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DEVELOPMENT OF A SIMULATION MODEL OF THE ACTIVITIES OF A TRANSPORT AND FORWARDING ENTERPRISE IN THE ORGANIZATION OF INTERNATIONAL ROAD CARGO TRANSPORTATION

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The object of this study is the process of planning the work of a transport and forwarding company when serving different categories of customers who need organizational support for the delivery of goods by road transport in international traffic.

The solved problem is due to the need to devise recommendations for organizing the work of forwarders when interacting with customers of transport and forwarding services that export or import different categories of cargo.

A simulation model of the transport and forwarding company's work in customer service was developed and implemented in the GPSS World simulation automation package.

The model provides for the optimization of organizational and management processes in cooperation with customers of transport and forwarding services.

When developing the model, the duration of the types of work in which freight forwarders are involved in the export and import of goods by road transport was taken into account. The model also predicts the probability of errors in the forwarder's work and the duration of their elimination. The application of the developed model in practice will enable the owners of transport and forwarding companies to plan the full-time number of forwarders and the duration of service provision under different conditions of interaction with customers. The simulation results reflect the performance indicators of the enterprise in serving different categories of customers. This will make it possible to optimize the work of the enterprise by planning personnel support. At the same time, the duration of transport and forwarding services will be reduced by 10–15 %, the capacity of the enterprise will increase by 6–11 %, and the reliability of service provision will increase by 8–14 %

Keywords: transport and forwarding service, simulation model, export, import, intermediary services, international transportation

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1. Introduction

The issue of the efficiency of the work of transport and forwarding companies is becoming more and more relevant in connection with the decrease in demand for services among customers. However, the existence of a significant number of competing organizations in the Ukrainian and international markets indicates interest in this type of activity as a business strategy.

This situation became an impetus to review the qualitative and quantitative indicators of the provision of transport and forwarding services by a separate enterprise, taking into account the individual needs of each customer. The duration of business processes, the probability of refusal of service due to insufficient number of forwarders in the company's staff and the level of service during the provision of services have a significant impact on the efficiency of transport forwarding service (TFS). At the same time, it is important to adjust the company's internal processes related to technical, technological, and organizational support, as well as the development of strategies for interaction with various categories of customers of transport and forwarding services.

The types of work performed by the freight forwarder have a clear sequence of implementation; however, depending on the physical and chemical properties of the cargo and the requirements for its transportation, the duration of each of the stages may vary. Accordingly, the forwarder's employment in the process of serving a particular customer will vary depending on the type of cargo that needs to be transported. In turn, cooperation with regular customers takes place according to a formed strategy of cooperation, which makes it possible to process orders more quickly compared to new consumers of services. Thus, the analysis of the categories of customers of a separate enterprise and the product range provided by them for TFS is important when forming the staffing of forwarders in order to minimize queues for service.

Scientific research into the efficiency of transport and forwarding enterprises under the conditions of competition and demand for the transportation of a wide range of goods is quite relevant and requires the application of modern management approaches. Their main goal is the development and application of software systems aimed at the reproduction of organizational and technological processes related to all stages of cooperation between freight forwarders and customers of transport and forwarding services. These implementations will contribute to the analysis and further optimization of the internal and external environment of the enterprise, taking into account factors affecting performance indicators.

The practical implementation of the research results will enable the owners of transport and forwarding companies to devise recommendations for planning the work of forwarders when interacting with various categories of service customers in the export and import of goods. In addition, it will be possible to determine the duration of the provision of transport and forwarding services when organizing the transportation by road of standard, oversized, dangerous, collected, and perishable goods.

2. Literature review and problem statement

In work [1], it is noted that the activities of modern transport and forwarding companies are aimed at comprehensive customer service for the comprehensive satisfaction of their needs. In addition, it is noted that in recent years the development of the transport and forwarding business took place under the conditions of the global globalization of production, integration of types of transport and material flows in the system of international movement of goods. However, the Ukrainian transport and forwarding business faced numerous negative factors caused by military aggression. This made it necessary to develop new logistics ways and services for the transportation of goods in international communication. At the same time, the work does not reveal the issue of feasibility studies of customers when organizing the transportation of goods by various modes of transport in international traffic.

Paper [2] also emphasizes that economic globalization and political events affect logistics processes in existing global supply chains. It is predicted that the next stage of development of the transport forwarding market is the market of logistics services. At the same time, logistics services are a more developed variant of forwarding services. But the work does not pay attention to the peculiarities of the organization of the process of transportation by various modes of transport, as well as their functioning in interaction.

Article [3] deals with the peculiarities of the organization of international transport and forwarding activities. The reasons and prerequisites for the emergence of specialized transport and forwarding organizations are identified and their influence on the efficiency of logistics processes on the international market is determined. It is noted that the popularity of transport and forwarding services is caused by the inefficiency of creating such departments in individual organizations. The interest of all participants in the logistics process in involving a freight forwarder-intermediary has been proven. It was determined that the main trends in the international transport and forwarding market are the shift of the scope of work and responsibility for cargo from senders and receivers of cargo to forwarding companies and carriers. It is important to note that the article does not contain any recommendations regarding the study of the effectiveness of the involvement of forwarding companies in the service of international transportation by various modes of transport, as well as their interaction in the transportation process.

Approaches to improving the transport and logistics service of international freight transportation are considered in work [4]. The study showed that the integrated provision of transport and logistics services is one of the most priority directions for improving the system of transport and logistics services for international cargo transportation. Research results do not reveal how the quality of freight forwarding service affects the organization of cargo transportation in international traffic.

Article [5] considers the possibility of optimizing processes in a transport and forwarding company that provides services for international road transportation. For research, a simulation model (SM) built in the SSMUL8 environment was used, which provides the possibility of dynamic discrete modeling of the company's processes. But this model is limited only to the functioning of the company's warehouse, where the sequence of loading and unloading operations of vehicles is carried out and possible downtimes are investigated. Such a model cannot be used to investigate the entire supply chain.

In article [6], SM is proposed to improve the business processes of production management in the enterprise's logistics system. The developed model makes it possible to simulate various scenarios of supply chain management organization by regulating, coordinating, and optimizing the existing logistics system. The authors performed simulations of scenarios of logistics supply-distribution chains of an optimized structure. This SM is intended for use at a separate enterprise that has its own transport department. The developed model cannot be used for the study of supply chains where the TFS of customers is concentrated in a separate link.

