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Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

FUZZY MODEL IN FUZZY-TECH ENVIRONMENT FOR THE EVALUATION OF TRANSPORTATION'S QUALITY FOR CARGO ENTERPRISES IN UKRAINE

Oleksandr Dorokhov[1], Ludmila Dorokhova[2]

[1] *Kharkiv National University of Economics*
9-a, str.Lenina, 61001, Kharkiv, Ukraine
E-mail: aleks.dorokhov@meta.ua

[2] *National Pharmaceutical University,*
53, str. Pushkinska, 61002, Kharkov, Ukraine
E-mail: dorohova@meta.ua

The basic criteria of quality vehicle servicing and operation of road transport enterprises in the transportation market of Ukraine have been reviewed, classified, described and structured. Their formalization by linguistic variables with appropriate terms has been done. Usage of methods of fuzzy inference to determine the integral generalized level of freight transportation's quality has been proposed. Corresponding computer model has been developed in fuzzyTECH – a specialized package of fuzzy modelling

Keywords: transport service, the quality of freight transportation, the criteria for the level of transport service

1. Introduction

In conditions of hard competition in the freight market in Ukraine defining components for the commercial success of carriers are both economic performance and quality of transport service for customers. Transport companies must constantly monitor both the level of their own work and activities of competitors by a significant number of diverse economic, technical, technological and market criteria.

This problem can be efficiently solved only by using modern mathematical methods, computer simulation and information technologies [1–3].

2. Overview of the Main Indicators of the Transportation Quality and Customer's Service for Transport Enterprises in Ukraine

Issues of transport service quality in general and freight transportation in particular are constantly receiving considerable attention of researchers in Ukraine. Analysis of the literature and practical state of the problem based on author's expert researches (surveys among carriers and customers of transportation services), allows to identify for further analysis four main groups of service quality criteria in the Ukrainian freight market (of course, the list is not exhaustive) [1–4].

There are the technological characteristics of individual transportation flight, the quality of customer service in Transport Company for a certain time period, the criteria for evaluation of transport service from its customers (clients) and the images characteristics of the transport service producers on the market. Purely economic criteria in this model will not be considered, as they will be the subject of separate investigations. Next, we briefly examine the criteria for each of these groups, given that some of them may simultaneously belong to multiple groups. In this case, the difference will consist in the method and estimation's units for the same parameter.

2.1. Parameters of quality for performance of a single trip

Evaluation of the separate trip is an important part of operative, daily control of quality for a single driver in his performance of a particular trip. This assessment may include, inter alias, the following parameters [2, 3]:

- implementation of speed limits during the process of truck's motion („speed mode");
- timely passage of geographic reference points on the route motion („time mode");
- performance of the ordered (prescribed) route of vehicle movement („route mode");
- fuel consumption within the planned for trip („fuel expense");

- the number of recorded traffic violations or accidents („road incidents” and „road rule”);
- loss or damage of the cargo at a separate trip;
- delay to the customer upon delivery of the cargo or supply of transport for loading;
- the time of truck’s preparing for the next trip after previous („readiness”).

2.2. Summary measure of service orders for a certain period of time

For identify and evaluate the work of the transport company as a whole, and during a certain time period, it can be used next indicators:

- powerful of the transport park („park power”);
- degree of satisfaction (on the requested amount) of customer orders („park cover”);
- total transportation safety – environmental and road motion („road safety”);
- overall style of trips („trip style”);
- safety of cargo and claims of customers („maintenance” and „claim”);
- timeliness of customer service – delays, trucks failures and replacements („delays”).

2.3. Criteria for assessing the transport service by clients

With heightened competition and the struggle for the customer to the market in Ukraine rating service, completeness and quality of execution of clients becomes an important component of a lasting market position, competitive advantage for the carrier. For customers it is usually not as important economic components of transportation other than price.

At the same time, customers primarily concerned with the characteristics of service quality and range of additional services provided by freight transport companies:

- speed of movement and safety of cargoes;
- timeliness and flexibility of service conditions;
- information support and maintenance services;
- provision of such services as customs clearance, temporary storage of cargoes etc;
- forwarding and cargo handling services.

