Quality Management Mathematical Methods in Transport Logistics Information Systems

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***Abstract*— The paper presents quality management approaches based on logistics providers' key characteristics analysis using mathematical methods. Logistics departments throughput and fault tolerance model problem estimating is presented using the software implementation developed on the theory of mass service provisions basis. Considered logistics departments abnormal situations revealing mechanism on the basis of the Pareto analysis methodology program implementation.**

***Keywords*— quality management; logistics; information system; Pareto analysis; queuing system; software implementation**

I. Introduction

Corporate information systems applied research prior direction is software development aimed to support decision-making in the strategic planning and management tasks. Companies and corporations are interested in developing up-to-date software packages made for calculations automation and weighted solutions formalization [1].

Dynamically developing spheres experiencing economic growth are large cargo transportation and logistics services provision sectors. Companies and corporations development trends indicate the transition to an outsource logistics services model. Currently, more and more companies attract 3PL providers, delegate shipments, monitoring and goods delivery. Fig. 1 presents the 3PL-services world market 2010-2016 diagram.

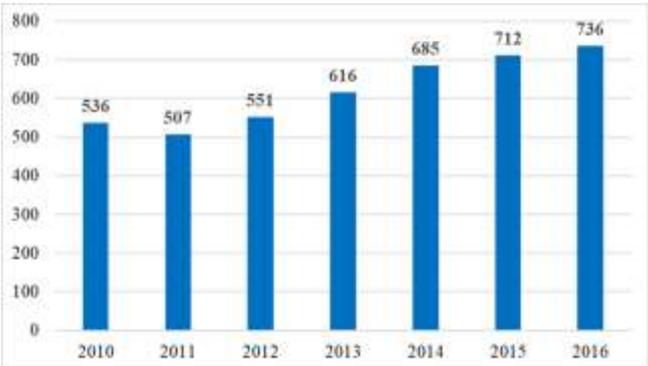

Fig. 1. 3PL services world market dynamics from 2010 to 2016, billion dollars

Logistics providers offer a wide services variety, integrated solutions for business. 3PL-providers responsibility area includes:

- cargo transportation provision and monitoring;
- goods warehousing;
- quality control in accordance with standards;
- cargo registration and document management;
- individual cargo insurance.

The presented list is not complete, yet allows to draw conclusions about the variability and versatility of the arising problems. Modern competitive relations presuppose the up-to-date technologies introduction for information process and analysis, in order to increase competitiveness. One of the prospective directions in the corporate governance problems solving area is the decision support systems (DSS) development – information systems that integrate information processing and analyzing methods in a structured program environment [2-5].

II. Mass Service Theory and Pareto Analysis in the Logistics Tasks

Logistics providers' competitiveness maintains in close correlation with orders serviced numbers alongside customer satisfaction degree. Logistics departments throughput and resiliency are considered to be transport companies' key indicators. Multiple requests tasks processing modeling is based on queueing systems mathematical apparatus. Regarding the subject, queueing system should be considered as a set of requests: logistics tasks and service devices – logistics departments.

Queueing systems are classified as follows:

- systems with failures for which requests that are not secured by a free performer are lost;
- waiting systems, where requests transit to an infinite capacity accumulator which forms the service queue;
- systems with finite-capacity queues (waiting and constraints) which allow queue length under the specific amounts.

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As applied to logistics tasks, third-type systems are most relevant, with waiting and restrictions on the length of the queue. Fig. 2 shows the queueing systems model with constraints and failures.

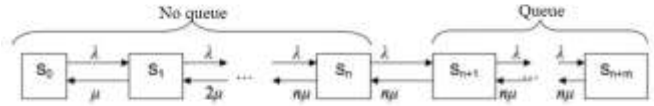

Fig. 2. Limited queueing system graph

Cargo services design involves a thorough examination of the forecasted congestion characteristics, cargo volumes stored and transported, rent costs, labor compensation funds, etc. There is a need to analyze the heterogeneous factors that influence the projected system. Along with the tasks of planning, it is necessary to take into account contingencies arising during the implementation of the developed management strategies.