In work [7] a model of planning and transportation of materials was developed taking into account the quality of processes related to suppliers and customers. Research results show that taking transportation planning and material quality into account reduces overall cost by speeding up planning and reducing transportation costs. The developed model is limited for use in modeling the functioning of supply chains in international communication due to the impossibility of taking into account the specifics of transportation by various modes of transport.

In article [8], the authors constructed mathematical models of the internal grain supply chain using road and rail transport. This model makes it possible to study the interaction of road and rail transport, to optimize the duration of transportation when using different types of trains. But this model cannot be used for studies of international transportation, the logistics chains of which include a larger number of links and have more complex technology.

In work [9], a complex model of the supply chain was developed, which allows taking into account the complexity of making certain decisions regarding the process of organizing transportation. The authors explore the strategic and cognitive human abilities to manage the complexity of the supply chain. The research helps to better understand the sources and consequences of supply chain complexity and how to manage them. At the same time, the developed model does not provide an opportunity to vary the composition of the supply chain and to investigate the influence of individual links on the effectiveness of its functioning.

In [10], modeling of management of the main factors of the supply chain of logistics services was carried out. The model includes such components as transport management, inventory management, process management procedure, information flow management. This model is focused on researching the process of managing certain logistics processes in oil companies. This limits its use for modeling the processes that occur during the organization of transportation in international traffic.

Article [11] discusses the process of managing cooperation in the supply chain, which helps increase the competitiveness of enterprises and the entire supply chain. For this, a two-level hybrid simulation model was developed, which allows coordination of information about the supply chain between its participants. But this model can only solve problems such as excessive inventory or short-term non-compliance with order requirements caused by poor information exchange. In this model, the main attention is paid to the coordination of information regarding the supply process. This does not make it possible to use the developed model in researching complex logistics chains, where, in addition to cargo information, it is necessary to coordinate other components of the transportation process.

In article [12], SM of the process of goods delivery in international road transport using various types of logistics chains was developed. The results of the application of the model provide an opportunity for exporters to obtain information about the duration and reliability of the stages of a foreign trade operation and the feasibility of involving consulting companies in cooperation. However, this model is designed only for the use of road transport during international transportation. The use of other types of transport, as well as the use of multimodal transportation, requires a change in the configuration of the supply chain and its improvement or the development of a new SM.

In the considered simulation models, the vast majority consider the activities of transport and forwarding companies as links in the logistics chain, but at the same time they do not take into account the internal processes taking place in the organization. This is important because the qualitative and quantitative indicators of the work of a separate business entity involved in a foreign trade operation have a significant impact on the efficiency of the entire logistics chain. Therefore, an important feature is the involvement in the process of goods delivery of enterprises and organizations with a high level of corporate governance, able to plan their activities based on available personnel and material and technical resources. This will make it possible to ensure timely and high-quality provision of services to customers, to effectively interact with other business entities due to the improvement of the company's internal processes.

Given the specificity of the transport and forwarding company's activities, its influence on the construction of communication with the subjects of foreign economic activity involved in the delivery of goods is quite significant and needs to be studied. Therefore, there is a need for the construction of SM, which will ensure the analysis and further optimization of the performance of the transport and forwarding company from the point of view of the effectiveness of staffing and the duration of the provision of services to customers.

3. The aim and objectives of the study

The purpose of this work is to develop a simulation model of the process of providing transport and forwarding services when organizing the transportation of various types of cargo, taking into account the duration of all stages of the forwarder's work. This will make it possible to determine the duration of service for an individual customer, taking into account his/her individual needs, and to establish the necessary number of specialists of the transport and forwarding company capable of ensuring his smooth operation.

To achieve the goal, the following tasks were set:

– to formalize the model of work of the transport and forwarding company when organizing the transportation of various categories of cargo in international traffic;

– to develop a SM of the work of a transport-forwarding company when organizing the transportation of various categories of cargo in international traffic;

– to perform a verification of the adequacy of the SM;

– to evaluate the simulation results.

4. The study materials and methods

The object of our research is the feasibility study process of customers who need the organization of transportation of standard, oversized, collected, perishable, and dangerous goods by road transport in international traffic.

The research hypothesis assumes that the construction of a simulation model of the work of a transport and forwarding company will provide an opportunity to improve the organization, planning, and management of internal corporate processes of the business entity, will ensure a reduction in the duration of customer service and an increase in the reliability of service provision.

When performing the research, the provision of transport and forwarding services for the export and import of goods is considered. Customers of transport and forwarding services are divided into categories: permanent customers; first-time customers; customers who apply periodically (served by various transport and forwarding companies). Two strategies of the forwarder's work are considered, such as the possibility of making mistakes at various stages of service and providing services without errors and, accordingly, without additional time spent on their elimination.

When developing the simulation model, the list of types of work performed by the freight forwarder when serving customers was taken into account, namely:

– receiving an application from the customer;

– conclusion of an agreement on the provision of transport and forwarding services with the customer;

– search for rolling stock and transport company for transportation;

– planning the optimal route of cargo transportation;

– concluding a transport service contract with the carrier;

– preparation of documents for transportation; organization of preparation of customs documents;

– delivery of rolling stock for loading;

– loading of rolling stock;

– fulfillment of customs formalities in the country of departure;

– fulfillment of customs formalities in the country of destination;

– unloading of goods;

– fulfillment of documentary formalities regarding the transfer of goods to the consignee;

– execution of financial calculations for the services provided.

In order to detail the implementation of organizational and technological processes at each stage of service of orders, the category of the consumer of services is taken into account, taking into account the conditions of cooperation with the transport and forwarding company and the range of the cargo. For each type of cargo, the estimated duration of the types of work, the probability of errors occurring during the provision of transport and forwarding services and the time for their elimination are taken into account. It is suggested to use the theory of mass service to examine the activity of the enterprise during the feasibility study. When modeling the activity of a transport and forwarding company, it is necessary to take into account a number of random factors that cannot be described analytically. For this purpose, this study used a modeling method called the method of statistical testing (Monte Carlo method). The essence of the statistical testing method is that instead of describing random phenomena with analytical dependences, a random phenomenon is drawn using a certain procedure that gives a random result. Repeatedly performing such a draw accumulates statistical material that must be treated using statistical methods.

The GPSS World general-purpose simulation system was used to develop SM [13]. The GPSS World environment is a machine implementation of the statistical testing method and makes it possible to automatically obtain information about simulation results – simulation statistics.

