International Journal of Engineering Research and Application www.ijera.com ISSN : 2248-9622, Vol. 6, Issue 6, (Part -6) June 2016, pp.75-84

RESEARCH ARTICLE OPEN ACCESS

Dimensioning of Transport Capacities in Railway Freight Transport by Using Fuzzy Logics Model

Madan Mohan Sahu[1],P Paulpandian[2], Manas Kumar Samantaray[3]

[1,3]Assistant Professor, Department of Mechanical Engineering, Gandhi Institute For Technology (GIFT), Bhubaneswar

[2] Assistant Professor, Department of Mechanical Engineering, Gandhi Engineering College, Bhubaneswar

ABSTRACT: As any transportation system, the railway system is based on significant capital and is an important national and economic potential. In same time the economy and society need to enable efficient, massive, environmen- tally friendly, fast and quality transport. On the other hand, is engaging directly and indirectly a significant part of the work force in a society and an important part of national resources. Therefore, the transport by rail must be cost effec- tive, operationally flexible and followed by reliable and high quality service in order to make the balance of the re- quirements that arises during the planning of transportation facilities and the opportunities which are determined by the capacities. The available capacity of the rail freight and the market demand are determining their planning and alloca- tion. The planning and allocation is a very complex process that directly affects the efficiency and effectiveness of the rail transport, and by that, the efficiency and effectiveness of the economy. Worldwide, despite the analytical and graphical methods, different models based on queuing theory, special mathematical and statistical models as inputs are using statistics. Within this paper in order to achieve the objective, which is efficient and effective operation of the railway system, through proper planning of the capacities, a fuzzy model was designed based on the theory of artificial intelligence, such as Model for dimensioning capacities in freight transport by using Fuzzy Logic (FL). Produced model will alow delivering operational (capacity planning by demand for transport market) and strategic decisions (predicting demand for transporting facilities in the future). The testing of the models is applied to the example of Macedonian Railway Transport JSC (MRTJSC) railway operator which core business is the transportation of passengers and goods in domestic and international markets.

Key words: modeling; dimensioning; railway freight wagons; fuzzy logic

I. INTRODUCTION

The railway system with its huge capital is a significant national and economic potential, which needs to enable efficient, massive, environmentally friendly, fast and quality transport to the economy and to the citizens. On the other hand, engage di- rectly and indirectly a significant part of the work force in a society and an important part of national resources. Therefore, transport by rail must be cost effective, operationally flexible and followed by re- liable and high quality service in order to make the balance of the requirements which are arising in the process of planning of transportation facilities which are directly determined by the capacities.

The transport capacites of the railway under- taking mostly are planned based on intuition, based on partial facts relating to the prospects of transport in the future, based on industry trends and based on partly outdated analytical methods which are less used in the process of planning capacities.

Since all systems cannot be modeled based on statistical data, the use of modern techniques for definition of specific inputs is increasing. The the- ory of artificial intelligence is most applied. Some of the techniques which are used are the techniques of Fuzzy logic, Neural networks, Swarm intelli- gence (ant colony, bee colony), CBR [1].

There is lack of established models which can enable efficient, effective and technologically opti- mal allocation of limited transportation facilities and resources in the everyday functioning of a com- pany that deals with rail transport, but also for those companies who rent capacity of railway undertak- ings. The establishment of that kind of model would allow better financial and economic functioning of the companies and would improve the services of- fered to the market.

Rail transport is part of the logistics chain, and therefore part of the complete logistic service. This means that the implementation of a high quality model for planning and allocation of the capacites in the rail transport can directly affect the perfor- mance and the logistics chain as a whole.

The rail freight transport and market demand of rail transport services are determining the plan- ning and allocation of available capacities. The planning and allocation is a very complex process that directly affects the efficiency and effectiveness of rail transport, and thus the efficiency and effec- tiveness of the economy. On the one hand, insuffi- cient capacity of rail transport may affect the choice of transport modality, or ultimately the inefficiency of the economy, and on the other hand the oversized and irregularly structured facilities affect the effi- ciency and effectiveness of the railway undertaking (loss of transport, costs of "tied" capital, mainte- nance, loans, etc.).

The scope and the structure of the capacity in- crease the complexity in the planning process. The market claims which from day to day are more dif- ferent and more specific in terms of the types of cargo that would be transport, also affect the plan- ing. Although the opinion that the use of unified transport units would reduce the problem complex- ity of planning capacity is increasingly govern, yet that such transport units can not fully meet the vari- ous requirements of the economy. Until the man and his uniqueness are existing, there will be different requirements for different types of products with different sizes, color, conditions, types, etc., there- fore the need for different types of vehicles.

