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Development and Application of a Simulation Model for Analyzing and Optimizing Freight Forwarding Service Processes

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Abstract

The article is devoted to the development and application of a simulation model for the analysis and optimization of the processes of providing freight forwarding services by a company specializing in the organization of road freight transportation.

The purpose of the study is to determine the optimal organizational structure of the company to improve its work efficiency. The paper presents a formalized model of the company's key business processes. The model is implemented in the GPSS World simulation environment and is described as a queuing system. As a result of the simulation, quantitative estimates of key performance indicators were obtained, such as the average time to service an application, staff workload, queue length, and probability of failure. Based on the analysis of the results, "bottlenecks" were identified in the process of servicing applications for freight forwarding services.

Practical recommendations on restructuring processes and changing staffing levels are formulated, aimed at reducing order processing time, reducing the failure rate and increasing the overall throughput of the company.

Keywords: Simulation Modeling, Freight Forwarding Services, Logistics Company, Road Transportation, Queuing System, GPSS World, Business Process Optimization

1. Introduction

The globalization of the economy and the expansion of international trade are imposing heightened requirements for efficiency, reliability, and speed on the transport and logistics industry. Road freight transport plays a critical role in this environment, ensuring the flexibility and adaptability of supply chains. Nonetheless, the organization of such transport is a complex, multi-faceted process fraught with significant uncertainty stemming from fluctuating demand, vehicle availability, customs regulations, and other variables.

Consequently, optimizing the internal business processes of logistics firms offering freight forwarding services has become a pressing issue. Conventional analytical methods frequently fall short in capturing the stochastic nature of order flows, the variability in processing times, and the imperative to make decisions under resource constraints.

Therefore, there is a need to develop a simulation model for analyzing and optimizing the service delivery processes of a logistics company specializing in road freight transportation.

2. Formalization of the company's work model in the organization of road freight transportation

The operation of a logistics company providing forwarding and logistics services in organizing motor freight transportation is examined.

A flow of requests for forwarding and logistics services is received from customers. The processing of a request by managers during the organization of motor freight transportation involves performing tasks W_{ij} across stages ST_i (Table 1). The duration of each task is considered a random variable with a given distribution law.

Table 1: The stages of execution of work on the maintenance of applications by managers

№	ID	Maintenance stages	Manager
1	ST_1	Stage 1. Receiving the order from the client	
1.1	W_{11}	Order receipt and margin assessment	Customer Service Manager
1.2	W_{12}	Checking a one-time client	Customer Service Manager, Lawyer
2	ST_2	Stage 2. Search for transport for cargo transportation	
2.1	W_{21}	Transfer of the order to the transport manager	Customer service manager, Transport Manager
2.2	W_{22}	The decision to place an order with own transport	Transport Manager
2.3	W_{23}	Transfer of the order to the operational logistics department	Transport Manager, Operational Logistician
2.4	W_{24}	Operational logisticians call the existing database	Operational Logistician
2.5	W_{25}	Search for transport on the transport exchange	Operational Logistician
2.6	W_{26}	Search for transport with modified transportation conditions	Operational Logistician
3	ST_3	Stage 3. Registration of documents for cargo transportation	
3.1	W_{31}	Transfer of the order	Operational Logistician, Customer service manager
3.2	W_{32}	Request the necessary data for transportation by an operational logistician	Operational Logistician
3.3	W_{33}	If have worked with a carrier	Operational Logistician
3.4	W_{34}	If have not worked with the carrier before	Operational Logistician
3.5	W_{35}	Verification of documents by a lawyer	Lawyer
3.6	W_{36}	Execution of the contract and application	Operational Logistician
3.7	W_{37}	Approval by the deputy director	Associate Director
3.8	W_{38}	Correction of the application	Operational Logistician
3.9	W_{39}	Sending a request	Operational Logistician
4	ST_4	Stage 4. Signing of the application by the carrier and control over the cargo transportation process	
4.1	W_{41}	Carrier's approval of the application	Operational Logistician
4.2	W_{42}	The application was not approved by the carrier	Operational Logistician, Lawyer, Associate Director
4.3	W_{43}	The documents are signed	Operational Logistician
4.4	W_{44}	Informing customer service managers	Customer service manager
4.5	W_{45}	Control over the cargo transportation process	Operational Logistician

The controllable factors of model X are:

- the incoming flow λ_r of applications for the provision of freight forwarding services for the organization of road freight transportation in the r-th direction (Republic of Belarus, Russian Federation, European Union, Republic of Kazakhstan).