Thus, when modeling the work of a transport-forwarding enterprise, it is necessary to take into account the level of partnership relations with the customer of services and the previous experience of its service, as well as the specific properties of the cargo that requires the organization of transportation.

The SM examines the work of a transport and forwarding company in the organization of international road transportation of goods. A stream of requests for service is received from customers of transport and forwarding services. TFS is carried out under two customs regimes: export and import of goods.

TFS customers can be represented by the following categories: permanent; those that apply periodically (served by various transport and forwarding companies); those who for the first time turned to the transport and forwarding company for the organization of international road transportation of goods.

Exported or imported cargo is divided into the following categories: standard, oversized, collected, perishable, and dangerous.

The conditions under which the forwarder can make mistakes in the service process or organize work without the need to re-process the order are being studied.

The following parameters are fixed as the results of SM work:

– the number of forwarders required to work at the enterprise under the given working conditions;

– the duration of transport and forwarding service for each individual type of cargo, provided that the forwarders work without errors and in the presence of errors;

– waiting time in the queue for TFS, taking into account each individual type of cargo, provided that the forwarders work without errors and in the presence of errors;

– the length of the queue for the TFS of each individual type of cargo, provided that the forwarders work without errors and in the presence of errors;

– throughput capacity of the enterprise when providing transport and forwarding services;

– probability of service refusal by types of cargo;

– the optimal number of forwarders that can be in reserve to expand the company's capabilities;

– the reliability of TFS, which is defined as an assessment of the probability of timely performance of transport and forwarding services by types of cargo.

5. Results of the construction of a simulation model of the activity of a transport and forwarding company in the organization of international road transportation of goods

5. 1. Formalization of the activity model of the transport and forwarding enterprise

In general, the model of the operation of the enterprise during the feasibility study can be represented by the structure:

$$F = \left\{ \begin{matrix} X_1, X_2, ..., X_i, ..., X_n \\ G_1, G_2, ..., G_j, .., G_k \end{matrix} \right\}, \tag{1}$$

where X_i is a set of parameters that can be changed during experiments; G_j is a set of model variables that can be measured but cannot be controlled; n is the total number of model parameters; k is the total number of model variables.

Parameters (X) of the model are:

– the intensity λ_i of receiving applications for TFS under two customs regimes (λ_1 – export of goods, λ_2 – import of goods;

– the intensity γ_i of receiving applications for feasibility studies for different categories of customers (γ_1 – regular customers; γ_1 – customers who apply periodically; γ_1 – customers who applied for the first time);

– the intensity α_i of receiving applications for feasibility studies when organizing international road transportation of each individual type of cargo (α_1 – standard, α_2 – oversized, α_3 – collected, α_4 – perishable, α_5 – dangerous).

Variables (G) of the model (which can be measured but cannot be controlled, and which acquire only those values that are characteristic exclusively for the given object of modeling or the conditions of its operation) are:

– estimate of the average time $m_i \pm \sigma_i$ for the i-th job PR_i. The list of works of the forwarder is given in Table 1;

– the percentage of errors of forwarders β_i when performing the i-th work PR_i.

Table 1

Types of work of a freight forwarder

No.	Work ID	Types of work of a freight forwarder
1	PR_1	Acceptance of the application from the customer
2	PR_2	Conclusion of an agreement on the provision of transport and forwarding services with the customer
3	PR_3	Search for rolling stock and transport company for transportation
4	PR_4	Planning the optimal cargo transportation route
5	PR_5	Conclusion of a transport service contract with the carrier
6	PR_6	Preparation of documents for transportation
7	PR_7	Organization of preparation of customs documents
8	PR_8	Delivery of rolling stock for loading
9	PR_9	Loading of rolling stock
10	PR_{10}	Completion of customs formalities in the country of departure
11	PR_{11}	Completion of customs formalities in the country of destination
12	PR_{12}	Unloading of goods
13	PR_{13}	Fulfillment of documentary formalities regarding the transfer of goods to the consignee
14	PR_1	Performing financial calculations for the services rendered

The processing of the application by the forwarder represents the performance of work (Table 1), which must be performed 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 a random variable are established as a result of statistical processing of field research data. FIFO (first-in-first-served) order is adopted as the main order of service of applications.

The initial characteristics – responses (Y) of the model are:

– the number of forwarders n needed to work at the enterprise;

– load factor of freight forwarders ψ;

– the average number of employed forwarders ρ;

– duration of transport and forwarding service t_k;

– duration of waiting in line for TFS w_k;

– the length of the queue at TFS η_k;

– the share of applications served without downtime in the queue ν_k;

– throughput capacity of enterprise A;

– probability of denial of service q_k;

– the optimal number of forwarders that can be in reserve to expand the capabilities of the enterprise m;

– reliability of TFS p_k.

Response and Y models are considered as performance indicators that determine modeling goals.

5. 2. Simulation model of the activity of a transport and forwarding company in the organization of international road transportation of goods

The block diagram of the implementation of the feasibility study process in the organization of international road transportation of each separate category of cargo under both customs regimes for different categories of customers is shown in Fig. 1.

