Journal of KONBiN 2,3 (14,15) 2010
ISSN 1895-8281

FUZZY INTERPRETATION OF A TRANSPORT SYSTEM OPERATION QUALITY ASSESSMENT

ROZMYTA INTERPRETACJA OCENY JAKOŚCI DZIAŁANIA SYSTEMU TRANSPORTOWEGO

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Abstract: *The paper deals with issues connected with an assessment of transport systems operation quality .The considerations concern real, systems with an intended set of operations, belonging to socio – technical systems of the type whose operation quality assessment is performed depending on value changes of features describing actions of operators, technical objects operated by them and he impact of he environment. Their assessment and providing them with the required functional and operational quality, both in terms of their operation safety efficiency, reliability and ecology, provides basis for accomplishment of the transport service according to the set requirements. This work presents possibilities of application of elements of fuzzy logic in selected stages of the assessment, on the basis of the developed method and the assessment model. Operation quality has been defined as being expressed by means of numerical values identified features, whereas it should be emphasized, that in some cases their direct identification is a significant problem. In connection with this, there was built a fuzzy assessment model for which the scope of changes of the system analyzed features is covered with fuzzy numbers , whereas, their sharp values account for the model initial data. Then, there was presented a fuzzy representation of values of features determined for the system assessment, their graphic interpretation was presented, along with an example of application of fuzzy logic elements for a municipal transport system assessment.*

Keywords: *system operation quality, evaluation model, quality vector, fuzzy evaluation model, fuzzy form of quality vector*

Streszczenie: *Opracowanie dotyczy zagadnień związanych z oceną jakości działania systemów transportowych. Rozważania dotyczą systemów rzeczywistych, złożonych, działających z zachowaniem celowym, zaliczanych do typu systemów socjotechnicznych, których ocenę jakości działania dokonuje się w zależności od zmian wartości cech opisujących działania operatorów, sterowanych przez nich obiektów technicznych oraz wpływu otoczenia. Ocena i zapewnienie wymaganej jakości ich działania i funkcjonowania, zarówno pod względem bezpieczeństwa, efektywności, niezawodności oraz pod względem ekologicznym, stanowi gwarancję realizacji usługi transportowej zgodnie z ustalonymi wymaganiami. Na podstawie opracowanej metody i zbudowanego modelu ocenowego, w niniejszej pracy zaprezentowano możliwości zastosowania, na wybranych etapach oceny, elementów teorii logiki rozmytej. Zdefiniowano, że jakość działania systemu jest wyrażona za pomocą wartości liczbowych wyróżnionych cech, przy czym należy podkreślić, że w niektórych przypadkach istotnym problemem badawczym jest bezpośrednie ich wyznaczenie. W związku z tym zbudowano rozmyty model oceny, w którym zakres zmienności analizowanych cech systemu pokryty jest liczbami rozmytymi, natomiast ich ostre wartości stanowią dane wejściowe do modelu. Następnie przedstawiono rozmytą reprezentację wartości cech wyznaczonych do oceny systemu, przedstawiono ich interpretację graficzną oraz zaprezentowano przykład zastosowania elementów logiki rozmytej w ocenie systemu transportu miejskiego.*

Słowa kluczowe: *jakość działania systemu, model ceny, wektor jakości, rozmyty model oceny, rozmyta reprezentacja wektorów jakości.*

1 Introduction

All the considerations are related with research on operation quality of complex transport systems. The analyzed objects belong to the group of real systems with an intended set of applications. These are socio-technical objects of the type <H-M-E> (human-machine –environment), where their operation quality depends on quality changes of characteristic features describing actions of operators, operation of technical objects controlled by them and the impact of the environment.

The basis for these considerations are evaluations of the transport system operation quality, performed according to the defined conception of the system operation quality (Woropay & Muślewski, 2005):

„*System quality – is a set of the system features expressed by means of their numeric values, at a respective moment t, determining the fulfilment level of the requirements in question*".

In connection with the above, the basis for the research is to determine assessment criteria meeting the set requirements and to identify and choose the features on the basis of which the operation quality assessment will be performed.

