without cargo	with cargo	without cargo	with cargo	without cargo	with cargo	without cargo	with cargo	without cargo
q_k	0.18	0.17	0.14	0.13	0.16	0.10	0.15	0.08	0.16	0.14	0.15	0.13
A_k	22.2	22.6	23.2	23.6	13.6	14.6	13.8	15.0	54.6	55.9	55.3	56.6

6. Discussion of results based on modeling the work of a transport enterprise when transporting goods along international routes

When planning the delivery of goods, the activities of each participant in a foreign trade operation are aimed at achieving the efficiency of both the implementation of a separate task of the enterprise and the impact on the overall result of all organizations involved. A key feature of the quality of international cooperation in the field of export and import of goods is compliance with delivery terms in accordance with the foreign economic contract. Delays at any stage can affect the interests of the counterparty and reduce the level of trust in the supplier of goods and business entities involved in customs and logistics services. The activities of a separate organization that provides similar services on the market may be characterized by different performance indicators due to differences in the level of personnel and material and technical support. In addition, it should be noted the influence of organizational, managerial, technical, and technological measures that are used by the management team of the enterprise to optimize the main and auxiliary production processes.

Each of the organizations involved in the implementation of a foreign trade operation has its own functional responsibilities and provides a list of services agreed in advance, taking into account the individual needs of the customer. However, the duration of the execution of a separate order is quite difficult to predict, thereby this can cause queues for service, and possibly even refusals due to a significant workload of specialists and the need for a long wait. In turn, there is a need to determine the optimal number of company personnel capable of providing quality and timely services to customers. It should be taken into account that depending on the type of goods provided for transportation, a different number of specialized intermediary organizations may be involved in the process. Accordingly, the list and duration of the necessary work, depending on the specificity of the goods, may also have significant differences.

The direct process of performing an international road trip, the characteristics of its main, auxiliary, and service performance indicators, has a significant impact on the implementation of export and import operations. The key objective of transport enterprises is the effective organization of both internal processes and external interaction with service customers, partners, and other participants in foreign economic activity. However, the study of the performance indicators of a separate business entity in order to implement management decisions or optimize existing processes depends on a number of factors. The main ones are:

– the number, composition, and structure of the fleet of motor vehicles;

– intensity of demand for transportation among customers;

– the number of specialists involved in servicing orders by type of activity;

– types of cargo transported by the rolling stock of the enterprise;

– a list of works necessary for the performance of an international trip;

– the duration of work;

– presence of errors in the performance of work;

– probability of errors in service;

– duration of elimination of errors in the execution of activity.

Depending on the efficiency of using the internal resources of the transport enterprise, it will be possible to achieve a reduction in the duration of all types of work during the delivery of goods. It is advisable to pay special attention to studying the procedure for transporting a given cargo, taking into account the route and type of cargo, which may require additional time spent on carrying out commercial, transport, customs, and permit formalities. Given the significant differences in the implementation of the transport process with

different goods, it is necessary to conduct a study on the work of transport enterprises depending on their specialization. Organizations that provide services for the transportation of general, oversized, and hazardous goods require a detailed study of the types of work inherent in a particular category of cargo. The use of a generalized approach will cause significant time deviations in the planning of delivery times, thereby affecting the reputation and trust in the carrier and its customer of services from counterparties.

The modeling results allow us to provide recommendations to a separate transport enterprise, taking into account the specialization of the existing rolling stock and the number of staff by activity. This will make it possible to optimize the current state of the enterprise and plan personnel and material and technical support for future periods. In addition, the developed software package makes it possible to analyze the process of transporting various types of cargo, taking into account the technology of performing all stages of service.

A significant advantage of a separate transport enterprise is the ability to meet the individual needs of the customer, taking into account the physical, chemical, volumetric, and mass characteristics of the cargo. In this process, high indicators of the efficiency of the enterprise and the service of a separate order can be achieved by applying modern software packages to the organization of the fleet of vehicles for the transportation of various types of cargo. Unlike [1, 2], the simulation model built makes it possible to reproduce all the necessary stages and processes associated with the organization of the transportation of a separate type of cargo. Thus, it will be possible to more accurately plan the duration of service, as well as the probability of errors when performing all types of work.