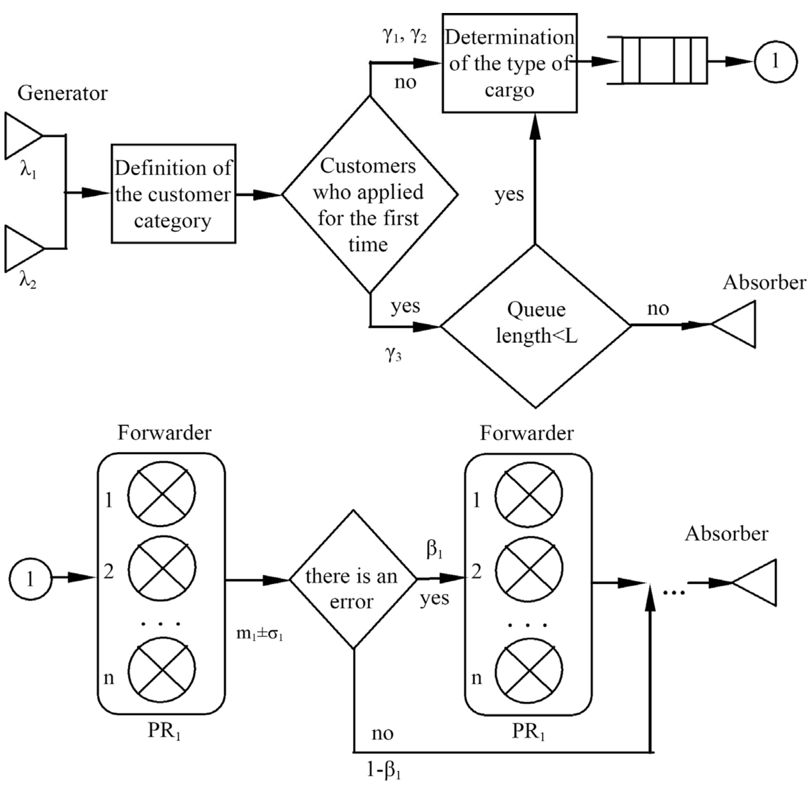
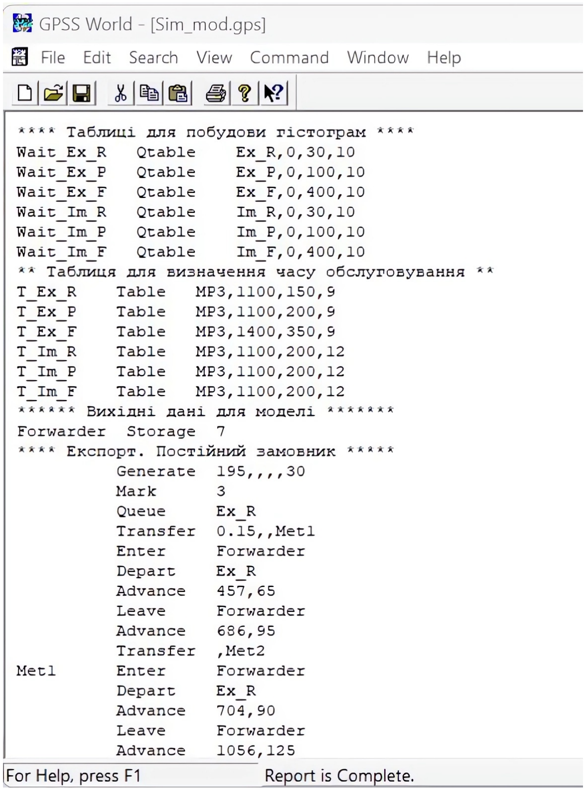


Fig. 1. Block diagram of the simulation of the cargo delivery process

The proposed model of the transport and forwarding company's activity is implemented in the GPSS World simulation automation package [13]. An example of the SM text of the transport and forwarding company's activity in GPSS World is shown in Fig. 2.

GPSS World provides the possibility of step-by-step debugging of the model (Fig. 3).

