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Research paper

Assessment of Cargo Delivery Quality Using Fuzzy Set Apparatus

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Abstract

The influence of the existing operation conditions for the time of cargo transportation, i.e. ferrous metals to the port station, was investigated. It was proposed to carry out the management of cargo delivery on the basis of determining the values of cargo handling duration while implementing the stages of the schedule. It was proposed to carry out assessment of the delivery process, including transportation using the fuzzy set apparatus. To determine the quality of transportation, an ordered categorized scale of values of the duration of cargo's staying in certain conditions at delivery stages was proposed. The assessment of deviations at all the stages of transportation with the use of linguistic definitions of conditions allows quantifying such an indicator as the transportation quality. The characteristics of deviations during transportation are provided in the linguistic form to the dispatching unit for making a decision. The revealed regularities in deviations from the standard schedules of trains during delivery of cargos are an objective basis for taking into account them in the mathematical models of the forecast of time of cargo delivery at each of the defined stages of transportation. The data on the forecasted and actual transportations are accumulated in the existing information base, forming data files for assessing the quality of the transportation process, the adequacy of the mathematical model and correcting of the model in case of significant organizational or technical changes.

Keywords: *assessment of cargo delivery quality, method of making control-time points, model goods delivery processes, prognosis deviation, scale of values.*

1. Introduction

The concept of the cargo delivery quality assessment and, namely, the reliability of compliance with the time commitments of transportation participants is related to the process modeling and the accuracy of determining the forecasted time of implementation of each of the delivery stages. Obviously, the control of transportation time is a key factor in management of logistic processes, especially in the processes of interaction between several subsystems as far as it occurs in ports, at the frontiers of countries or in the interaction of railway and powerful industrial enterprises. To forecast and control the time of delivery according to transport stages, the different models and methods of forecasting are used by scientists in the world. There are also different approaches to assess the quality of logistic service.

2. Literature Review and Defining Problem

Logisitcs experts claim [1], that currently there is no business competition but competition of Supply Chain Management (SCM). SCM competition is directly related to the quality of service at each stage of delivery. The paper [2] states that one of the ways of reforming and integrating the Ukrainian railways into the European transport system is connected with the implementation of logistics processes in all areas of the railway. The model of transport system is presented, a part of which components are operators, whose functions are related to the control of transport processes and operations with objects in time.

The problems of customer service quality assessment are considered in the context of the integration strategy of logistics chains [3], an integrated evaluation of the service cost model includes logistics cost index, network service time and customer service quality.

The paper [4] presents the models and analysis of the systems of cargo delivery from the place of production to the consumer. In this connection, the problem of informational asymmetry is considered, associated with the fact that the manufacturer and the consumer have different levels of knowledge about the quality of products. It considers the possibilities of assessment (by measured means) of the delivery system quality, including, when the system quality depends on the decision making by several persons.

The classification of forecasting means by classical statistical methods for modelling of cargo delivery processes is presented in [5]. It emphasizes the need in accurate forecast of time points. In the work they are defined as transit points (LTg), pp. 342–343, especially in the complex models of material resources management in multi-chained delivery chains.

In [6], the authors argue that there are objective deviations, p. 346, in the organization of traffic flows on the railway network and the need in a control of time parameters such as the time of shipment, stopping, arrival in real time.

The paper [7] considers the structure of supply chain organization and the ARA-model of interaction with partners. It is noted that technology and planning of integration involves the use of computing system data, as well as the existence of the structure of intellectual exchange of delivery chain data with customers.

When modelling processes in delivery chains, the work [8] takes into account competition problems, demand and distribution planning. It was emphasized that interaction depends on the synchronization of information and its exchange in real-time mode, p. 237, between the participants in the delivery chains and the recipients of the goods.

The accuracy and quantitative effectiveness, p. 155 of the work [9], of the modern delivery of cargo is a function of reliability and speed of goods replenishment in warehouses, observance of delivery terms, minimization of losses during transportation and storage in warehouses, etc. The time, as noted therein, is the most important factor in the management of logistics processes in case of considering the minimizing of full time costs when moving goods from the production point to the end user through all the process chains.

For modeling of logistics processes and networks in order to optimize and control their operation, such approaches as fuzzy logics, neural network methods and genetic algorithms [10, 11] are used. The fuzzy logic is used also by the authors [12] in systems for control of technical systems.

The paper [13, 14] proposes the model for forecasting control points in the process of cargo delivery. The authors propose to accumulate data on the transportation process, including data on deviation from the forecast in the existing information base to control the adequacy and evolution of the model.