2.4. Image components of the transport service producers in the transportation market

We should separately identify some image characteristics of the transport company's on freight transportation market, in particular:

- duration and work’s experience in the market;
- presence of large and well known corporate clients and the amount of their services;
- structure of the vehicle fleet (types, models of trucks, its age);
- staffing drivers, availability and feasibility of transport firm's own repair facilities.

Often for owner clients listed characteristics play a role commensurate with the cost and other technological conditions of transportations.

3. Features Practical Estimation of Transport Companies

Practical evaluation of the transport services quality, especially external (from other members of the transport market – customers, competitors, regulatory organizations), is faced with considerable difficulties in gathering accurate and complete source information. Its objectivity is the main basis for obtaining adequate and reliable results. However, we can see corporate secrecy, trade secrets, a small amount and unreliability of statistical data available for outside use. As result, it makes very difficult (and often, almost impossible) to use for the analysis the traditional, classical probability and statistical techniques and approaches. This situation requires the use fundamentally different modelling techniques.

3.1. The appropriateness and necessity of using fuzzy modelling

Obviously, that the competitive transport market, the interaction of producers and consumers of transport service contains a large amount of uncertainty of various actions and backgrounds.

Among them the uncertainty of nature, own market, demands, preferences and desires of clients, customers, actions of competitors, government agencies and other internal and external factors.

Under these conditions, one of the most efficient methods of modelling are presented hikes based on the theory of fuzzy sets using appropriate computer software.

3.2. Features and benefits of using the program fuzzyTECH for computer model's implementation.

In several previous papers of the authors [3–5] multi-criteria estimations of the transport service quality were calculated using fuzzy-set approach and its implementation in the software component Fuzzy Logic Toolbox from the MATLAB package.

However, this tool has some serious limitations, including:

- model can be only one-level and in case of tree-structure data transfer from lower to upper level could be achieved only by writing software code, but is impossible through operations in the user interface;
- for single-level model with the number of input variables more than three, there is excessive number of decision rules that clutters the model and makes the practical work with it very difficult;
- user can select only the standard membership functions of linguistic terms and fuzzy variables from the available limited list, but creation of own custom functions in arbitrary forms is provided that does not correspond with practical situations.

These drawbacks may be are overcome in professional fuzzy modelling package fuzzyTECH, which we have chosen for practical computer implementation of the problem.

4. Definition of the Integral Index of Customer Service Quality

Thus, aims of further study were to develop a practical computer model of multi-criteria assessment for transport service quality of freight customers in an environment of fuzzy modelling fuzzyTECH5.5. The article presents light variant of model with using a demo version of this program tool.

4.1. Taken into consideration the parameters of service quality and their characterization

As a result of holding and processing the results of experts' polls on several large transport enterprises in Kharkiv we have identified for further consideration and inclusion in the model the following parameters (their corresponding numbers are listed in Table 1):

- speed mode (2), time mode (3), route mode (1), which in common define intermediate parameter motion mode (14);
- number of road incidents (4), infringements of the traffic regulation – road rules (5), which in common define intermediate parameter road safety (15);
- time for truck's prepare to next trip – readiness (6), age of trucks (7), which together define intermediate parameter trucks (16);
- park power (9), park cover (8), which both define intermediate parameter park possibilities (17);
- client's claim (10), time delays (11), cargo maintenance (12), which together define intermediate parameter service level (20).

In turn, intermediate parameters (14 and 15) together with fuel expenses (13) define parameter trip style (18); (16 and 17) define parameter park (19).

At last, parameters (18, 19 and 20) define overall integrated, total estimation (21), and (18 with 19) provide for transport enterprise an internal estimation of its work's level (22). Graphic representation for relationships between input, intermediate and output parameters in the model is represented on Figure 1.