According to the previous in terms of exploi- tation of the capacity in rail transport, the problem of (un)rational exploitation is identified exactly and the need to be solved by quantitative and qualitative planning and determination (dimensioning) is fore- seen.

II. RESEARCH OBJECTIVE

In order to provide the needed level of quality of transport services in rail transport, it is necessary to determine the necessary facilities and to set the correct organization. This means, above all that it is necessary to know what transport facilities are needed what kind of capcaities for which types of goods as the way of organizing transport etc. will beapplied. These are a basic prerequisite for the ra- tional use of vehicles. While forecasts and decisions relating to the future are high risk despite its large number of possible detailed data analyzis, that can be made from the previous period in terms of plan- ning and use of the structure and size of transport facilities.

An important element in decision making and planning is choosing [2], and the decision is a choice of one share of the group of available alternateves [3]. The decision must be operational, tactical and strategic.

There are also cases when the problem can not be solved by analytical way or that solution is too complex. In those cases, different techniques of simulation can be used.

Considering the types and amount of infor- mation on which a decision for the allocation of ca- pacity should be reached, their mutual incorsistancy and comparison, then it is the model that would al- low dimensioning to be based on the application of mathematical methods and techniques. This model should take into account the availability of capacity and market demand for a solution that will enable the adoption of correct and incorrect decisions.

III. PREVIOUS RESEARCH

The transport capacity of the railway systems is directly proportional to the volume and structure of available vehicles. For successful management of the rail transport service, the securing enough rail vehicles it is needed, which structure must suit the type of goods intend to be transported. When it comes to rail transport, this issue is not sufficiently processed in the scientific and professional litera- ture. As a result there is an established and widely used scientific method for dimensioning the trans- port capacity of the railway traffic based on multi- dimensional involving multiple factors that deter- mine the real needs and capacities which enable ef- ficient and effective rail transport.

Specific planning and design capacity in the rail transport in the available literature can find a limited number of models, but some of them will be presented.

Authors Etezadi and Beasley studied the prob- lem of determining the optimal structure of the fleet and its optimal size [4]. Given that the decision of these tasks is the long term, they have presented a model that is based on integer linear programming. In the same paper the authors suggest that the prob- lem may more accurately be solved by using simu- lation.

One of the first papers concerning the sizing of the fleet but in the maritime sector is published in 1954 by the authors Dantzig and Fulkerson [5]. They have presented the problem of determining the minimum number of tankers to carry out the timeta- ble. While Kirby [6] in 1959 had one of the first at- tempts concerning optimization of the fleet of the railways. He deals with the problem of increasing the degree of utilization of wagons owned by the small rail system and reduces the level of rental cars by determining the relative cost of own and leased cars per day.

Bojović and other authors [7] in 2010 worked out the problem of determining the optimal compo- sition of the freight wagon fleet. The problem is di- vided into two parts, determining the optimal mix and determine the optimum size of freight wagon fleet. The first part is processed through the method multicriteria decisioning and solves the application of Fuzzy-analytical hierarchical process. The solu- tion of this section consists of the most appropriate types of wagons for the carriage of goods. The sec- ond part of the solution to the problem of the size of the fleet is obtained through model Fuzzy multiple- layer linear programming. Same author [8] in 2002 addressed the problem of optimizing the size of the fleet through meeting demand and minimize the to- tal cost.

Lima and other authors [9] in 2004 have des- cribed a mathematical algorithm to solve the prob- lem. This algorithm is a hybrid of genetic algorithm and local search based on GENIUS algorithm.

Wu and other authors [10] in 2005 addressed the problem of dimensioning fleet in road traffic. Operational and tactical decisions for heterogene- ous fleet explicitly designed by the model of linear programming in order to determine the optimal size and mix of the fleet. Demand is assumed as known while travel time is stochastic parameter.

Choi and Tcha [11] in 2007 represent approach based on generating columns to resolve the prob- lem. The authors propose an integer programming model whose LP relaxation is dealt with the method of generating columns.

Song and Earl [12] in 2008 represent an inte- grated model for determining the optimal manage- ment policy of the allocation of empty wagons and sizing the fleet in the system comprising two depots. The times of arrival of the vehicles and the times of travel of empty wagons accepted as stochastic vari- ables. Under this approach the optimal strategy for allocating vehicles in homogenous fleet is based on the management of the limits in terms of minimizing the expected discount cost consisting of the cost of maintenance, rent and moving vehicles in an empty condition.