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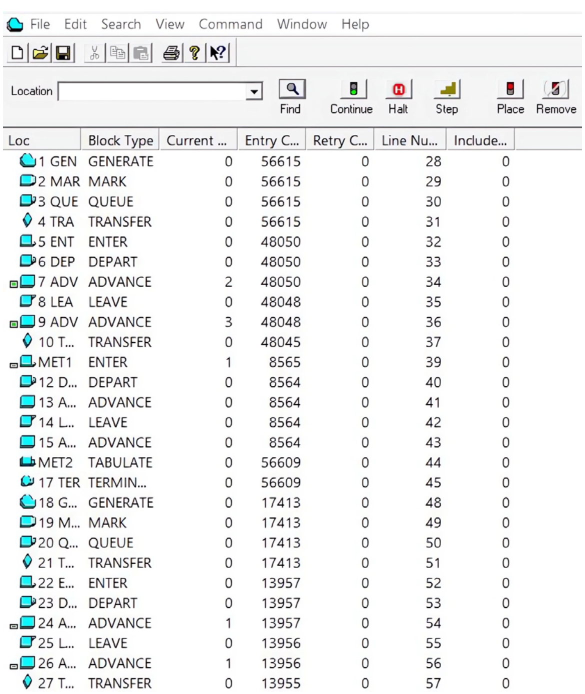
**** Таблиці для побудови гістограм ****
Wait_Ex_R   Qtable    Ex_R,0,30,10
Wait_Ex_P   Qtable    Ex_P,0,100,10
Wait_Ex_F   Qtable    Ex_F,0,400,10
Wait_Im_R   Qtable    Im_R,0,30,10
Wait_Im_P   Qtable    Im_P,0,100,10
Wait_Im_F   Qtable    Im_F,0,400,10
** Таблиця для визначення часу обслуговування **
T_Ex_R     Table    MP3,1100,150,9
T_Ex_P     Table    MP3,1100,200,9
T_Ex_F     Table    MP3,1400,350,9
T_Im_R     Table    MP3,1100,200,12
T_Im_P     Table    MP3,1100,200,12
T_Im_F     Table    MP3,1100,200,12
****** Вихідні дані для моделі *******
Forwarder  Storage  7
**** Експорт. Постійний замовник *****
          Generate  195,,,,30
          Mark      3
          Queue     Ex_R
          Transfer  0.15,,Met1
          Enter     Forwarder
          Depart    Ex_R
          Advance   457,65
          Leave     Forwarder
          Advance   686,95
          Transfer  ,Met2
Met1      Enter     Forwarder
          Depart    Ex_R
          Advance   704,90
          Leave     Forwarder
          Advance   1056,125
```

Fig. 2. A partial program listing of SM implemented by us in GPSS World



Loc	Block Type	Current ...	Entry C...	Retry C...	Line Nu...	Include...
1 GEN	GENERATE	0	56615	0	28	0
2 MAR	MARK	0	56615	0	29	0
3 QUE	QUEUE	0	56615	0	30	0
4 TRA	TRANSFER	0	56615	0	31	0
5 ENT	ENTER	0	48050	0	32	0
6 DEP	DEPART	0	48050	0	33	0
7 ADV	ADVANCE	2	48050	0	34	0
8 LEA	LEAVE	0	48048	0	35	0
9 ADV	ADVANCE	3	48048	0	36	0
10 T...	TRANSFER	0	48045	0	37	0
MET1	ENTER	1	8565	0	39	0
12 D...	DEPART	0	8564	0	40	0
13 A...	ADVANCE	0	8564	0	41	0
14 L...	LEAVE	0	8564	0	42	0
15 A...	ADVANCE	0	8564	0	43	0
MET2	TABULATE	0	56609	0	44	0
17 TER	TERMIN...	0	56609	0	45	0
18 G...	GENERATE	0	17413	0	48	0
19 M...	MARK	0	17413	0	49	0
20 Q...	QUEUE	0	17413	0	50	0
21 T...	TRANSFER	0	17413	0	51	0
22 E...	ENTER	0	13957	0	52	0
23 D...	DEPART	0	13957	0	53	0
24 A...	ADVANCE	1	13957	0	54	0
25 L...	LEAVE	0	13956	0	55	0
26 A...	ADVANCE	1	13956	0	56	0
27 T...	TRANSFER	0	13955	0	57	0

Fig. 3. Step-by-step simulation model debugging window in GPSS World

GPSS World has a high degree of interactivity when debugging the model, that is, visual control of the passage of applications through the blocks of the GPSS model with the analysis of their values and parameters.

5. 3. Verification of the adequacy of the simulation model and estimation of the simulation error

The verification of the adequacy of SM to the real object was carried out for the case when it is possible to determine the value of the system responses during field tests.

To check the adequacy of the model, the hypothesis about the proximity of the average values of each response of the model $\bar{Y}$ to the known average value of the response of a real object $\bar{Y}^*$ as tested. $N_1=5$ experiments were conducted on a real object and a sample of values $\{Y_i^*\}$, $i=\overline{1,5}$. was formed. With the help of the simulation model, $N_2=5$ experiments were conducted, samples of $\{Y_i\}$; $i=\overline{1,5}$. values were obtained based on the feedback of the model.

The results of full-scale and model experiments are given in Table 2.

Estimates of the mathematical expectation and variance of the model and system responses (Table 2) were determined by the samples using the following ratios:

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

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

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

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

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

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

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

E_n and D_{an} values are independent statistics, so you can use t-statistics:

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

With the number of degrees of freedom $\nu=N_1+N_2-2=8$ and the significance level $\alpha=0.05$, the critical value ($t_{cr}=1.85$) was determined according to Student's distribution tables. Comparing each of the t-statistic values in Table 2 with t_{cr} ($t_n \le t_{cr}$), the hypothesis about the closeness of the average values of the responses of the model and the real object is accepted. Thus, we can talk about the adequacy of SM and the real object.

After checking the adequacy of SM, it is necessary to evaluate the simulation error caused by the presence of pseudorandom number generators in the SM.

Table 2

Checking the adequacy of the simulation model