The factors A of the model are:

- an estimate of the average time $m_{ij} \pm \sigma_{ij}$ of performing the j-th work W_{ij} of the i-th stage of ST_i (Table 1) for processing the application by the manager;
- the number of N_k managers working with clients.

The factors of the U model are:

- the probability γ_l of choosing the movement of the application depending on the verification of the condition.

The output response characteristics of the Y model are simulation statistics:

- average freight forwarding service time by stage (t_i);
- the average length of the queue to the manager for processing the application (η_k)
- the average waiting time for the client in the queue to the manager (w_k),
- the proportion of applications served without downtime in the queue (ν_k);
- probability of denial of service (q_k);
- manager load factor (ψ_k);
- the average number of managers loaded (ρ_k).

To substantiate structural solutions and improve the efficiency of processing requests to a logistics company, a mathematical model based on queuing theory has been developed. The model allows system performance indicators (average request processing time, probability of failure, loading of service channels) depending on its configuration and the intensity of the incoming flow.

Fig 1 shows a flowchart of a queuing system model that visualizes the logic of the interaction of its elements and simulates the operation of the first stage ST_1 of the execution of maintenance work by managers.

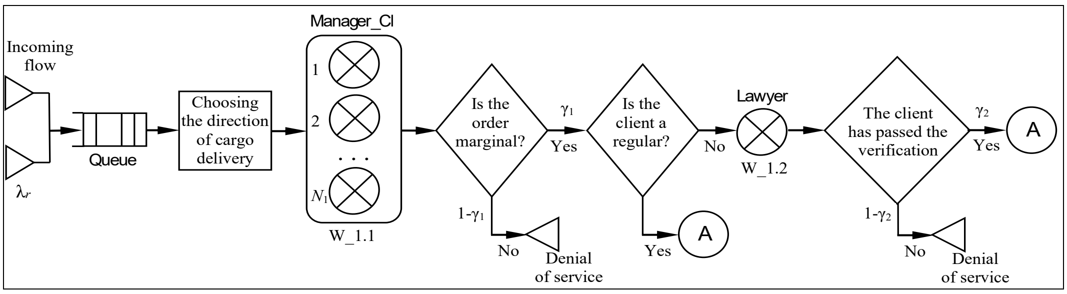


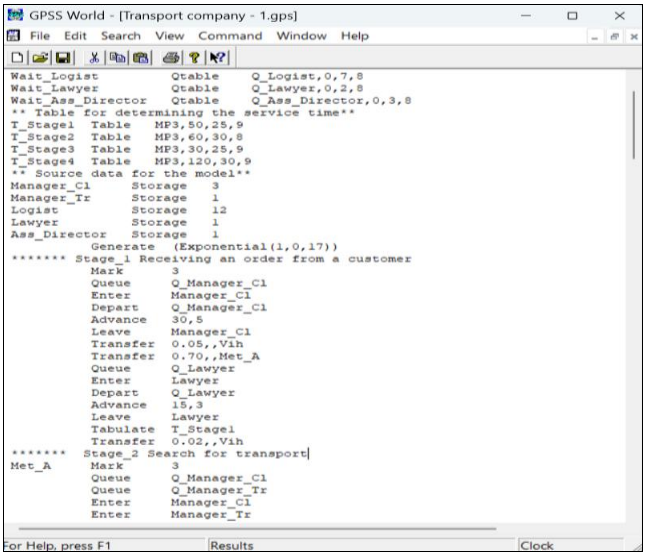
Fig 1: A flowchart for modeling the stage of receiving an order from a customer (ST_1)

The schematic representation of the ST_2 – ST_4 stage model with indication of application flows, service channels and decision-making nodes has a similar form.

3. Simulation model of freight forwarding services by a logistics company

The proposed model for the provision of forwarding services was created in the GPSS World simulation automation package [4, 12, 23].

The text of the simulation model in GPSS World is shown in Fig 2.