Sayarshad and Ghoseiri [13] in 2009 suggested the formulation and procedure for solving optimiza- tion of fleet size and allocation of wagons with de- mand and travel times for freight wagons being treated as deterministic. The authors assume that un- fulfilled demand becomes zero at the end of the planning period. The calculation tests on small ex- amples can be solved with an exact procedure for a short period of getting results, while for medium and large instances this is not possible. For this rea- son these authors propose an algorithm of simulated problem solving.

Sayarshad and other authors [14] in 2010 pro- posed formulation and procedure for solving opti- mization size of freight wagon fleet and allocation of wagons for the case of stochastic demand. The authors propose a two-phase procedure based on the algorithm of simulated problem solving.

Loxton and other authors [15] in 2012 have considered the problem of forming a heterogeneous fleet with the presence of stochastic demand. The problem is based on determining the number of ve- hicles to be purchased for each type of vehicle spe- cifically so that the total expected cost of the fleet to be set to minimum. These authors developed an al- gorithm that combines the dynamic programming method and the golden section to resolve the prob- lem.

Models of optimization based on the behavior of swarms (colonies) named by Teodorović "swarm intelligence" is partly inspired by the behavior of ants and bees in nature. They solve problems of combinatorial organization. It is a problem that oc- curs in the dimensioning of capacity in railway transport [16].

Overall the models pertaining for sizing and planning of transport facilities in railway transport newer generation are related to the analysis and de- termination of transport capacity on the basis of his- torical data and predict future needs. Based on that information, a model that can provide facilities that will satisfy the needs of the company and customers is defined. It is therefore necessary to take into ac- count factors such as: types of facilities, types of goods, industry trends, uses of facilities, costs etc.

The model should be able to include more fac- tors commonly with different sizes and values. To avoid mixing of different sizes and values or the lin- guistic variables as the most appropriate method that can measure and compare differences represent

the method of artificial intelligence – "Fuzzy logics" (fuzzy logic). This method allows measuring, com- paring and synthetizing different variables that are hard to be quantified to carry more qualitative fea- tures, as well as simplifying the uncertainty regard- ing the input data and parameters in terms of uncer- tainty, subjectivity, inaccuracy and ambiguity.

1. FUZZY LOGICS

Fuzzy sets, as an entirely new concept, defined in 1965 (Lotfi Zadeh,) were introduced with the main objective of formalized mathematical way to present and modeled uncertainty in linguistics.

Great application of fuzzy logic (FL) is found in the situations where there is an adequate mathe- matical model for display in a complex process that is necessary to use the knowledge of experts. By us- ing different modeling techniques based on fuzzy logic allows solving a wide range of problems and enables making the right conclusions. Fuzzy logic uses the experience of experts in the form of linguis- tic rules and mechanism of aproximative reasoning can give an appropriate decision on a particular case.

Fuzzy logic has occurred as a result of trying to model human thinking, experience and intuition in the process of making decisions based on inaccu- rate data. Suitable for expressing uncertainty, appli- cation of fuzzy logic proved excellent in those mod- els in which intuition and assessment are the pri- mary elements.

It is important to recognize that the essence of fuzzy logic is quite different from the essence of classical logic that strengthened since Aristotle. Conventional logic is based on clear and precise rules established and is based on the theory of sets, a respective element can belong or not to belong to a specific group (set). If it mathematically present, then the degree of belonging to that element is 1 if it belongs to a set, or 0 if it does not belong to the set.

2. MODEL FOR DIMENSIONING CAPACITIES IN FREIGHT TRANSPORT USING FUZZY LOGIC

The main problem in the process of forming the model by applying fuzzy logic to the transport capacity dimensioning is based on determining the fuzzy rules and parameters of membership func- tions. For defining the rules have been used data ob- tained by polling experts for rail transport. Knowledge of experts in the process of determining

the type, the amount of transport capacity is ex- pressed by a number of linguistic variables.

The choice of the type and the parameters of the function of belonging is implemented on the ba- sis of the positive experiences of certain authors and subjective estimates of the authors. With literature review, it was determined that the application of the origin function with Gaussian shape achieves ut- most precision outputs. Therefore, in this model this type of curve is generated. Its parameters are deter- mined on the basis of subjective evaluation. The in- terval of size of the input and output variables are defined on the basis of the amounts of real values within the system Macedonian Railways Transport JSC (MRTJSC). Only the values of the turnover of cars, and the level of immobilization of the same where not taken into account. These two criteria for each series and subseries of wagons have a different value of these two criteria and affect only the in- crease in capacity needs from the specified series of wagons.