Responses	Values of sample components					Response average value $\overline{Y}_n, \overline{Y}^*_n$	Response variance score $\overline{D}_n, \overline{D}^*_n$	Variance difference D_{an}	*t*-statistics t_n
	$j=1$	$j=2$	$j=3$	$j=4$	$j=5$				
t_{1j}	1309	1280	1125	1159	1133	1201.2	7517.2	8145	0.4625
t^*_{1j}	1350	1302	1130	1170	1186	1227.6	8772.8		
t_{2j}	1558	1433	1134	1237	1144	1301.2	35026.7	29187.45	1.2827
t^*_{2j}	1542	1500	1600	1307	1250	1439.8	23348.2		
t_{3j}	2076	2049	1870	1334	1296	1725	146531	79037.35	0.8447
t^*_{3j}	2005	1978	1799	1816	1778	1875.2	11543.7		
t_{4j}	1337	1310	1131	1166	1128	1214.4	10233.3	8976.3	0.4005
t^*_{4j}	1340	1313	1134	1175	1230	1238.4	7719.3		
t_{5j}	1428	1401	1222	1204	1166	1284.2	14648.2	15589.6	0.3141
t^*_{5j}	1460	1433	1254	1218	1180	1309	16531		
t_{6j}	1651	1624	1445	1410	1372	1500.4	16421.3	13067.3	0.5837
t^*_{6j}	1662	1635	1456	1499	1461	1542.6	9713.3		
w_{1j}	73	57	45	16	15	41.2	649.2	644.45	0.4111
w^*_{1j}	77	63	56	18	25	47.8	639.7		
w_{2j}	188	124	73	12	13	82	5685.5	5639.15	0.1179
w^*_{2j}	192	135	69	19	23	87.6	5592.8		
w_{3j}	586	667	108	20	67	289.6	96374.3	91923.3	0.1408
w^*_{3j}	533	633	88	15	44	262.6	87472.3		
w_{4j}	75	69	33	15	22	42.8	756.2	644.45	0.2118
w^*_{4j}	72	65	48	19	27	46.2	532.7		
w_{5j}	77	67	52	14	36	49.2	627.7	637	0.2130
w^*_{5j}	73	71	63	12	44	52.6	646.3		
w_{6j}	73	66	89	10	58	59.2	886.7	1060.6	0.3787
w^*_{6j}	100	75	97	18	45	67	1234.5		
ψ_j	0.98	0.91	0.78	0.893	0.77	0.8666	0.0081	0.0051	1.0283
ψ^*_j	0.93	0.88	0.89	0.85	0.82	0.82	0.0022		

The GPSS World environment uses random number simulation generators. GPSS World provides various random number generators, each of which uses a base generator simulating uniformly distributed numbers on the interval [0, 1]. Random number generators and the probabilistic nature of SM are a source of simulation error. Usually, these two types of errors are difficult to separate. Therefore, a procedure for checking the simulation error, which is simultaneously formed by both causes, is proposed.

10 simulation experiments were conducted in the middle point of the SM parameter values to determine the error of SM responses of the transport and forwarding company. At the same time, in the lth simulation experiment $(l=\overline{1,10})$, the SM parameters were not changed, but only the initial values of the basic generator algorithms were modified. As a result of the simulation experiment, samples with a volume of $N=10$ of each k-th SM response $\{Y_{nk}\}$ were formed. Based on these samples, mathematical expectation estimates and sample variances of model responses $(\overline{Y}_n, \overline{D}_n)$ were calculated according to formula (2). The resulting values of dY_n errors in percentages for SM, calculated by formula (5), are given in Table 3:

$$dY_n = \frac{t_{0.05}}{\overline{Y}_n}\sqrt{\frac{\overline{D}_n}{N-1}} \cdot 100\,\%. \quad (5)$$

Table 3

Estimation of the error of simulating the responses of the simulation model

Responses	Imitation error dY_n %	Responses	Imitation error dY_n %
t_1	2.1	η_5	1.5
t_2	2.6	η_6	2.5
t_3	1.9	w_1	2.1
t_4	1.8	w_2	1.8
t_5	2.2	w_3	2.7
t_6	3.3	w_4	2.2
η_1	2.5	w_5	2.6
η_2	2.8	w_6	3.3
η_3	2.2	ψ	2.4
η_4	3.5	–	–

The accuracy of the simulation is determined by the formula:

$$d_S = \max_n \{dY_n\}. \quad (6)$$

During the trial simulation experiment, it was established that the upper limit of the simulation error is equal to d_{SM}=3.5 % with a permissible 5 %. Thus, the simulation error is insignificant for this study.

5. 4. Evaluation of simulation results

Forwarders may make certain mistakes during the performance of official tasks, which increases the TFS time. In the paper, the feasibility study of the organization of international road transportation was performed, taking into account each separate category of cargo under both customs regimes for different categories of customers and the presence/absence of errors in the work of forwarders. As a result, simulation statistics were obtained. An example of screening the simulation results for TFS in the presence of forwarder errors is shown in Fig. 4, and their interpretation is in Table 4.

Examples of the histogram of the duration of service in the organization of transportation under export customs regimes for various categories of customers under the conditions of the work of forwarders in the presence of errors are shown in Fig. 5, 6.

The histogram of the average length of downtime in the queue when organizing transportation under export customs regimes for regular customers in the presence of forwarder errors is shown in Fig. 7.