One of the highly efficient methods for abnormal situations causes investigating is Pareto analysis. In general, the Pareto rule could be formulated as follows: "In the inside of 80% problems that arise are 20% reasons." The Pareto rule is relevant for most situations that are subject to cause-effect relationships: plant failures, technological failures, project implementation delays, etc. [6]. As applied to logistics tasks, the Pareto methodology has a high usability in abnormal situations causes regarding transportation and storage tasks, logistics departments work, and freight escort services provisions. Pareto analysis provides an opportunity to conduct a one-time study of heterogeneous factors, identifying the reasons based on the statistical sample accumulated over a certain period of time. Pareto analysis, along with Ishikawa charts, SWOT and PEST analysis, was adopted as one of the quality control doctrines in Japan in state-owned enterprises and in 2009 was introduced into the quality control structure of Russian Railways by the relevant standard.

III. Logistics Department Throughput and Resiliency Parameters Simulation

Let's consider an example of the queuing systems usage in order to find the key 3PL providers characteristics and Pareto analysis in order to ensure provided logistics services quality control. The freight transportation department analysis task formulates as follows: the estimated capacity utilization is 9 trucks per hour, 5 operators are responsible for cargo distribution and dispatch. The average lead time for a logistics order is 25 minutes. The maximum queue length is 3 units, in case the queue is full, the order is lost. Let's structure the initial data in the form of a table and estimate the service failures and queue formation probability (Table 1).

TABLE I. Initial Data for Throughput and Resiliency Task

Incoming data	
Serving operators number	$n = 5$
Requests receipt intensity	$\lambda = 0{,}15\ min^{-1}$
Average lead time	$\mu = 0{,}04\ min^{-1}$
Max queue length	$m = 3$

Speaking of the model problem solution with the developed DSS "ShAG" decision support system (DSS "ShAG") [7]. In order to do this, in the dialog box, user should select the menu item corresponding to the presented model – multi-channel queueing system with limited queue and failures. The problem initial data and calculated output parameters are presented on the Fig. 3.

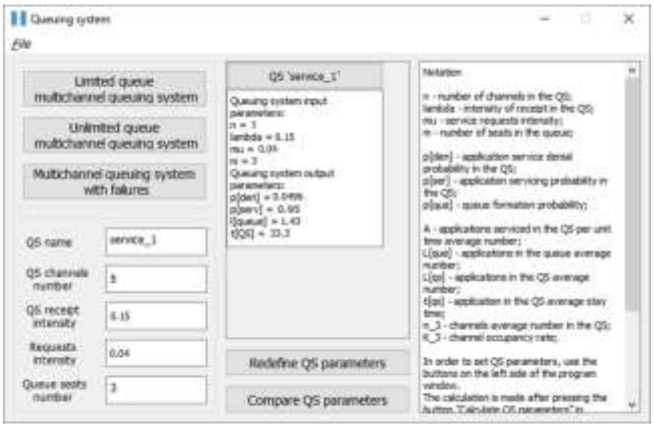

Fig. 3. Queueing systems program module main window

Output parameters based on the estimated production system results are the following: the probability of successful order processing is 95%; the average number of orders in the queue is 1.42 units; the average service time is 33 minutes. The received data testify to sufficient fault tolerance values at the given loads parameters.

IV. 3PL-Providers Abnormal Situations Causes Analysis

The following part is about the Pareto analysis software module, aimed to determine abnormal situations most significant causes set. It is supposed that during the certain time interval the following statistical data was formed (Table 2).