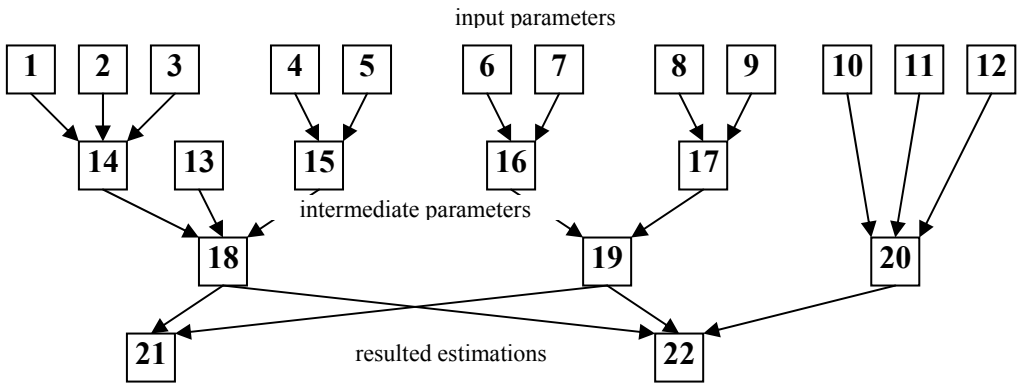


Figure 1. Relationships between input, intermediate and output parameters of trip quality model

Several of these parameters (2, 3, 4, 6, 10, 11, 12, 13, 14, 18) previously have been discussed in detail in [3]. Therefore, let's concern only some of the newly introduced parameters.

Route mode (1) characterizes the degree of deviation of truck's motion from the pre-planned and approved route. It is clear that the change of the route even though it may lead to faster delivery, but on the other hand it may interfere with the truck's weight and size requirements and restrictions, other terms and requirements of safety. And eventually the deviation from the route is an important factor in the reduction of transport safety.

Traffic rules violations (5), which fixed and recorded properly by police (road control, automobile inspection, service safety of the enterprise or by technical means of verification) drastically reduce the safety of transportation.

Age (7) for a single car and for the whole truck's park of transport firm is a serious parameter influencing on technical conditions of park, also it, in many respects, defines the image of carrier, transportation cost and safety, working conditions for drivers etc.

Coverage of orders (8) describes the ability of transport companies to cover peak for orders on transportation of constant clients.

Suppose, during 30 days with regular daily orders of various amount of transport there was required to provide 140 trucks. The carrier has provided 105, and then cover will be 75%. If total requirement was 80, but received was only 40 trucks – covering will be 50%.

Park power (9) is determined as the degree of satisfaction (by the carrier) of orders for transportation from regular clients during a certain period of time.

Let's assume that during the month (30 days), the carrier every day receives requirements of transport (a certain number of trucks) from the client. For example, if 15 requirements (from 30) were made in full (but other 15 – only partially), the power will be 50%. In the case of providing transport in full only for 10 requirements total capacity will be 33%.

4.2. Fuzzy formalization of quality parameters of transportation by membership functions and sets of linguistic variables

As mentioned above, as well as described in [6, 7], first step to develop a model must be formalize of the selections linguistic variables and corresponding membership functions. The corresponding numerical values were obtained from expert surveys and subsequent statistical analysis by the methods described in [7].

Without loss of generality and without compromising the reliability of the model, for its simplified representation in the paper, we will use the linear membership functions (triangular and trapezoidal).

Also, all linguistic variables will be represented by sets of three terms. Their characteristics are presented in Table 1, and process of their construction was described in detail in the works [3].

Now, consider a graphical representation of the input, output parameters and decision rules in the interface software fuzzyTECH5.5.

Graphical representation (kinds and views of membership functions) for input parameters (1–13) are shown on Figure 2, and for the output parameters of all levels are shown on Figure 3. At each of the drawings the picture of one of the options is given in an enlarged form.

It should be noted that given in the table (and reflected on the graphics) performances of variables can be changed directly in the graphical mode, moving the necessary points with the mouse on the relevant parts of the graph, or typed numeric values directly in the appropriate fields interface.

The next step to create a model is construction of fuzzy inference rules for all model variables and sets of their linguistic terms.

For each set of the „group of input variables – the output variable" we construct fuzzy inference rules (a decision on the estimation), similar to those was described in [3, 7]. It should be remembered that we must consider all possible combinations for values of linguistic variables of input parameters. And for each terms combination from this set it is necessary to determine corresponding term from output parameter.

Example of graphical representation of the rules for the input variables „park power" and „park cover" and the corresponding intermediate output variable „park possibilities" in the used package fuzzyTECH5.5 are shown on Figure 4.