```
GPSS World - [Sim_mod.179.1  -  REPORT]
File  Edit  Search  View  Command  Window  Help

QUEUE              MAX CONT. ENTRY ENTRY(0) AVE.CONT. AVE.TIME   AVE.(-0) RETRY
 EX_R                3    1  56615   8790     0.373     72.780     86.157   0
 EX_P                3    0  17413   3009     0.297    188.194    227.508   0
 EX_F                5    0  13004   1834     0.690    586.169    682.412   0
 IM_R                2    1  37679   6235     0.258     75.481     90.448   0
 IM_P                1    0  11596   1902     0.081     77.337     92.511   0
 IM_F                1    0   8699   1901     0.058     73.435     93.970   0


STORAGE            CAP. REM. MIN. MAX.  ENTRIES AVL.  AVE.C. UTIL. RETRY DELAY
 FORWARDER           7    0    0    7   145004   1    6.887  0.984    0    2


TABLE              MEAN    STD.DEV.       RANGE           RETRY FREQUENCY CUM.%
 WAIT_EX_R        72.780   65.978                           0
                                      _  -      0.000             8790   15.53
                                  0.000  -     30.000             9878   32.97
                                 30.000  -     60.000             9611   49.95
                                 60.000  -     90.000             8780   65.46
                                 90.000  -    120.000             7132   78.06
                                120.000  -    150.000             5066   87.00
                                150.000  -    180.000             3076   92.44
                                180.000  -    210.000             1970   95.92
                                210.000  -    240.000             1176   98.00
                                240.000  -  _                     1135  100.00
 WAIT_EX_P       188.194  205.850                           0
                                      _  -      0.000             3009   17.28
                                  0.000  -    100.000             4768   44.66
                                100.000  -    200.000             3273   63.46
```

Fig. 4. Screening of simulation results in GPSS World

Table 4

Results of TFS modeling in the presence of forwarder errors

Key modelling indicators	Export			Import		
	Regular customers *Ex_R*	Customers who apply periodically *Ex_P*	Customers who applied for the first time *Ex_F*	Regular customers *Im_R*	Customers who apply periodically *Im_P*	Customers who applied for the first time *Im_F*
Average service time, t_k, min	1309	1558	2076	1337	1428	1651
Average downtime in line w_k, min	73	188	586	75	77	73
Average queue length, η_k	0.37	0.30	0.69	0.26	0.08	0.06
Share of applications served without downtime in the queue, $\nu_{k, \%}$	16	17	12	17	16	13
Probability of denial of service, q_k	–	–	5	–	–	3
Reliability of service, p_k	0.88	0.80	0.56	0.86	0.82	0.62
Number of freight forwarders, n			7			
Freight forwarders' load factor, ψ			0.98			
Average number of freight forwarders employed, ρ			6.89			
Throughput, A, service requests per mounth or application/mounth			136			

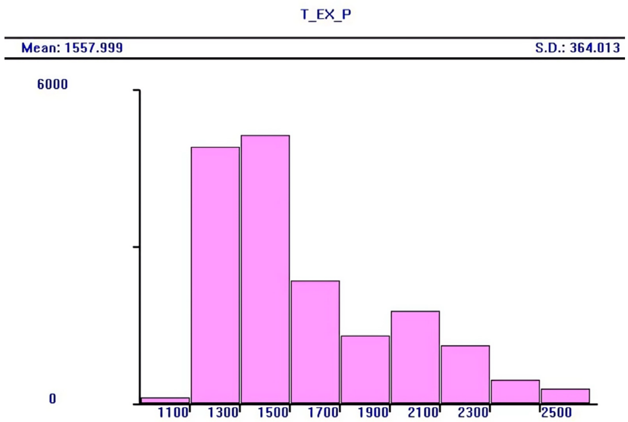


Fig. 5. Distribution of the duration of service during export for customers who apply periodically in the presence of errors by forwarders

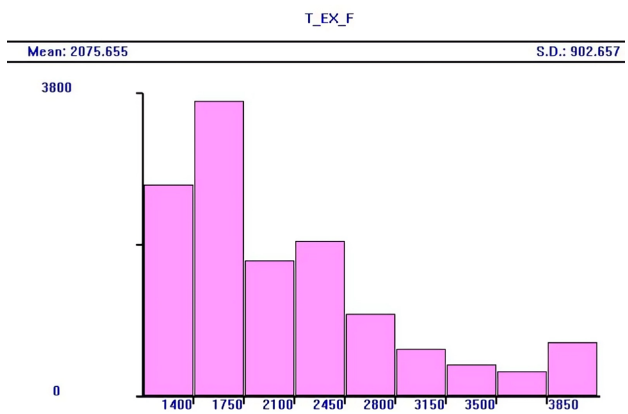


Fig. 6. Distribution of the duration of service during export for customers who applied for the first time in the presence of errors by forwarders

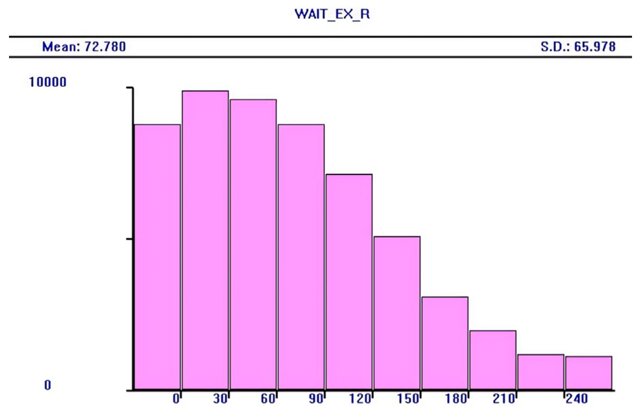


Fig. 7. Distribution of the average duration of downtime in the queue during export for regular customers in the presence of forwarder errors

As a result of TFS simulation in the organization of international road transportation, taking into account each separate category of cargo under both customs regimes for different categories of customers, provided that the forwarders work without errors, statistics on queues and devices were obtained, which are given in Table 5.

The histogram of the duration of service during the organization of transportation without errors by forwarders under export customs regimes for customers who apply periodically is shown in Fig. 8.

The results of our research show that if the forwarder makes mistakes during export, the average service time for regular customers will be 1309 minutes, and during import – 1337 minutes. Accordingly, the reliability of service for the export of goods of regular customers is 0.88, and for import – 0.82. Provided there are no errors in servicing regular customers, the average service time for exporting cargo will decrease by 150 minutes, and for importing by 171 minutes. At the same time, the reliability for export is 0.94, and for import – 0.93.

Table 5

Results of TFS simulation without errors of forwarders

Key modelling indicators	Export			Import		
	regular customers *Ex_R*	customers who apply periodically *Ex_P*	customers who applied for the first time *Ex_F*	regular customers *Im_R*	customers who apply periodically *Im_P*	customers who applied for the first time *Im_F*
Average service time, t_k, min	1159	1237	1334	1166	1204	1410
Average downtime in line w_k, min	16	12	20	15	14	10
Average queue length, η_k	0.08	0.02	0.02	0.05	0.02	0.01
Share of applications served without downtime in the queue, $\nu_{k,\%}$	66	77	65	72	69	68
Probability of denial of service, q_k	–	–	–	–	–	–
Reliability of service, p_k	0.94	0.87	0.84	0.93	0.89	0.80
Number of freight forwarders, n			7			
Freight forwarders' load factor, ψ			0.893			
Average number of freight forwarders employed, ρ			6.251			
Throughput, A, request/day			141			

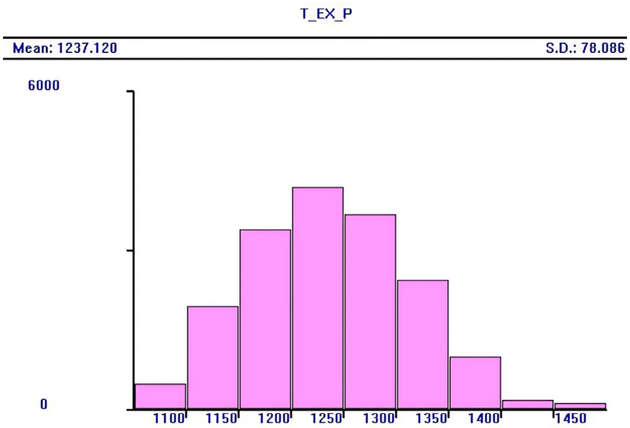


Fig. 8. Distribution of the duration of service without errors of forwarders during export for customers who apply periodically

The key features in making a decision on the implementation of organizational and management measures regarding the planning of the work of forwarders are the determination of the average service time and the reliability of this process. Accordingly, each category of cargo requiring service has individual characteristics within the scope of the business under study. At the same time, the management of the enterprise is considering the strategy of the forwarders' work, when mistakes may be made in their work at various stages of service.

The data according to the performed calculations are given in Table 6.

In order to compare the efficiency of the specialists' work, it is proposed to evaluate the duration and reliability of the service to customers carrying out export and import operations with different categories of cargo without making mistakes. The results of our research are given in Table 7.

Table 6

Service indicators by types of cargo in case of errors by forwarders

No.	Order type	Cargo category				
		Standard	Oversized	Collected	Perishable	Dangerous
Average time of freight forwarding services t_k, min						
1	Export; regular customers (*Ex_R*)	1099	1432	1340	1260	1414
2	Export; customers who apply periodically (*Ex_P*)	1339	1928	1520	1440	1562
3	Export; customers who applied for the first time (*Ex_F*)	1773	2299	2123	1953	2232
4	Import; regular customers (*Im_R*)	1193	1462	1344	1275	1412
5	Import; customers who apply periodically (*Im_P*)	1278	1532	1445	1377	1508
6	Import; customers who applied for the first time (*Im_F*)	1374	1831	1683	1602	1765
Reliability of freight forwarding services p_k						
7	Export; regular customers (*Ex_R*)	0.98	0.80	0.86	0.91	0.81
8	Export; customers who apply periodically (*Ex_P*)	0.91	0.61	0.82	0.86	0.80
9	Export; customers who applied for the first time (*Ex_F*)	0.64	0.50	0.55	0.59	0.52
10	Import; regular customers (*Im_R*)	0.95	0.78	0.86	0.90	0.81
11	Import; customers who apply periodically (*Im_P*)	0.91	0.76	0.81	0.85	0.77
12	Import; customers who applied for the first time (*Im_F*)	0.72	0.55	0.61	0.64	0.58

Table 7

Service indicators by types of cargo without making mistakes by forwarders

No.	Order type	Cargo category				
		Standard	Oversized	Collected	Perishable	Dangerous
Average time of freight forwarding services t_k, min						
1	Export; regular customers (*Ex_R*)	973	1268	1186	1115	1252
2	Export; customers who apply periodically (*Ex_P*)	1063	1531	1207	1144	1240
3	Export; customers who applied for the first time (*Ex_F*)	1139	1477	1365	1255	1435
4	Import; regular customers (*Im_R*)	1040	1275	1172	1112	1231
5	Import; customers who apply periodically (*Im_P*)	1077	1292	1218	1161	1272
6	Import; customers who applied for the first time (*Im_F*)	1174	1564	1437	1368	1508
Reliability of freight forwarding services p_k						
7	Export; regular customers (*Ex_R*)	0.99	0.85	0.92	0.97	0.86
8	Export; customers who apply periodically (*Ex_P*)	0.97	0.66	0.89	0.94	0.87
9	Export; customers who applied for the first time (*Ex_F*)	0.94	0.75	0.82	0.89	0.78
10	Import; regular customers (*Im_R*)	0.98	0.84	0.93	0.97	0.88