TABLE II. Initial Data for Throughput and Resiliency Task

Cause number	Cause name	Amount
Cause 1	Additional services disclaimer	33
Cause 2	Cargo corruption	45
Cause 3	Road traffic accidents	15
Cause 4	Vehicles breakage	56
Cause 5	Freight transport idleness	23
Cause 6	Hazardous weather conditions	5

Let's take o closer look at the revealing task of significant failures causes using the developed DSS "ShAG" software module. The interface of the program module includes input windows for initial data and intermediate analysis results output, as well as the window for most significant abnormal situations causes (Fig. 4). Regarding the solution of the model problem: in order to work with the program, user must specify the initial data, click the "Analysis" and "Calculation" interactive buttons. The results show that reasons # 4, # 2 and # 1 are the main ones and account for 76% of the total reported abnormal situations number.

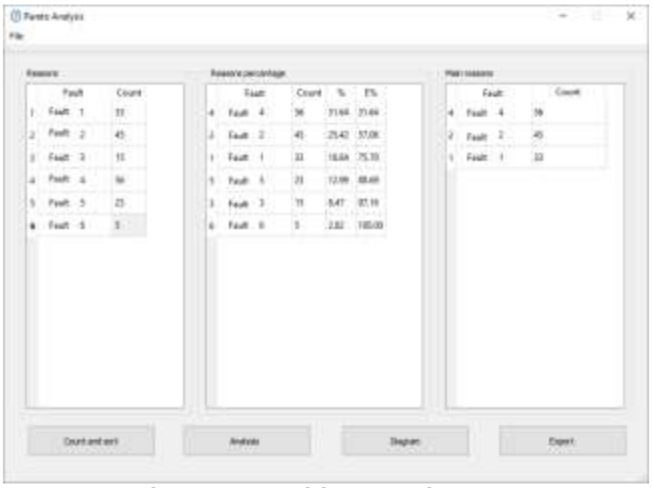

Fig. 4. Pareto analysis program module main window

Fig. 5 shows the Pareto diagram based on the calculations' results. The graph represents columns reflecting failures number percentage values, a cumulative line representing the accumulated failures percentage and perpendiculars separate more important causes from less important ones.

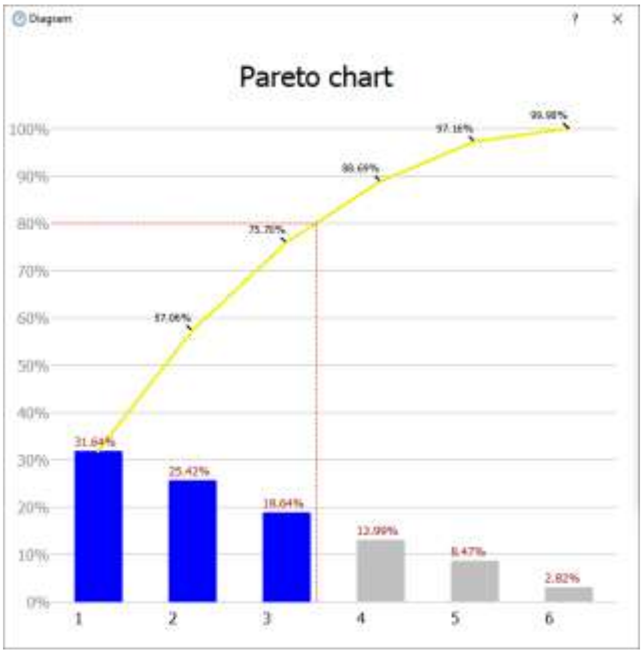

Fig. 5. Pareto diagram

The diagram represents most significant abnormal situations occurrence causes in a graphical way. The next step should be the development of measures aimed to eliminate the presented reasons and reduce the negative impact on the overall system's stability.

V. Conclusion

The systematic approach towards production planning and management problems solving is a prior direction for companies and corporations progress [8]. The presented decision support system software modules allow to analyze complex systems with relevant mathematical methods and simulation models. Modern software solutions in transport logistics systems can facilitate the information processing and analysis and ensure the high quality of the provided services.

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