3. Methodology

The railway dispatching services control the movement of trains according to the established traffic schedule, but the control and management of cargo delivery, assessment of the quality of implementation of the process of delivery remain problematic.

On the other hand, using railway services, the business environment expects transparency in actions and compliance with logistic principles during cargo delivery, especially when it concerns transportation related to receipt and transfer of cargoes abroad or to other modes of transport. The quality of the cargo delivery service is conditioned by observance of the established time parameters, which are stipulated by agreement between the participants of transportation.

As to the problem of defining the time parameters which would take into account both the needs of service users in minimizing the delivery time and the possibilities of railway in its current organizational and technical condition, it requires a separate study and remains unsolved. However, the problems of justification of deviations from the agreed time of cargo delivery can not be objectively regulated.

In order to identify the objective aspects of the mentioned problem within this scientific search, the analysis of data on transportation of routes (and group shipments) with ferrous metals from Kryvyi Rih to the port of Odessa on several routes during a year was carried out. The dataset contains information on operations and the time of operations during transportation.

For data analysis, a table of scheduled norms was developed taking into account the time of handling at the transfer points and at the stations of changing locomotive brigade or locomotive. Let us call deviation from the scheduled norm as operational deviation (OD).

Figure 1 shows the mean value and the mean squared deviation of OD. The mean value of OD is noticeably increasing at the stations Tymkove, Kropyvnytska, Kolosivka and Odesa-Sortuvannaya, and from the station Kolosivka it increases significantly. The mean squared deviation exceeds the mean value of OD almost everywhere, it increases sharply at the same stations as the mean one, and from the station Kolosivka it almost and more than twice exceeds the mean value. This variation most likely indicates that the minimization of cargo delivery time is not the objective function of the considered system.

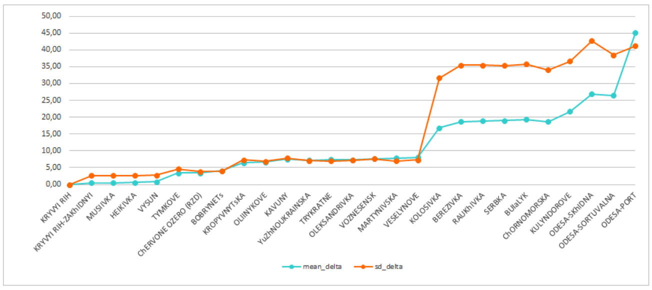

Fig. 1: The mean value and the mean squared deviation of OD

Figure 2 shows similar characteristics of the movement of single and group cars. Here, the mean squared deviation of OD is about a half of the mean value, which exceeds the scheduled norm of cargo delivery in many times.

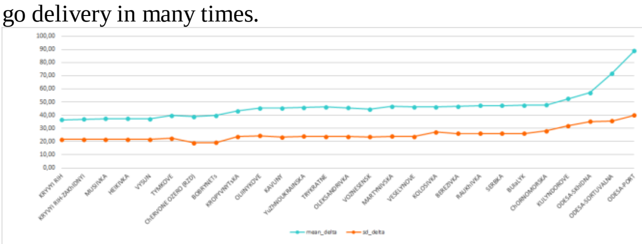

Fig. 2: The movement of single and group cars

A many times increase in the scheduled norms of running time is observed. The time of routes service (about 75% of the routes) is approximately 50 hours, 25% is higher than the mean value, 50% is 34 hours of running to the destination station, Figure 3.

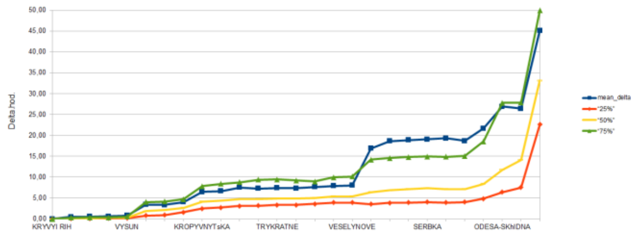

Fig. 3: Deviation from "norm"

During transportation of groups and single cars, only a quarter of them are delivered in 60 hours, a half in 79 hours, and 25% of them in more than 110 hours.

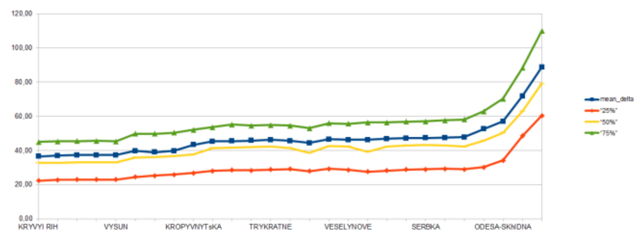

Fig. 4: Single and group transfers

The diagrams of scattering data for the stations Kropyvnytska, Kolosivka, Odessa-sortuvalna and Odessa-port, Figure 5, demonstrate the existence of a certain correlation between the values of OD, namely the limitation of the possible deviation from the scheduled norm.