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GPSS World - [Transport company - 1.gps]
File  Edit  Search  View  Command  Window  Help
Wait_Logist         Qtable    Q_Logist,0,7,8
Wait_Lawyer         Qtable    Q_Lawyer,0,2,8
Wait_Ass_Director   Qtable    Q_Ass_Director,0,3,8
** Table for determining the service time**
T_Stage1  Table   MP3,50,25,9
T_Stage2  Table   MP3,60,30,8
T_Stage3  Table   MP3,30,25,9
T_Stage4  Table   MP3,120,30,9
** Source data for the model**
Manager_Cl       Storage   3
Manager_Tr       Storage   1
Logist           Storage   12
Lawyer           Storage   1
Ass_Director     Storage   1
          Generate   (Exponential(1,0,17))
******* Stage_1 Receiving an order from a customer
          Mark       3
          Queue      Q_Manager_Cl
          Enter      Manager_Cl
          Depart     Q_Manager_Cl
          Advance    30,5
          Leave      Manager_Cl
          Transfer   0.05,,Vih
          Transfer   0.70,,Met_A
          Queue      Q_Lawyer
          Enter      Lawyer
          Depart     Q_Lawyer
          Advance    15,3
          Leave      Lawyer
          Tabulate   T_Stage1
          Transfer   0.02,,Vih
*******   Stage_2 Search for transport
Met_A     Mark       3
          Queue      Q_Manager_Cl
          Queue      Q_Manager_Tr
          Enter      Manager_Cl
          Enter      Manager_Tr
For Help, press F1    Results    Clock
```

Fig 2: Program Listing

The adequacy of the simulation model to the object of study was verified by matching the values of the characteristics of the functioning of the model with the data obtained by analytical calculation methods with a given accuracy.

As a result of the simulation, the average service time of an incoming request is shown in Table 2.

Table 2: The results of modeling the average service time by stages

Maintenance stages	Republic of Belarus	Russian Federation	European Union	Republic of Kazakhstan
Stage 1. Receiving the order from the client (t_1, min)	33,2	43,2	50,2	63,2
Stage 2. Search for transport for cargo transportation (t_2, min)	54,1	61,3	62,7	61,3
Stage 3. Registration of documents for cargo transportation (t_3, min)	46,5	49,6	49,6	53,5