It should be noted that the features determined for assessment of the transport system operation quality should bear signs of: independence, essentiality, variability, and measurability. Independence of the features is necessary, those ones which provide the same information on the research object, have to be eliminated. In the resultant model there should be distinguished features that are of biggest significance from the point of view of the carried out examinations. Whereas, features of little significance due to their slight influence on the research results, should be neglected. Their variability conditions purposefulness of acceptance of a given feature as a feature whose values do not undergo changes in a considered period of time, does not provide any information on the system state and causes that the considered set is outsized. Measurability of the features, according to the accepted definition of quality, is the basis for the quality assessment, and it must be remembered that the set of features accepted for the examined transport system operation quality description consists of two subsets: measurable features (eg. costs) and immeasurable ones eg.(aesthetics) (Smalko, 1998; Smalko at al., 2004).

Immeasurable features are such that, due to their nature, can not measured. The impossibility of measuring them results from their technical characteristics, or the researcher's inability or ignorance. For each measurable feature describing the examined system X_{Mi} (i = 1, 2, ..., n) there must be given permissible boundaries of their variability $X_{M,i}^{\min}$, $X_{M,i}^{\max}$, corresponding to the criteria of the system proper operation quality. Similarly, for each conventionally immeasurable feature X_{Nj} (j=1,2,...,m), there must be established criteria so that it will be possible to state unequivocally if a given feature meets them. For this purpose, different values from 0 to m are assigned to immeasurable features. It must also be remembered that in the set of features, distinguished for a given transport system operation quality assessment, there can be features evaluated in a constant way (eg. pollution emission) and a discreet way (eg. the vehicle equipment). The desired assessments of some features are such whose values are the highest (eg. degree of transport task accomplishment) but in the considered set there can also occur such features for which the most favorable values are the lowest ones (eg .noise emission) (Woropay, 1996).

In the model to evaluate operation quality of the transport systems $X_i(t)$, i=1,2,…,p, stand for a feature being a random variable which depends on the time, realisation of which at the given moment t describes the quality of the system operation. The following vector of the quality features is being considered:

$$X(t) = \langle X_1(t), X_2(t), ..., X_p(t) \rangle \quad (1)$$

The component $X_i(t)$, i=1,2,…,p, of the vector X(t), is one-dimensional random process in the space R, describing ith feature of the quality of the operation system. While the vector X(t) is a p – dimensional random process describing comprehensively the quality of the system operation within the space R^p, at the given moment t. For the purposes of this work, there has been accepted that “criterion” is one of the basic conditions imposed on the feature value. The basic criteria of the transport system operation quality assessment include: safety, reliability, availability, ergonomics, efficiency and eco-friendliness. While taking up the research and constructing a resultant model, it should be remembered that the kind and multiplicity of the distinguished features set is closely conditioned by the set criteria and complexity, destination and specificity of a given system operation.

2 Possibilities to apply elements of fuzzy logic in evaluating a transport system operation quality

The set of the system features can be divided into two groups. The first group consists of the features described in form of continuous measured values. The second one consists of the features assessed in the digital way. To combine both types of the features in one coherent assessment system the fuzzy modelling could be implemented (Pająk & Muślewski, 2005). In case of the measured features the value is determined with the accuracy of the measure device (Von Winterfeld & Edwards, 1986). So it is not possible to specify the value precisely. It is only possible to determine the interval which covers the value:

$$X_o(t) \in \left\langle X_p(t) - \delta_u, X_p(t) + \delta_u) \right\rangle \tag{2}$$

where:

$X_o(t)$ - calculated value of the feature,

$X_p(t)$ - measured value of the feature,

δ_u - accuracy of the measure device.

Additionally in case of the indirect measurements the value is burden with the inaccuracy of the calculation method. Because of that it is necessary to consider the interval of the tolerance of the value. During the studies the interval of tolerance is expressed in form of fuzzy set.