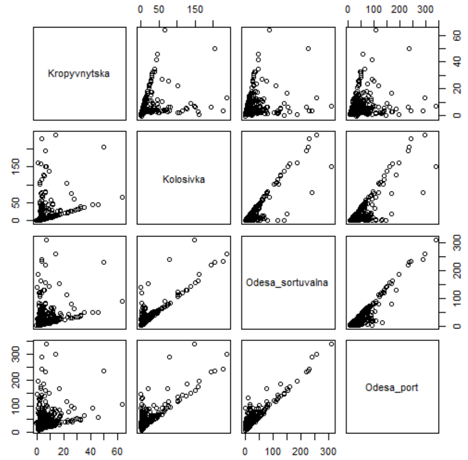

Fig. 5: The diagrams of scattering data

However, the diagrams of scattering the same data in the range of up to 50 hours, Figure 6, indicate a significant mixing of data at these stations with increasing tendency while moving to the destination point. Such a diffusive behavior of data, obviously, can prevent the ability of forecasting the time of delivery of a particular cargo according to the data of its movement on the route.

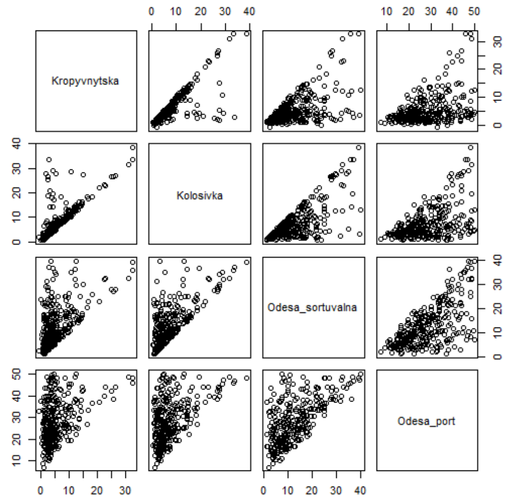

Fig. 6: The diagrams of scattering data in the range of up to 50 hours

Let us construct the model of the considered system to find out the very possibility of forecasting on the available data. As a model, let us accept the fuzzy problem of classification with several (4) inputs – OD at the stations with a sharp increase in the mean value of operational deviation, and one output – OD at the destination station.

For representation of data, it appears to be advisable to select a scale which would reflect the degree of deviation from the established schedule and guarantee the presence of each of its values at an arbitrary stage of the cargo delivery. Obviously, such a scale can only be relative, therefore, it is proposed to establish it based on the ordinal statistics, namely on the values of percentiles, see Table 1. It is assumed that the left boundary is not included in the corresponding range.

Table 1: The values of percentiles

№	Assessment of operational deviation	Range (percentiles)
1	Acceptable	(0; 5]
2	Noticeable	(5; 15]
3	Apparent	(15; 25]
4	Significant	(25; 50]
5	Serious	(50; 75]
6	Critical	(75; 90]
7	Overcritical	(90; 100]

An example of the values of deviations and the corresponding values for the stations Tymkove and Odessa-port are shown in the Table 2. Thus, the value "Significant" (deviation) amounts from 0.79 hours to 1.81 hours and from 22.61 to 33.13 for the mentioned stations, respectively. The scale corresponds to the data on the movement of cargoes through the indicated stations available for the certain time and should be regularly recalculated in order to remain relevant.

Table 2: An example of the values of deviations and the corresponding values for the stations Tymkove and Odessa-port

Assessment of operational deviation	Tymkove (hours)	Odessa-port (hours)
Acceptable	(-0.22; 0.11]	(7.05; 14.69]
Noticeable	(0.11; 0.53]	(14.69; 19.35]
Apparent	(0.53; 0.79]	(9.35; 22.61]
Significant	(0.79; 1.81]	(22.61; 33.13]
Serious	(1.81; 4.00]	(33.13; 49.91]
Critical	(4.00; 8.39]	(49.91; 79.58]
Overcritical	(8.39; 44.71]	(79.58; 337.88]

Each value of the scale can be presented as a linguistic variable with the corresponding membership function, see Figure 7.