The model is based on a system of Mamdani fuzzy logic and min-max method of direct locking,

while for the process of defuzzification the method of centroids was applied. The model has been tested for the most common series and subseries of freight wagons in groups (open, closed, plateau and spe- cial) that are obtained on the basis of a matrix con- sisting of correspondence "type of goods - type of wagon" of Macedonian Railways Transport JSC. The observed series and subseries in groups of wag- ons are typical in other major rail carriers (17).

3. ASE STUDY: FUZZY MODEL FOR DIMENSIONING A GROUP OF OPEN FREIGHT WAGONS AS TRANSPORT CAPACITIES (MODEL FL)

The fuzzy model for dimensioning the group of open wagons (Eas, Eanos, Fad) has five input variables: coal / lignite, ores of nonferrous metals, wood, scrap metal and ballast. Each variable fuzzy model has three linguistic values. Also the output variables for each series of open wagons has three values (Figure 1).

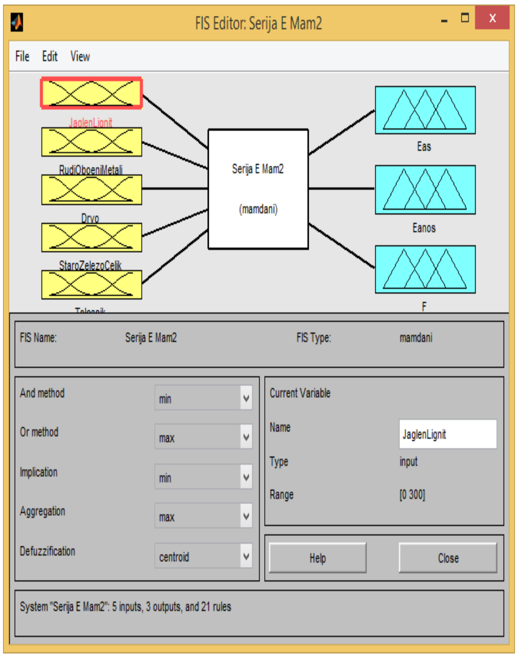


Fig. 1. Fuzzy system FL for dimensioning of open wagons of series Eas, Eanos and F

International Journal of Engineering Research and Application *www.ijera.com ISSN : 2248-9622, Vol. 6, Issue 6, (Part -6) June 2016, pp.75-84*

The input variable coal / lignite has the follow- ing values: a small amount of coal (MKJ), medium amount of coal (SKJ) and a large amount of coal (GKJ). The values of the input variables relating to ores of non-ferrous materials are presented as: a small amount of ore (MKR), medium amount of ore (SKR) and a large amount of ore (GKR). When questioned variables relating to wood as a commod- ity, they have the following linguistic values: a small amount of wood (MKD), medium amount of wood (SKD) and a large amount of wood (GKD). The same goes for scrap metal and ballast: a small quantity of scrap iron (MKS), medium amount of scrap metal (SKS) and a large amount of scrap metal(GKS), and a small amount of ballast (MKT), me- dium amount of ballast (SKT) and a large amount of ballast (GKT).

With the fuzzyfication of the actual values that over the last five years occurred annually, are re- Membership functions of the input variables to the tree 1000 tons are defined by the following pa- rameters: MKD [10 –5 10 5], SKD [10 45 10 55] and GKD [10 95 10 105] for x ε [0, 100] (Figure 2c):□(x□5)2 flected in the membership functions in the following intervals (in 1000 tons) of coal / lignite [0 – 300], ores of nonferrous metals [0 – 700], wood [0 – 100],

The input and output variables have Gaussian membership functions defined as:

$$\mu_A(x) = e^{\frac{-(x-c)^2}{2\sigma^2}} \qquad (1.1)$$

The Gaussian stage number is described with two parameters $A = (\sigma, c)$. The first number repre- sents the left and right distribution bell curve length of both the abscissa and the second number repre- sents the value at which the Gaussian curve has a value of 1 on the abscissa. While the bell curve com- bined with dual center is described by four numbers and in which the first two are describing the left side of the function and the other two right side of the function.