Table 1. Characteristics of linguistic variables for the model parameters

№	Name of the parameters and levels	Unit of measurement	Terms of variables, values of membership function					
			Starting		Middle			Finishing
			Equal 1	Decrease from 1 to 0	Increase from 0 to 1	Equal 1	Decrease from 1 to 0	Increase from 0 to 1
1	Route mode (good fair poor)	%	0-10	10-30	15-30	30-35	35-45	40-55
2	Speed mode (good fair poor)	%	0-1	1-5	2-10	10-15	15-20	16-35
3	Time mode (good fair poor)	%	0-2	2-5	3-8	8-12	12-15	13-30
4	Road incident (few normal lot)	%	0-1	1-3	2-3,5	3,5-4	4-5	4-6
5	Road rule (few normal lot)	%	0-3	3-5	4-7	7-10	10-14	12-18
6	Readiness (high medium low)	day	0	0-2	1-4	4	4-5	4-8
7	Trucks age(small medium large)	year	0-1	1-3	2-3,5	3,5	4,5-5	4-7
8	Park cover (low medium high)	%	0-20	20-40	25-40	40-60	60-80	60-85
9	Park power (low medium high)	%	0-10	10-30	15-30	30-60	60-90	60-90
10	Claim (low medium high), number	%	0-2	2-3,5	2,5-7	7	7-10	8-15
11	Delay (low medium high), time	hour	0	0-1,5	1-2,5	2,5	2,5-4,5	3-6
12	Maintenance (low medium high), coast	%	0-1	1-3	2-5	5	5-8	7-10
13	Fuel expenses (normal medium high)	%	0-5	5-10	6-14	14-20	20-30	23-45
14	Motion mode (poor fair good)	point	0	0-5	2,5-5	5	5-7,5	5-10
15	Road safety (low medium high)	point	0	0-5	2,5-5	5	5-7,5	5-10
16	Trucks (satisfactory good excellent)	point	0	0-5	2,5-5	5	5-7,5	5-10
17	Park possibility (low medium high)	point	0-2,5	2,5-5	2,5-5	5	5-7,5	5-7,5
18	Trip style (poor fair good)	point	0	0-5	3-5	5	5-8	6-9,5
19	Park (insufficient medium enough)	point	0-2,5	2,5-5	2,5-5	5	5-7,5	5-7,5
20	Service level (low good excellent)	point	0-2,5	2,5-5	2,5-5	5	5-7,5	5-7,5
21	Work level (poor fair good)	point	0-25	25-50	25-50	50	50-75	50-75
22	Total estimation (low good excellent)	point	0-25	25-50	25-50	50	50-75	50-75