The proposed technological advancement, unlike [3, 4], makes it possible to analyze the performance indicators of a transport enterprise that has a different structure of the fleet of vehicles. Accordingly, this will affect the operational performance indicators of the rolling stock and the duration of technical, technological, and organizational work by the company's specialists when organizing the transportation of various cargoes. In addition, the devised model, in comparison with [5], takes into account the execution of activities involving specialists of the transport enterprise at all stages of the foreign trade operation. Our technological advancement, in contrast to [6], provides the ability to change the parameters of the study, the stages of process execution depending on the individual specificity of the delivery of goods, which will make it possible to take into account the needs of the main customers, rather than generalizing processes.

The issue of rational operation of vehicles on the route is key in the organization of international transportation. Therefore, in comparison with works [7, 8], our SM takes into account efficiency indicators in the presence of reverse loading of the vehicle and movement without cargo. In addition, SM, unlike [9, 10], makes it possible to consider the work of a transport enterprise taking into account the probability of making errors at each stage of organizing delivery, as well as with high-quality and timely provision of services.

Planning and development of the necessary stages of business process execution that will affect the efficiency of a foreign trade operation are carried out at the initial stage of service. Therefore, in comparison with [11, 12], the proposed SM takes into account the time characteristics of involving the enterprise's specialists in performing preparatory operations for the delivery of goods. This will make it possible to take into account their employment in the process of servicing various types of cargo depending on customer demand. Therefore, the use of the devised model in studying the work of a transport enterprise that is part of the logistics chain structure, which was reported in [14], will make it possible to detail the duration of the delivery of goods, taking into account the individual needs of the customer.

Our results from modeling the work of a transport enterprise make it possible to plan the number of full-time staff at an enterprise by profession. In addition, based on the available number of vehicles for individual types of specialization, it will be possible to determine the duration of the preparatory and organizational and main processes of delivering goods along international routes. Appropriate adjustments to the employment of personnel can be made taking into account the probability of service with errors and without errors at different stages of delivery.

The list of types of work and performers involved in organizing the transportation of hazardous (Table 1), oversized (Table 2), and general cargoes (Table 3) indicates significant differences in the work of a transport enterprise. In addition, it is necessary to take into account the individual needs of the customer, which also affects the structure and volume of work.

Planning, coordination, and interaction of all involved specialists and organizations when performing an international trip requires constant optimization and coordination of the service process for timely and high-quality delivery of goods.

Automation of data processing on the work of transport enterprises, which involves the construction of a simulation model, makes it possible to take into account existing stochastic processes in order to reproduce all stages of service and related performance indicators. In turn, field tests carried out to verify the adequacy of the model (Table 4) indicate the possibility of its application for analyzing the work of transport enterprises. The capabilities of the model make it possible to assess the performance indicators of the enterprise when carrying out international road transport trips and take into account the time and probabilistic characteristics of the implementation of this process.

The assessment of the average delivery time along the Kyiv-Warsaw route of hazardous goods, provided that there are no errors in service, shows that the duration of the vehicle's operation when moving with cargo is reduced by 0.6%, and without cargo by 6.1% (Table 5). When transporting oversized cargo without errors in the work of specialists, the delivery time with cargo is reduced by 1.08%, and without cargo by 4.88% (Table 6). In turn, the delivery of general cargo under this condition is reduced by 1.9% in the presence of reverse loading and by 3.15% without cargo (Table 7). At the same time, the devised model allows for the detailing of business processes and consideration of various types of routes for delivering goods by road.