Functions belonging to fuzzy input variables coal and lignite in 1000 tonnes are defined by the following parameters: MKJ [50 – 15 50 15], SKJ [50 125 50 175] and GKJ [50 285 50 315] for x ε [0, 300] (Figure 2a).

$$\mu_{MKJ}(x) = e^{\frac{-(x-15)^2}{5000}}$$

$$\mu_{SKJ}(x) = e^{\frac{-(x-125)^2}{5000}}$$

$$\mu_{GKJ}(x) = e^{\frac{-(x-285)^2}{5000}} \qquad (1.2)$$

Membership functions of the fuzzy input vari- ables ore for ferrous metals in 1000 tonnes are de- fined by the following parameters: MKR [100 –35 100 35], SKR [100, 315, 100, 385] and GKR [100,

$$\mu_{MKD}(x) = e^{\frac{-(x-5)^2}{200}}$$

$$\mu_{SKD}(x) = e^{\frac{-(x-45)^2}{200}}$$

$$\mu_{GKD}(x) = e^{\frac{-(x-95)^2}{200}} \qquad (1.4)$$

The functions of belonging of the input varia- bles for scrap in 1000 tonnes are defined by the fol- lowing parameters: MKS [10 –5 10 5], SKS [10 45 10 55], GKS [10 95 10 105] for x ε [0, 100] (Figure 2d):

$$\mu_{MKS}(x) = e^{\frac{-(x-5)^2}{200}}$$

$$\mu_{SKS}(x) = e^{\frac{-(x-45)^2}{200}}$$

$$\mu_{GKS}(x) = e^{\frac{-(x-95)^2}{200}} \qquad (1.5)$$

GKS

The functions of the input variables belonging to ballast in 1000 tonnes is defined by the following parameters: MKT [10 –5 10 5], SKT [10 45 10 55], GKT [10 95 10 105] for x ε [0, 100] (Figure 2e):

$$\mu_{MKS}(x) = e^{\frac{-(x-5)^2}{200}}$$

$$\mu_{SKS}(x) = e^{\frac{-(x-45)^2}{200}}$$

$$\mu_{GKS}(x) = e^{\frac{-(x-95)^2}{200}} \qquad (1.6)$$

The functions of the output variables belonging to the series Eas, the amount of car, are defined by the following parameters: MKEas [9 3 9 –3], SKEas [9 9 23 28], GKEas [9 9 48 53] for x ε [0, 50] (Figure 2 f):

$$\mu_{MKEas}(x) = e^{\frac{-(x-3)^2}{162}}$$

665, 100, 735] for x ε [0, 700] (Figure 2b):

$$\mu_{MKR}(x) = e^{\frac{-(x-35)^2}{20000}}$$

$$\mu_{SKR}(x) = e^{\frac{-(x-315)^2}{20000}}$$

$$\mu_{GKR}(x) = e^{\frac{-(x-665)^2}{20000}} \qquad (1.3)$$

$$\mu_{MKEanos}(x) = e^{\frac{-(x-3)^2}{162}}$$

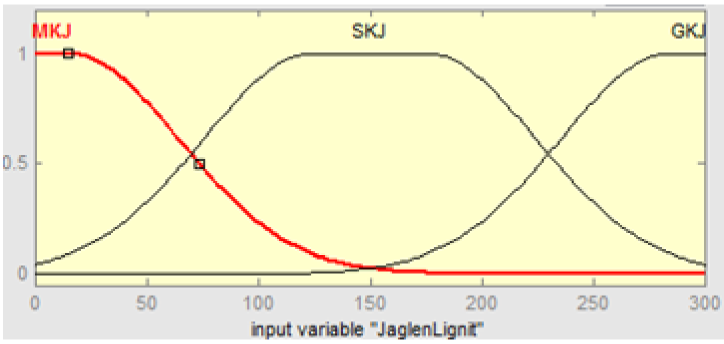
$$\mu_{SKEanos}(x) = e^{\frac{-(x-23)^2}{162}}$$

$$\mu_{GKEanos}(x) = e^{\frac{-(x-48)^2}{162}} \qquad (1.8)$$

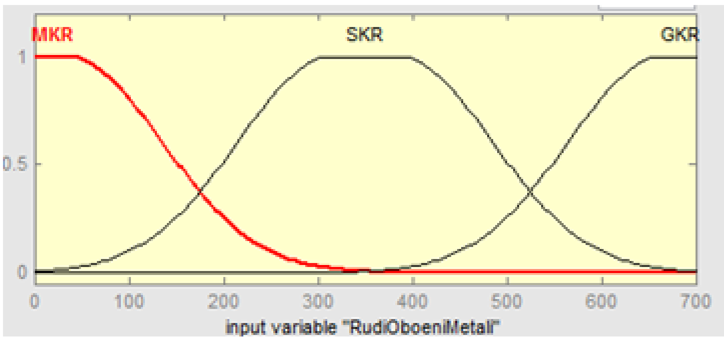
The functions of the output variables belong- ing to the series F, the amount of car, are defined by the following parameters: MKF [9 3 9 –3], SKF [9 9 23 28], GKF [9 9 48 53] for x ε [0, 50] (Figure 2h):