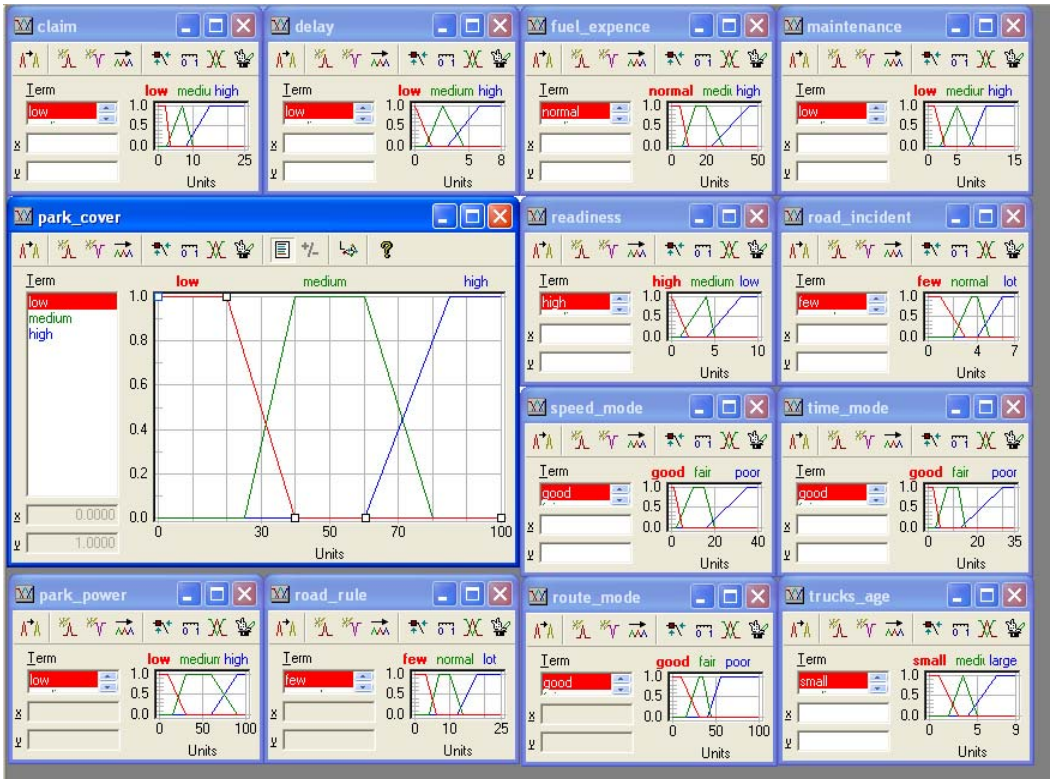


Figure 2. Computer representation of input variables of model

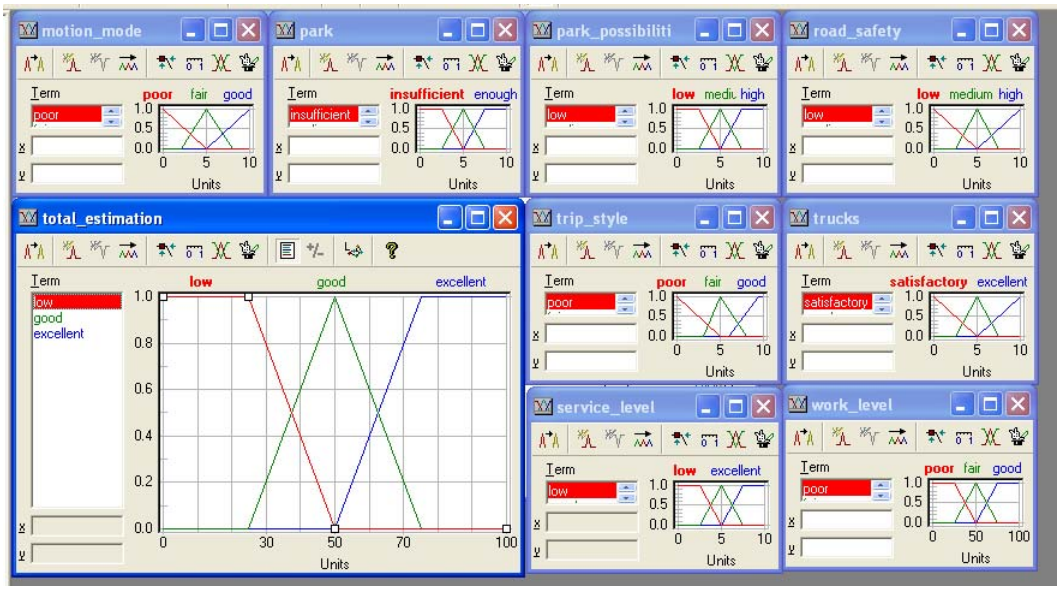
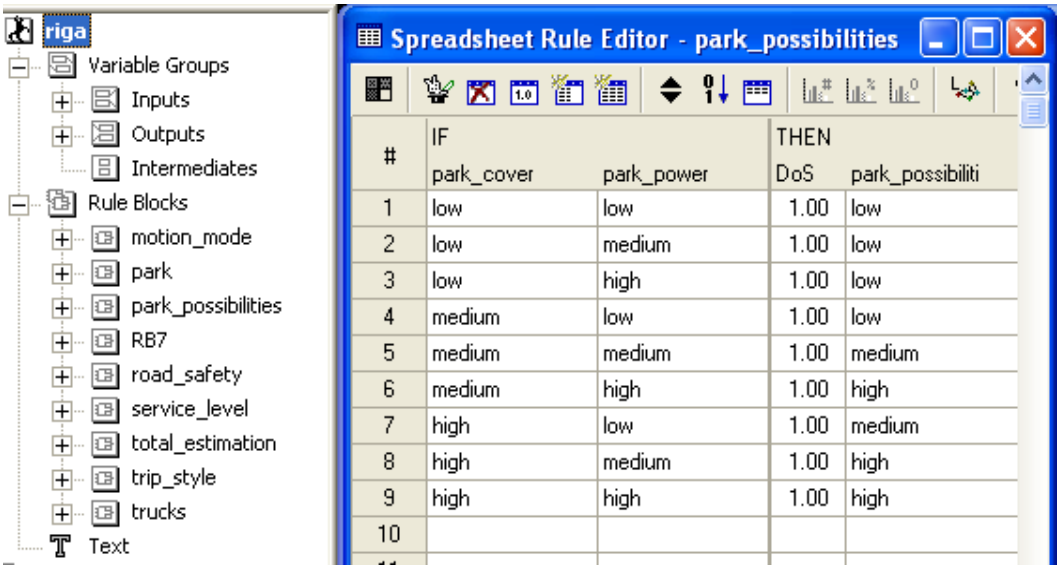