The SM built makes it possible to determine indicators for the efficiency of the work of specialists at a transport enterprise, taking into account errors in their work and without errors. When transporting hazardous goods, there is no impact on logisticians, loaders, mechanics, and accountants. At the same time, in the absence of errors in work, it is possible to achieve a reduction in the number of logistics managers by 50%, lawyers by 33%, and drivers by 53.5% (Tables 8, 9). When transporting oversized cargo, logisticians, lawyers, loaders, mechanics, and accountants are not affected. The number of logistics managers can be reduced by 50%, and drivers by 57.14% (Tables 10, 11). When transporting general cargo without errors, logisticians, lawyers, loaders, mechanics, and

accountants are not affected. In the absence of errors in work, the number of logistics managers can be reduced by 25%, and drivers by 32.79% (Tables 1–11).

The SM constructed provides for determining the optimal number of transport enterprise employees by functional areas that ensure the flow of orders for the transportation of various types of cargo in accordance with the existing fleet of vehicles.

The advantages of our study are the ability to assess the efficiency of the work of transport enterprise specialists in organizing the delivery of hazardous, oversized, and general cargoes, as well as determining the categories of employees whose number is stable under different operating conditions of the enterprise, or their reduction can be achieved by improving the quality of service.

The defined characteristics of the work of a transport enterprise in organizing the transportation of various types of cargo indicate significant differences in personnel performance indicators depending on the specialization of the fleet of vehicles and the level of qualification of specialists. At the same time, the duration of service is shorter in the absence of errors in the work of personnel support, which is associated both with the direct performance of job duties and with the elimination of shortcomings in the work of other specialists.

The main limitations of our SM include the fact that it can be applied to transport enterprises that own only one type of vehicle, and not a combined type of fleet.

The disadvantages of SM are that it takes into account the possibility of transportation exclusively by road transport and does not consider the comparison of alternative routes with other modes of transport.

This research has future prospects in the following areas:

– the possibility of determining the performance indicators for a transport enterprise that carries out the transportation of perishable and groupage cargo;

– construction of SM for choosing the optimal route for transporting various types of cargo by mode of transport;

– construction of SM for the operation of a transport enterprise that owns various types of rolling stock.

7. Conclusions

1. The model of a transport enterprise's operation when organizing the transportation of hazardous, oversized, and general cargoes by road along international routes has been formalized. The stages and related types of work performed by specialized specialists to ensure the organizational, managerial, technical, and technological processes of a transport enterprise specializing in the transportation of various types of cargo have been taken into account. To ensure the completeness of the process description, the duration of a particular type of work, the probability of errors and delays in servicing, with the appropriate parameters, have been taken into account.

2. Based on the formalized model, an algorithm for the functioning of a transport enterprise has been developed that takes into account the transportation of hazardous, oversized, and general cargoes along international routes. A feature of our algorithm is the ability to study the characteristics of the work of transport enterprises when transporting various types of cargo. This is aimed at planning the staffing level in order to ensure the effective operation of the fleet of vehicles when servicing customers. The proposed algorithm takes into account the possibility of errors in the execution of activity and the time required to eliminate them. Separately, possible delays in the organization of transportation are taken into account, that is, the probability of their occurrence and duration at different stages of service, taking into account the specificity of the work of the transport enterprise. This will allow for adjustments to be made when determining service terms in order to create an additional time reserve and avoid violation of the delivery terms specified in the foreign trade contract. In addition, the algorithm implements the possibility of attracting additional specialists in areas of activity in the event of an increase in demand for services or the need to improve production processes.

3. The results of our simulation modeling indicate that when organizing the transportation of hazardous, oversized, and general cargoes, a different number of specialists from transport enterprises is required by areas of activity. It has been established that compliance with specific transportation requirements has an impact on the types of service stages for each type of cargo and the duration of their implementation. At the same time, the probability of errors and the time to eliminate them for hazardous and oversized cargo will be greater, unlike general cargo, which will affect the efficiency of the vehicle fleet. Thus, our technological advancement will make it possible to increase the throughput capacity for transporting hazardous cargoes with reverse loading by 4.5%, oversized cargo by 1.47%, and general cargo by 1.28%.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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