$\mu_{GKF}(x) = e$ ... (1.9)

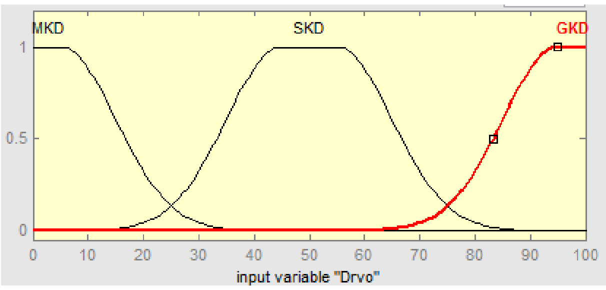
On Figure 3. the presented graph is for output variables for different batches of wagons depending on the input variables.



a)

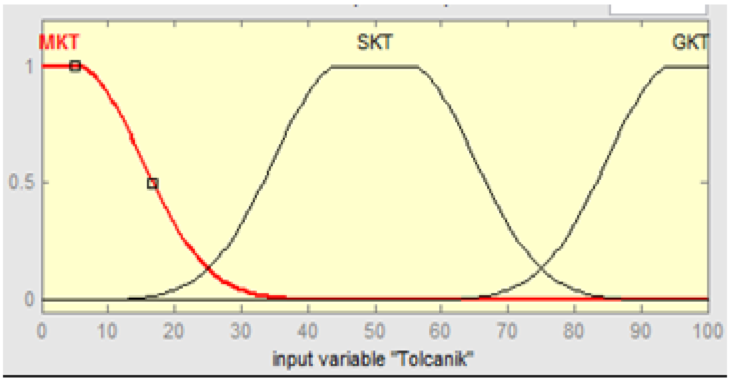


b)

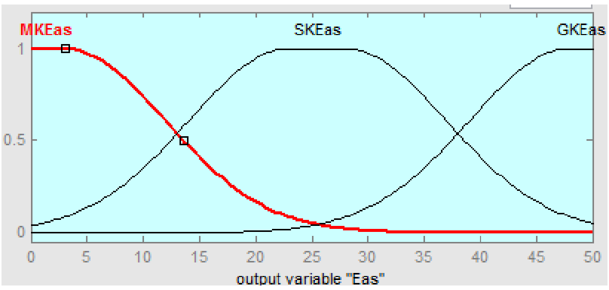


c)

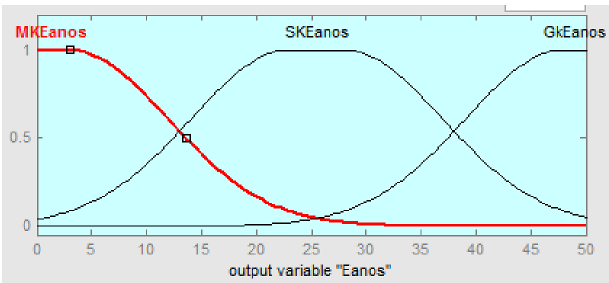
On Figure 3. the presented graph is for output variables for different batches of wagons depending on the input variables.



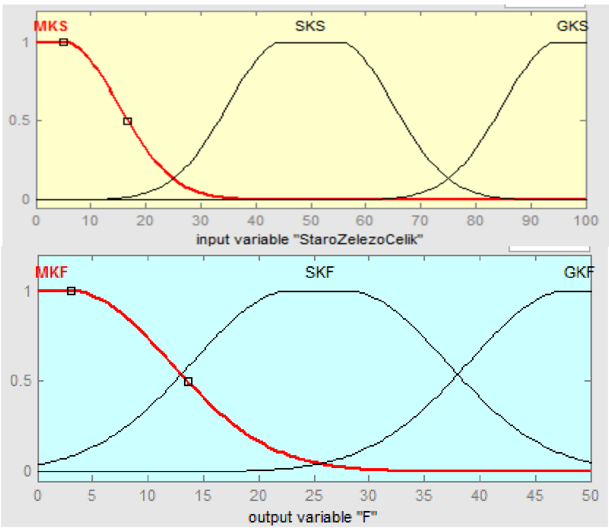
e)



f)



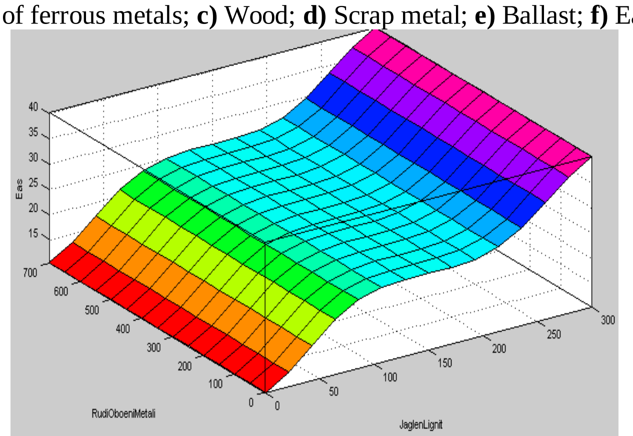
g)