Stage 4. Signing of the application by the carrier and control over the cargo transportation process (t_4, min)	40,7	63,5	131,0	81,9
Stages 1 – 4 (t, min)	175	218	294	260

Histograms of the distribution of the average service time for incoming request flows for processing operations to provide freight forwarding services in the organization of road freight transportation to the European Union are shown in Figures 3–6.

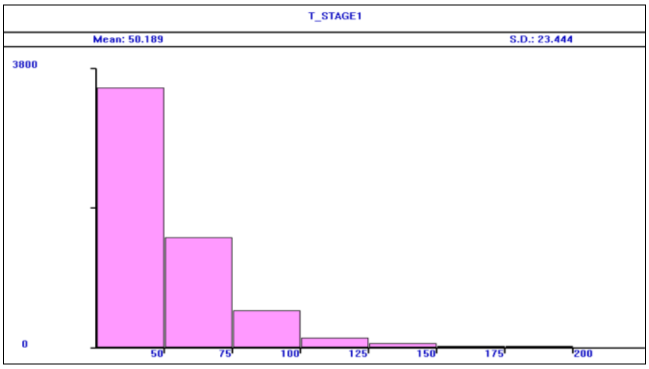

Fig 3: Histogram of the distribution of the average time of the order receipt stage from the customer (ST_1)

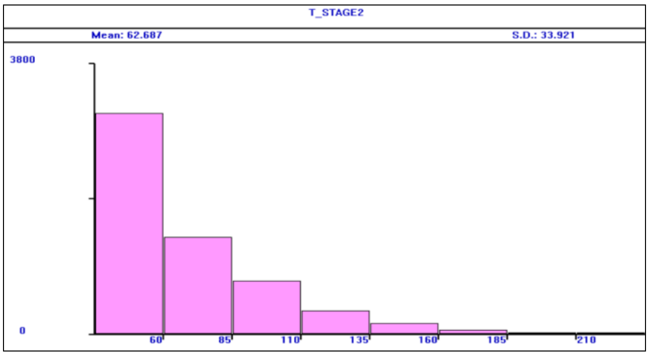

Fig 4: Histogram of the distribution of the average time of the transport selection stage (ST_2)

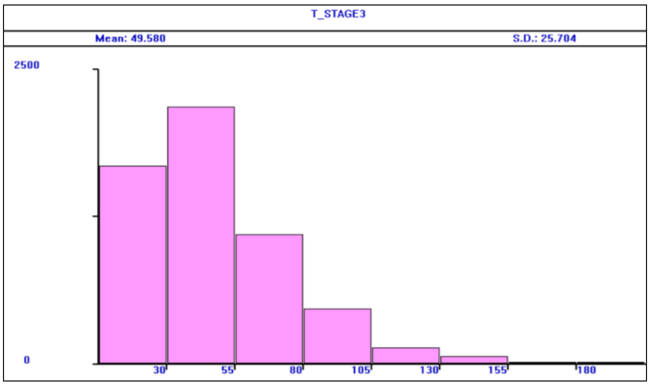

Fig 5: Histogram of the distribution of the average time of the paperwork stage (ST_3)

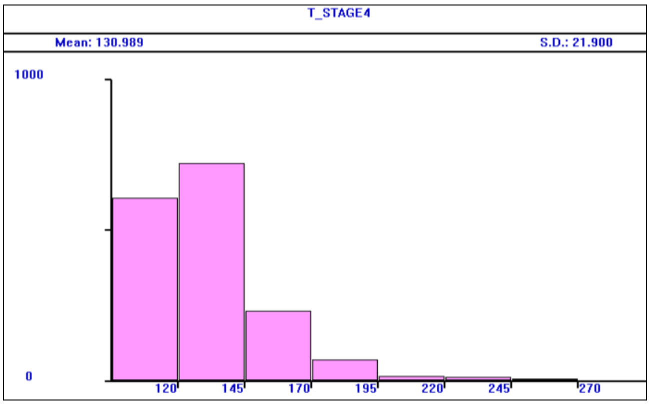

Fig 6: Histogram of the distribution of the average time of the stage of signing the application by the carrier and monitoring the cargo transportation process (ST_4)

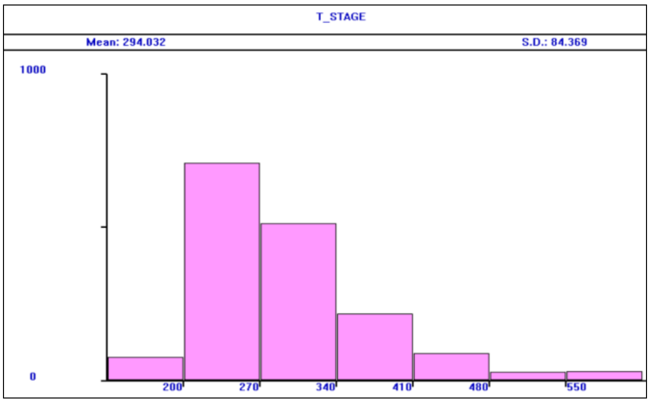

Fig 7: Histogram of the average service time distribution (ST_1-ST_4)

According to the reports obtained as a result of modeling the process of providing freight forwarding services, the main indicators are determined (Table 3).

Table 3: The results of modeling the process of providing freight forwarding services

Modeling indicators	Customer Service Manager	Transport Manager	Operational Logistician	Lawyer	Associate Director
Average waiting time in the queue w_k, min	17,1	11,8	2,6	3,9	1,0
Average queue length η_k, applications	3,6	1,7	1,2	0,1	0,06
The proportion of applications served without downtime in the queue, v_k %	30	26	76	61	76
Number of managers, N_k	3	1	12	1	1
Average number of managers loaded, ρ_k	2,36	0,71	7,70	0,40	0,21
Manager load factor, ψ_k	0,79	0,71	0,64	0,40	0,21
Probability of denial of service, q_k	0,07				

Figures 7 – 11 present histograms showing the distribution of the average queue waiting time for the company's managers when processing incoming requests for freight forwarding services related to the organization of road freight transportation to the European Union.

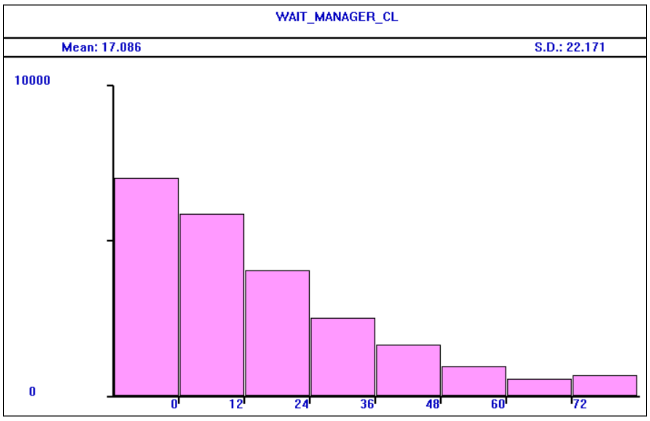