In case of the measurements with the intensivity zone the tolerance interval was model by the *Π* type fuzzy set (Fig. 1). Such an approach is characteristic when a measurement tool does not detect some values and treats such measurements as being equivalent – good ones. Subsequently the fuzzy set kernel is to be considered as an interval, the example of which is the *Π* type fuzzy set.

$$FS_{\Pi}(x) = \begin{cases} 0 & \Leftrightarrow x \le lrs \vee x \ge rrs \\ \dfrac{x - lrs}{lrk - lrs} & \Leftrightarrow lrs < x \le lrk \\ 1 & \Leftrightarrow lrk < x \le rrk \\ \dfrac{rrs - x}{rrs - rrk} & \Leftrightarrow rrk < x < rrs \end{cases} ; \tag{3}$$

where:

$FS_{\Pi}(x)$ – member function of *Π* type fuzzy set,

lrk – the lowest value of the fuzzy set kernel,

lrs – the lowest value of the fuzzy set support,

rrk – the biggest value of the fuzzy set kernel,

rrs – the biggest value of the fuzzy set support.

In the remaining cases the tolerance interval was modelled in form of the *Λ* type fuzzy set: In case when we take a measurement and it is burdened with an inaccuracy of the measuring tool, then one of the methods to solve such a problem is to present this value as a fuzzy number.

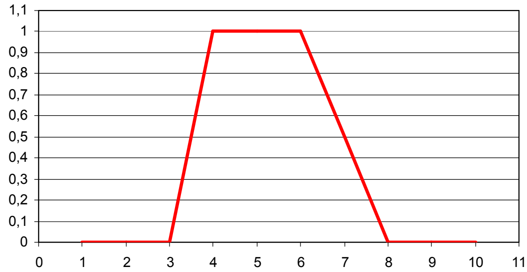

Fig. 1 Representation of the membership function for the Π type fuzzy set.

Fuzzy modelling with applying triangular functions, where the tolerance range is modelled as the *Λ* type fuzzy set, is most frequently used, in practical applications, to describe these numbers*:*

$$FS_{\Lambda}(x) = \begin{cases} 0 & \Leftrightarrow x \le lrs \vee x \ge rrs \\ \dfrac{x - lrs}{lrk - lrs} & \Leftrightarrow lrs < x \le lrk \\ \dfrac{rrs - x}{rrs - lrk} & \Leftrightarrow lrk < x < rrs \end{cases} \quad ; \qquad (4)$$

where:

$FS_{\Lambda}(x)$ - member function o

lrk – the lowest value of the fuzzy set kernel,

lrs – the lowest value of the fuzzy set support,

rrs – the biggest value of the fuzzy set support.

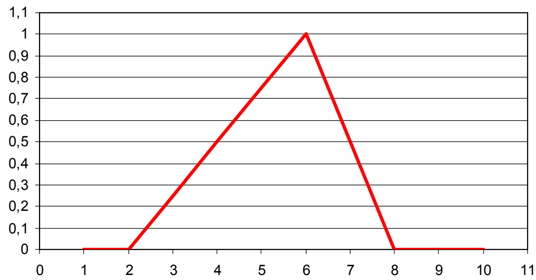

Fig. 2 Representation of the membership function for the Λ type fuzzy set

As a modal value of the fuzzy set the measured value was admitted. The support of the fuzzy set is equal to the sharp interval of the considered tolerance. In case of the features numbered between the elements of the second of the mentioned above sets the assessment could be subjective. Additionally, the assessment is done with the approximation resulted from the frequency of the discretisation. The inaccuracy was modelled using the Λ type fuzzy sets. For the fuzzy set the criterion fulfilment level was established as the modal value. The extent of the fuzzy set support is equal to the distance between the discret values of the criterion assessment scale multiplied by two. During the studies the system operation quality assessment process is considered as the multi-objective analysis issue. For each system feature the criterion was formulated. The fulfilment level of the criteria describes the quality of the system operation.