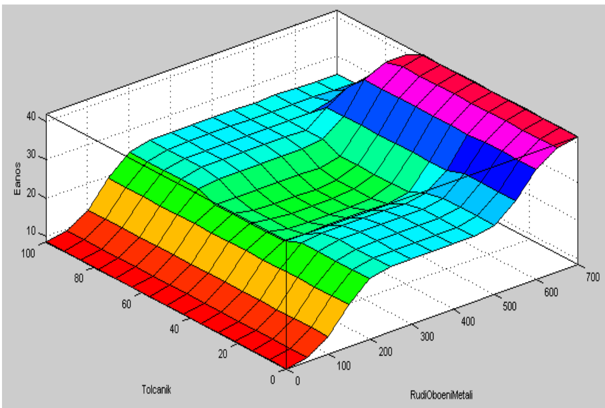
d) h)

Fig. 2. Membership functions of fuzzy sets:

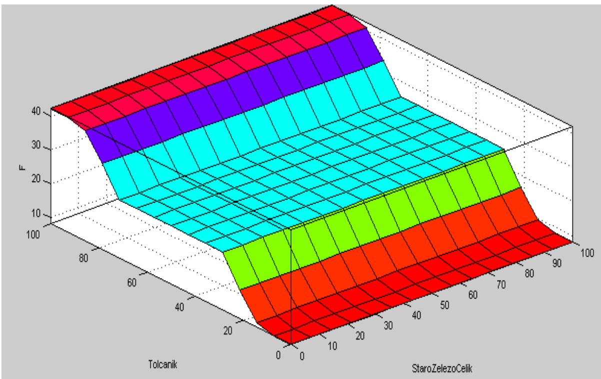
a) Coal / lignite; **b)** Ores of ferrous metals; **c)** Wood; **d)** Scrap metal; **e)** Ballast; **f)** Eas; **g)** Eanos; **h)** F



a)



b)



c)

Fig. 3. Graphic display of output variables for transport capacities as an open group of wagons depending on: **a)** Ores of colored metals and coal for Eas; **b)** Ballast, ores and non-ferrous metals for Eanos; **c)** Ballast and scrap for F

IV. ANALYSIS OF MODEL TESTING RESULTS

The FL model for open group of wagons has been tested on 10 samples (10 monthly data) from the statistical report of MRTJSC as known input values. Big difference between the results of oper- ating decisions and results obtained with FL model can be noticed.

The analysis of the validity of the model FL results for group of open wagons is runed on the ba- sis of the average relative error of the results in com- parison with the actual results from the real system. Based on the testing of 10 samples of data from sta- tistics of MRJSC obtained average relative error for Eas wagons is 39.5%, for Eanos wagons is 27.8%, while the F wagons 5.8%. Based on this analysis we can conclude that the expert system for dimension- ing of capacity using fuzzy logic shows significant statistical error that can not be rejected.

T a b l e 1 Sensitivity analysis of the fuzzy model FL for group of open wagons (17)

	FL		
	Membership function		
	Triangular	Trapezoidal	Bell
	19	16	13
	14	9	9
Eas	22	20	19
	22	19	19
	21	12	20
	12	8	10
	9	8	9
Eanos	9	8	9
	9	8	9
	10	8	9
	9	8	8
	9	8	8
Fad	9	8	8
	9	8	8
	9	8	8

SENSITIVITY ANALYSIS OF MODELS FL One of the basic requirements in the modeling process is achieving satisfactory sensitivity of the model. This means that during small changes in in- put variables, the output of the model must also have a small change of values. It is common procedure for verification of the models.

Sensitivity analysis of the expert system using fuzzy pattern FL is conducted by changing the shapes of membership functions of input and output variables (Table 1). Instead Gaussian curve which is applied to the base model, now triangular, trapezoi- dal and bell curve were tested. The analysis method used "prod" (product of array elements) operator and method "probor" (probably) for the operator "or". The sensitivity analysis model at this point is shown for two series and subseries of the group of open wagons.

V. CONCLUSION

The FL model for all groups of wagons was tested comparing to the statistical reports of MRTJSC, for which a significant difference be- tween the results of operating decisions and results obtained with FL model was noticed.