Figure 3. Computer representation of output variables of model

Parameter DoS (see Fig. 4) determines the relative weight for each of the rules (in this case they are the same weight) and can be changed by the user in the process of setting up a model. In our case, there are 9 of these units make decisions.



#	IF park_cover	IF park_power	THEN DoS	THEN park_possibiliti
1	low	low	1.00	low
2	low	medium	1.00	low
3	low	high	1.00	low
4	medium	low	1.00	low
5	medium	medium	1.00	medium
6	medium	high	1.00	high
7	high	low	1.00	medium
8	high	medium	1.00	high
9	high	high	1.00	high
10				

Figure 4. Set of decision making rules for input variables park cover, park power and output variable park possibilities

4.3. The resulting computer model of the problem, making calculations and analysis of its

The general form of a computer model of the problem, in particular, the causal interaction of input, intermediate and output variables in the environment of the fuzzy modelling fuzzyTECH5.5 presented on Figure 5. Clicking on each element of the structure (that take access to corresponding parameters) allows opening the appropriate box and changing the necessary characteristics of the selected variable and the rules of decision-making assessment.

After a description of all variables and entering of all the fuzzy rules all input data and calculation results are displayed in the interactive debug calculation's window which is shown on Figure 6.

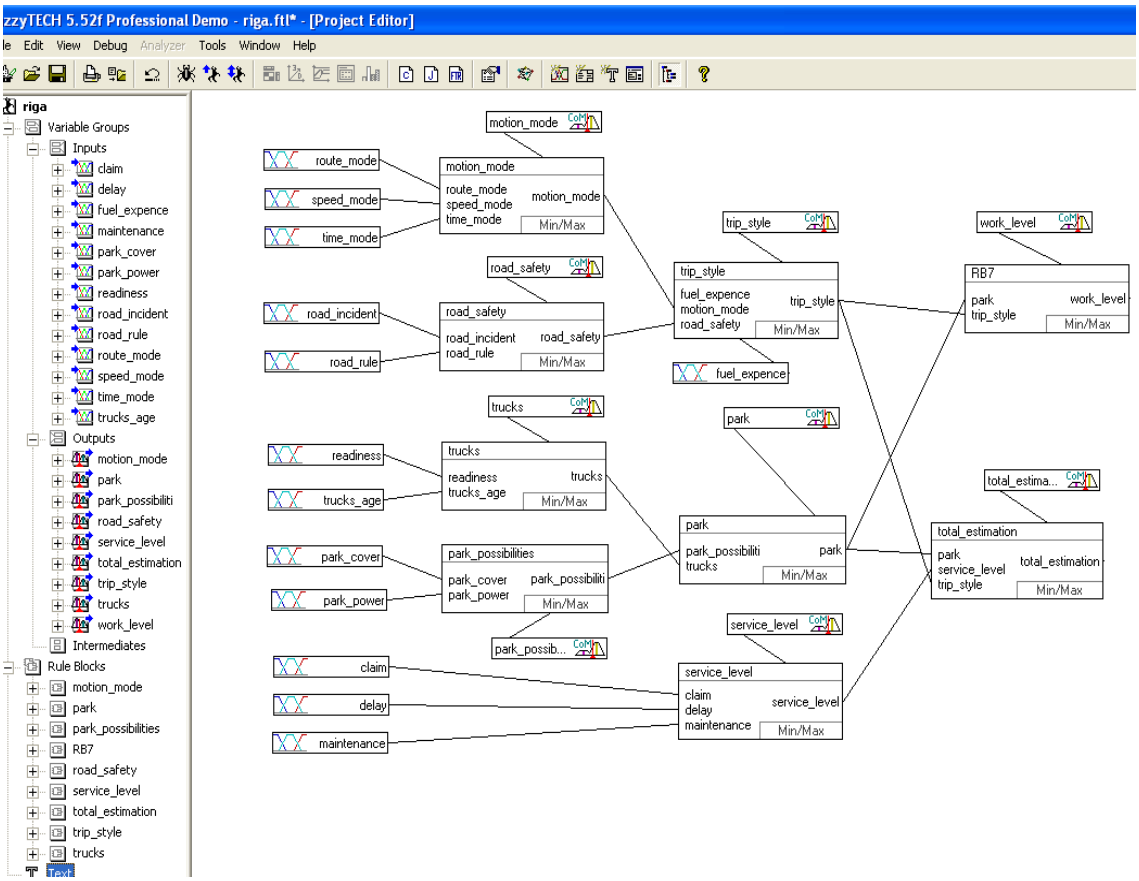


Figure 5. General computer model

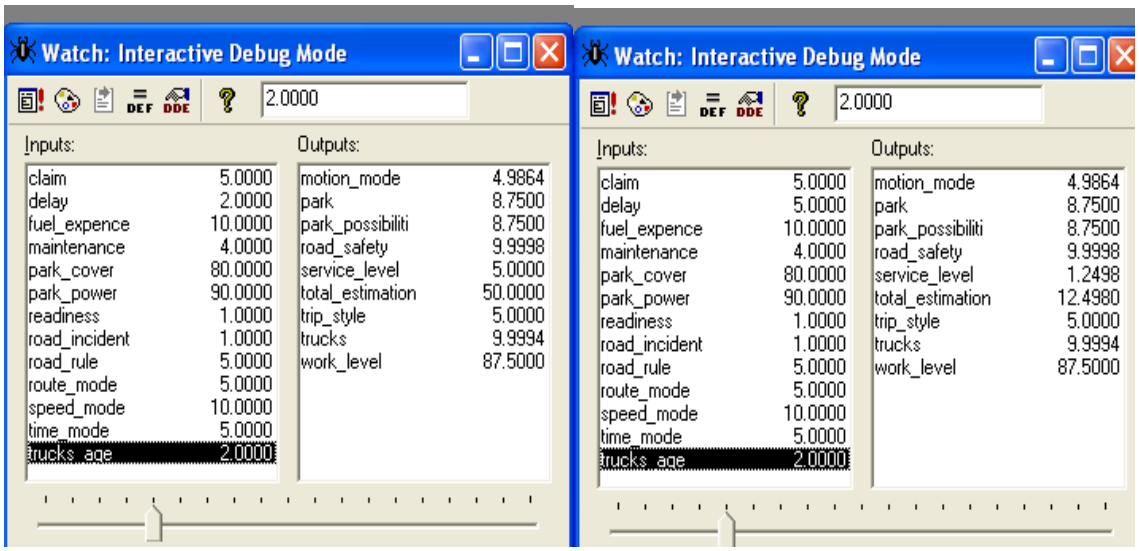


Figure 6. Interactive debug calculation's window

The Figure 6, as an example, shows two screenshots of interactive recalculation windows. In each of them (in the process of work within the program) the user enters (on the left) the numerical values (evaluation) of input parameters and (on the right)) program displays the results of calculations for all output parameters (intermediate and final).

These screenshots differ only in the numerical values of the parameter „delay" (for left – 2 hours, for right – 5 hours). The result is an overall assessment of quality of transportation („total estimation")

varies from 50 points (left) to 13 points (right), which is caused almost unacceptable value „delay" (it is very important for the recipient of transport services) in the second case.

At the same time, the characteristic „work level", which is an internal generalizing measure of the technological side of work for the transport company has 87 points and not changed (for other parameters remaining constant, of course).

A described window (see Fig. 6) enables modelling the general level of transportation, changing some or all input parameters and analysing the results. In the same purposes can be used the surfaces of interdependence between parameters, one of which is shown on Figure 6.