Fig 7: Histogram of the distribution of the average waiting time in the queue for the customer service manager

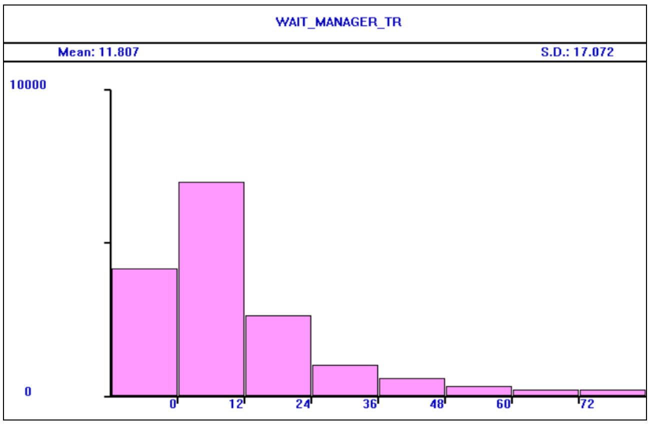

Fig 8: Histogram of the distribution of the average waiting time in the queue for the transport manager

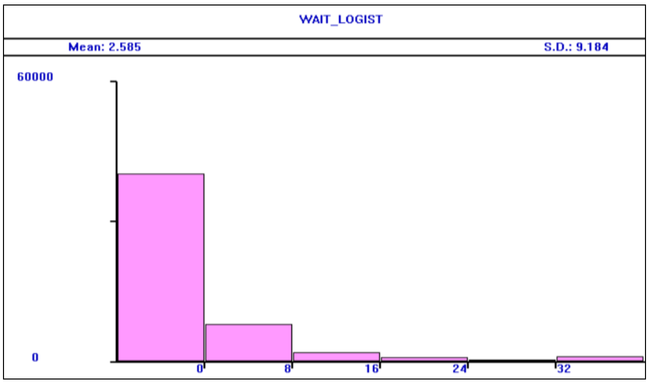

Fig 9: Histogram of the distribution of the average waiting time in the queue for the operational logistician

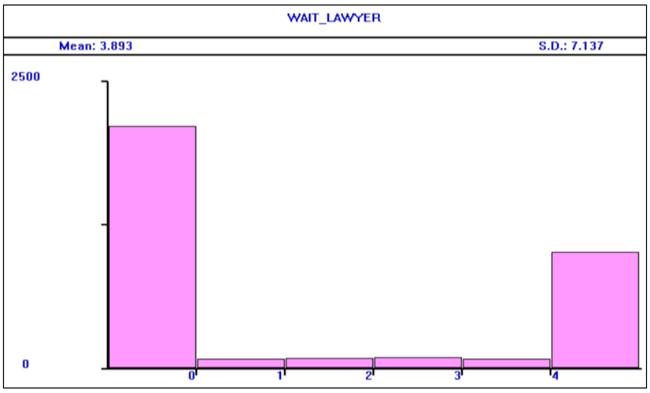

Fig 10: Histogram of the distribution of the average waiting time in the lawyer's queue

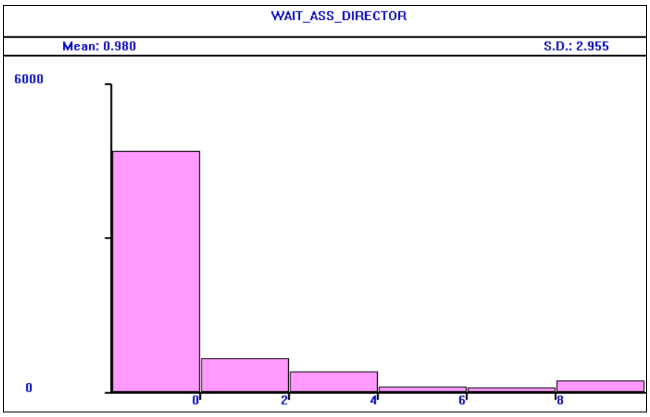

Fig 11: Histogram of the distribution of the average waiting time in the queue for the associate director

4. Conclusions

Based on the analysis of the simulation modeling results, two main areas for improving the company's efficiency were identified:

1. Improving the efficiency of operational logistics specialists. Despite a workload of 64%, their activities require restructuring. It is advisable to allocate more time to searching for transportation that meets customer requirements.

This will lead to:

- A reduction in the volume of requests forwarded to the freight exchange platform.
- A decrease in the average request fulfillment time.
- A reduction in the share of rejections due to non-compliance with transportation terms.

2. Eliminating the bottleneck in customer service. The current number of customer service managers limits the company's growth potential. The high average queue waiting time (17.1 min) and queue length (3.6 requests) indicate the need to increase staff to:

- Reduce the service time per client.
- Increase the overall throughput of the department and its ability to handle a larger flow of requests.

The implementation of these measures will optimize key service metrics, mitigate operational risks, and enhance the quality of freight forwarding services.

The proposed simulation model serves as an effective decision-support tool for management. It enables the evaluation of how changes in the company's structure, staffing levels, and request flow intensity affect key performance indicators, including service time, rejection probability, and employee utilization.

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