11	Import; customers who apply periodically (*Im_P*)	0.96	0.83	0.88	0.92	0.84
12	Import; customers who applied for the first time (*Im_F*)	0.92	0.71	0.78	0.82	0.75

The duration of transport and forwarding service for regular customers during the export of standard cargo is reduced by 16 %, while during import it is reduced by 10.79 %. At the same time, under the condition of serving customers who have contacted for the first time, the duration of the forwarder's work during export decreases by 14.6 %, and during import by 16.77 %.

6. Discussion of results of modeling the simulation model of the work of a transport and forwarding company

Our results indicate the expediency of applying SM and scientific approaches in the practical activities of transport and forwarding enterprises, which will allow justifying managerial decisions regarding the optimization of personnel support. This will make it possible to analyze the activity of a separate economic entity based on the developed SM, taking into account the structure of the flow of orders for transport and forwarding services in a certain period of time. Thus, the simulation results will contribute to the correction of the current customer service situation and the planning of staff work for future periods. As a result of this implementation, transport and forwarding companies will be able to gain competitive advantages in the market due to a high level of service reliability.

In contrast to the SM described in [5–7, 11, 12], our model allows for the following:

– to study the structure of the flow of orders and the range of cargoes that arrive for service, which will ensure the possibility of planning the staffing of forwarders;

– to distribute the functional responsibilities of forwarders and forecast the duration of certain types of work.

This makes it possible to improve the company's competitiveness on the market and to influence the level of trust on the part of customers of transport and forwarding services by adjusting the company's internal processes.

An equally important aspect is taking into account the specific features of the cargo when organizing the work of the freight forwarder. This issue will have a significant impact on the duration of the selection of the carrier, the development of the route, and the preparation of the accompanying and customs documents. Accordingly, the duration of providing transport and forwarding services will differ for each type of cargo, which can also complicate the process of planning the forwarder's employment. Circumstances of this kind can affect the increase in the duration of the customer's waiting for service, and as a result, refusal of cooperation in case of limited delivery terms.

The resulting time characteristics of the work of forwarders (Tables 4–7) confirm that the duration of service for different categories of customers and types of cargo differs significantly. At the same time, the time indicators of servicing regular customers are the smallest since the adjustment of business processes at all stages of work makes it possible to significantly reduce the time for agreeing the terms of cooperation.

In this study, it was possible to develop a simulation model for planning the work of a transport-forwarding enterprise in the organization of road transport. It provides the opportunity for the owner of the enterprise to organize the work of forwarders and optimize their activities at each stage of service in order to minimize the likelihood of errors in work.

The results of the calculations indicate a significant impact on the categories of the customer and the type of cargo received for service on the average time of each type of forwarder's work.

SM is implemented in the GPSS World simulation automation package, which, unlike [5–7], makes it possible to determine the duration of the provision of transport and forwarding services when organizing the transportation of various types of cargo by road transport.

SM provides for the determination of the need for specialists to serve customers, depending on the structure of the flow of orders for the transportation of goods in the customs regimes of export and import. Unlike other SMs, it provides for detailing the terms of execution of individual stages of transport and forwarding service, the probability of errors occurring at each of these stages, and the duration of error elimination in case of their presence. This aspect will allow taking into account the additional time that will require the involvement of the forwarder to re-process the order.

The limitation of the simulation model is that it can only be used for international road transportation of goods, its use is impractical for domestic transportation.

The development of this research has prospects for expansion in the following directions:

– the possibility of evaluating the key performance indicators of the transport-forwarding enterprise, provided that it is involved in the organization of transportation of a certain type of cargo;

– providing recommendations regarding the expediency of involving a transport-forwarding company in the logistics chain based on an assessment of its performance indicators;

– construction of SM of the work of transport-forwarding enterprises when transporting goods by sea, rail, and air transport.

7. Conclusions

1. The model of the work of the transport and forwarding company was formalized when serving customers who are characterized by different frequency of cooperation and need delivery of a wide range of goods under customs export and import regimes. The essence of the model is the possibility of development for the owners of transport-forwarding enterprises when determining the number of full-time forwarders capable of ensuring the smooth operation of the organization and minimizing customer service failures. The model built provides for the possibility of performing a comparative analysis of the performance indicators of feasibility studies when organizing the transportation of standard, dangerous, perishable, oversized, and bulk cargoes. In addition, the model provides a comparative analysis of the processing of service orders coming from customer categories that differ in terms of their needs and available previous work experience.

2. SM of TFS of customers was devised when organizing the transportation of various types of cargo by road transport in international traffic. The proposed model provides an opportunity to study the procedure of servicing regular customers; customers who applied for the first time and customers who apply periodically for the export and import of goods. The model built allows for the research and optimization of the TFS process of various cargo range under the condition of standardization of the types of work performed by freight forwarders. SM makes it possible to evaluate the efficiency of the forwarders available in the company's staff,

as well as to determine the reserve number of specialists who must be involved when the flow of orders changes. The characteristics of the company's activity are taken into account in the SM as this has an impact on the possibility of accepting an order for service in the event of a high level of workload of forwarders.

3. The verification of the adequacy of the SM showed that the upper limit of the simulation error when conducting a trial experiment is d_{SM}=3.3 % with permissible 5 %. Accordingly, the proposed SM of the transport and forwarding enterprise corresponds to the real working conditions of the organization.

4. The results of simulation modeling indicate that the establishment of cooperation with customers and their transition to permanent service will ensure the minimum terms of feasibility studies of various types of cargo. Such a result can be achieved by adjusting the internal business processes of the enterprise and ensuring a number of competitive advantages of the enterprise under study according to the criteria of duration and reliability of service. This will make it possible to reduce queues waiting for service by 9 %, the probability of service refusals by 11 %.

The reliability indicators of the provision of transport and forwarding services are the highest for regular customers, which is 8 % higher than for new customers. According to the types of cargo, there is a tendency to decrease this indicator when organizing cargo transportation, which may be accompanied by certain organizational and technological risks.

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 and the results reported in this paper.

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Data availability

All data are available 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 presented work.

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