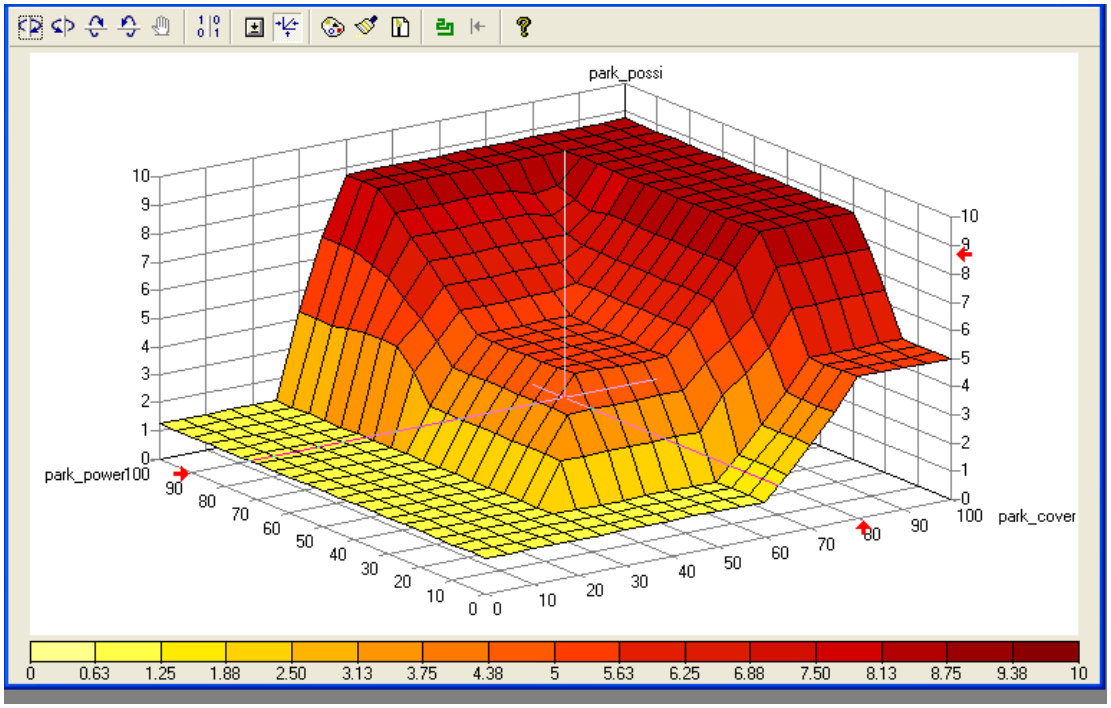


Figure 7. Surface of dependence between park power, park power and resulting park possibility

A more detailed analysis of the direct numerical simulation in the already constructed model is the subject of our further research. We assume, in particular, to consider (the list is not exhaustive and closed) issues such as:

- practical construction of membership functions based on statistical analysis of expert interviews;
- use of more complicated form of membership functions, including custom's (no standard);
- different forms of representation of the resulting data in fuzzyTECH5.5 package and they provide opportunities for analysis;
- opportunities for learning and adjustment of the constructed system of fuzzy inference using neural networks;
- increasing the number of initial parameters in the model;
- expert determination of weights of parameters;
- development of the model to using of different values of the weights for the various initial, intermediate parameters and the relevant rules of decision-making;
- the creation of executable modules (not requiring from the end user to have the program fuzzyTECH5.5) by compiling a model from fuzzyTECH5.5 to the C programming language, and then into an executable code.

The obtained results will be presented in detail in the following publications.

5. Conclusions

Thus, has been developed a multi-criteria model for evaluate the quality of freight transportation. Theoretical basis for constructing the model was the fuzzy set theory and practical tool for the creation was special fuzzyTECH5.5 software. Model is sufficiently substantiated and reliable. It takes into account

a significant number of quality parameters of freight services, and take possibilities to create and use these parameters with corresponding decision rules for generalizing estimates.

User can submit and save the results in a clear, understandable and suitable for further analysis form, and can perform calculations interactively. Using this model, management of transport enterprises and consumers of transport services can efficiently control the quality of transportation, the level of transport and associated services, which are very important tasks in market conditions.

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