Analysis of the results in the process of verifi- cation and validation of the model FL for all groups of wagons regarding the higher relative error of the results obtained from the results of the real system derived from the data of MRTJSC often shows a significant statistical error that cannot be rejected. However, also noteworthy is that the application of this model gives satisfactory results when it comes to modeling and design of facilities where there is no historical data or has a very small base. In this case, the application of fuzzy logic provides very satisfactory results.

The analysis of the sensitivity of the defined expert system of the fuzzy model (FL), was carried out by changing the shapes of the membership func- tions of input and output variables. The obtained re- sults were with the same or similar values with neg- ligible differences and show that expert model was shaped as it was expected.

The FL model showed it is more appropriate for the planning of transport facilities for new types of transport, where there are no historical data based on which the model can be based.

REFERENCE

[1]. Kennedy J., Eberhart R. C., Shi Y. (2001): Swarm Intelli- gence. San Francisco, Morgan Kaufmann Publishers.

[2]. Kickert W. J. M. (1980): Organization of Decision-Making (A system-Theoretical Approach). Amsterdam, North Holland Publishing Company.

[3]. Etezadi T., Beasley J. E. (1957): Vehicle fleet composition. Baltimore, Journal of Operational Research Society of America.

[4]. Dantzig G. B., Fulkerson D. R. (1954): Minimizing the number of tankers to meet fixed schedule, 3, Naval Research Logistics Quarterly, Vol. **1**.

[5]. Kiby D. (1959): Is your fleet the right size? Operational Research Quarterly,. Vol. **10**.

[6]. Bojović N., Bošković B., Milenković M., Sunjić Ć. (2010): A two-level approach the problem of rail freight car fleet composition, Transport, Vol. **25**.

[7]. Bojović N. (2002): A general theory approach to rail freight car fleet sizing, European Journal of Operational Research, Vol. **136**.

[8]. Lima C. M. R., Goldbarg M. C., Goldbarg E. F. G. (2004): A memetic algorithm for the heterogeneus fleet vehicle routing problem, Electronic Notes in Discrete Mathema- tics, **18**, pp. 171–176.

[9]. Wu P., Hartman J., Wilson G. (2005): An integreated model and solution approach for fleet sizing with hetero- geneous assets, Transportation Science, **39** (1), pp 87–103.

[10]. Choi E., Tcha D-W. (2007): A column generation approach to the hetereogeneous fleet vehicle routing problem, Journal Computers and Operations Research, **34** (7). pp. 2080–2095.

[11]. Song D. P., Earl C. F. (2008): Optimal empty vehicle epositioning and fleet-sizing for two-depot service systems. European Journal of Operational Research **185** (2)., pp. 760–777.

[12]. Sayarshad H. R., Ghoseiri K. (2009): A simulated annealing approach for the multi periodic railcar fleet sizing problem, Computers and Operations Research, **36** (6), pp. 1789–1799.

[13]. Sayarshad H. R., Javadian N., Tavakkoli-Moghaddam R., Forghani N. (2010): Solving multi-objective optimization formulation for fleet planning in ra railway industry, Annals of Operational Research **181,** pp. 185–197.

[14]. Loxton R., Lin Q., Teo K. L. (2012): A stochastic fleet composition problem, Computers & Operations Research, **39** (12), pp. 3177–3184.

[15]. Teodorović D. (2008): Swarm intelligence systems for transportation engineering: Principles and applications. Transportation Research, Part C: Emerging Technologies, Vol. **16** (6), pp. 651–667, Elsevier.

[16]. Dimanoski K. (2015): Model for planning capacities in railway transport. PhD Thesis, Bitola: Faculty of Technical Science.

[17]. Kennedy J., Eberhart R. (1995): Practicle Swarm Optimi- zation. Neural Networks IEEE International.

[18]. Tanackov I., Simić D., Martinov-Mihaljev J., Stojić G., Sremac S. (2009): The Spatial Pheromone Signal for Ant Colony Optimisation, In: Corchado E., Yin H. (eds): Intel- ligent Data Engineering and Automated Learning – IDEAL 2009. Lecture Notes in Computer Science, vol **5788**. Springer, Berlin, Heidelberg.

[19]. DOI https://doi.org/10.1007/978-3-642-04394-9_49

[20]. Turnquist M. A. (1985): Resarch opportunities in trans- portation system characteristics and operations. Trans- portation Research, Part A: General, Vol **19** (5–6), pp. 357–366.

[21]. Fu L., Ishkhanov G. (2004): Fleet size and mix optimiza- tion for paratransit services. Transportation