The data on 406 cases of cargoes transportation from Kryvyi Rih to the port of Odessa were used to construct a fuzzy rule-based system (FRBS) as a classification problem. The values of operational deviations at the stations TYMKOVE, KROPYVNYTSKA, KOLOSIVKA and ODESA-SORTVUALNA were accepted as the values of input variables and the assessment of transportation quality at the ODESA-PORT station as the values of the output categorized variable.

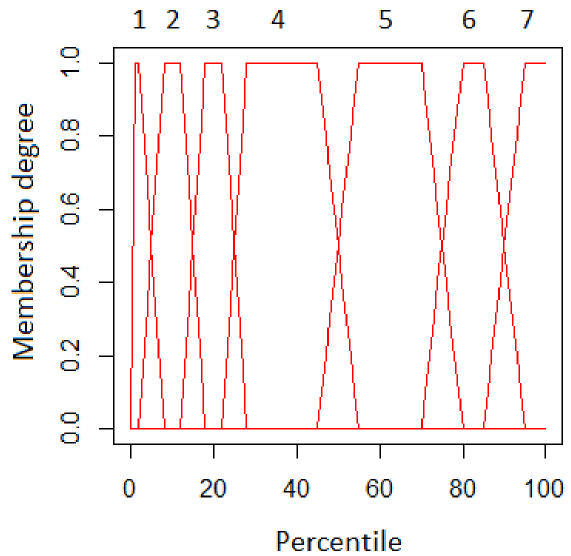

Fig.7: Membership functions of scale values

According to the results of training, the membership functions of input variables were generated in the normalized form, see Figure 8.

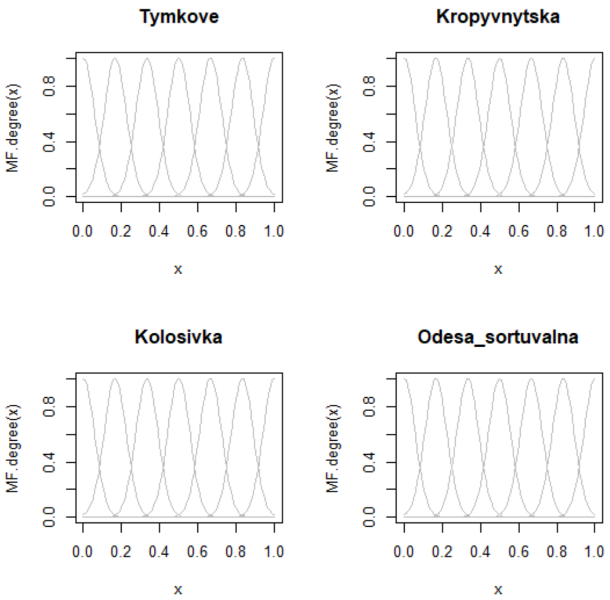

Fig. 8: Generated membership functions of input variables

The synthesis of the model was carried out by means of the library frbs of the system R, see [15]. The training sample included 306 points and the test one included 100. On the data of the training sample the rules within the Mamdani model were synthesized with the following basic parameters: types of t-norm and s-norm are MIN and MAX, respectively, a type of the output function is ZADEH.

At seven levels of input variables and with the GAUSSIAN membership function, a plurality of rules and their membership functions were generated, for example, the rule

"IF" "Tymkove" "is" "vv.small" "and" "Kropyvnytska" "is" "vv.small" "

and" "Kolosivka" "is" "vv.small" "and" "Odesa_sortuvalna" "is" "vv.small"

"THEN" "Odesa_port" "is" "5"

with a membership degree of 0.95.

At the set parameters, the accuracy of the forecast on the test data set amounts to at least 65% at the forecast of a minimum operational deviation.

4. Conclusion

The analysis of the data on transportation of routes (and group shipments) with ferrous metals from Kryvyi Rih to the port of Odessa during a year gives grounds for such conclusions.

1. The time of cargo delivery, as the basic quality indicator, is not an objective function of the system, obviously because of the absence of principles of its justified definition.
2. The different groups of cargoes, in particular, routes and single or group cars have statistic indicators which vary significantly.
3. The considered system can be assumed as a system with significant mixing, which is manifested in a significant scattering of data as the cargo moves to the destination point.
4. The construction of rules based on the fuzzy model of the system proves the applicability of modeling based on time data.
5. For a unified assessment of operational deviation values at different stations, an ordered categorized scale based on ordinal statistics is proposed.
6. The OD assessment on such scale can be transferred in the linguistic form of the dispatching unit for decision making. According to this scale, a sufficiently high quality of transportation is ensured at the OD values "acceptable", "normal". The transportation with the value "apparent", "significant", "serious", "critical", "overcritical" requires the management intervention.

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