According to the implemented method, the domain of each criterion was defined on base of the criterion argument extent. The domain was divided into six intervals. The size of interval increases according to the geometric series as a distance from the optimum value. The quotient of the series equals to *2* (Piegat, 1999). Different types of the criteria were expressed by different functions. The criterion where the optimal value is the smallest one and the most important differences in level of criterion fulfilment are around the minimum point of the criterion domain was expressed by the function:

$$\nu = \log_2\left(\frac{P_\nu - P_{min}}{P_{max} - P_{min}} \cdot 64\right) \tag{5}$$

The criterion where the optimal value is the biggest one was expressed by the function:

$$\nu = \log_2\left(\frac{P_{max} - P_\nu}{P_{max} - P_{min}} \cdot 64\right) \tag{6}$$

For the criterion described by the function (5) the function values respond to the arguments values determined by the formula (7),

$$P_\nu = P_{\mathbf{min}} + \left(P_{\mathbf{max}} - P_{\mathbf{min}}\right) \cdot \frac{2^\nu}{64}, \nu = 0,1,...,6 \tag{7}$$

in range from *4* to *10* according to (9).

$$g = 10 - \nu \tag{8}$$

For the criterion described by the function (5), the function values respond to the arguments values determined by the formula (8) and the range is described by (10) (Lootsma, 1996).

$$P_v = P_{max} - (P_{max} - P_{min}) \cdot \frac{2^v}{64}, v = 0,1,...,6 \quad (9)$$

$$g = 4 + v \quad (10)$$

where:

v - criterion function value,

P_{max} - maximum value of the criterion argument,

P_{min} - minimum value of the criterion argument,

P_v - the argument of the criterion,

g - fulfilment level of the criterion.

As it was mentioned above the method enables to create the coherent assessment system that take into consideration both types of the features. It could be also noticed that the features of the system could be defined in different domains. Described method transform all the criteria to one domain. Thanks to it the total assessment could be calculated.

During the studies it was recognized that because of the fuzzy characteristic of the system features it is not possible to establish the accurate level of the criteria fulfilment. To do it possible the fuzzy extension of the method was developed. The extension describes each criterion by the fuzzy set where the member function determines the criterion fulfilment level. The domain of the criterion is equal to the fuzzy set support. The member functions for the criteria were appointed as a linear interpolation of the points described by the formulas (5-10). The functions were scaled to the fuzzy set domain by the fuzzy set division into *64* equal parts.

The values of the functions are included in the range from *4* to *10*. So, they are transformed to create the normal fuzzy sets:

$$\sup \mu_{FS}(X_i) = 1 \quad (11)$$

where:

$\mu_{FS}(X_i)$ - member function for system feature no. i.

To do it the values of the function were divided by 10.

Thanks to described method implementation it is possible to carry out the system operation quality assessment process taking into consideration the inaccuracy of the system feature values.

The values of the system features weights are calculated according to the *AHP* method (Analytic Hierarchy Process) (Saaty, 1980).

The method compares the features between each other. It could be expressed using the matrix notation:

$$q = \begin{bmatrix} 0 & q_{1,2} & \cdots & q_{1,n} \\ 0 & 0 & \cdots & \vdots \\ 0 & 0 & 0 & q_{n-1,n} \\ 0 & 0 & 0 & 0 \end{bmatrix} \tag{12}$$

The values of the features importance creates the seven level system presented in the table:

Table 2. Relative preferences scale used to compare the features.

Feature Name	Features	Dispersion value of a fuzzy average value
Faults made by the operators	X_1	18.217
Realization degree of the transport tasks	X_{11}	13.890
Technical condition of the communication routes	X_{15}	1.1820
Visibility level over the respective routes	X_{16}	1.1798
Condition of the elements of the wheels and steering system	X_5	0.1714
Sum of the vehicle operation and maintenance costs	X_7	0.1613
Vehicle ergonomic features	X_8	0,1546
Value of the pollutants emission	X_{12}	0,1429
Value of the emitted noise	X_{13}	0,1411

The values of the weights are calculated according to the formula (13):

$$w_{wj} = \frac{1}{n_w} \sum_{k=1}^{n_w} q_{wjk} \tag{13}$$

where:

q_{wjk} - the value of the preference the feature no. *wj,* in relation to the feature no. *k,*
n_w - amount of the features,
w_{wj} - the value of weight for *wj* feature.

Calculated values could be imprecise because of the discret and subjective characteristic of the method. It was taken into consideration by the fuzzy digits implementation. Each value is expressed as the fuzzy triangular digit. The extent of fuzzy digit support is equal to *10%* of the range of the weight value. The modal value of the digit is equal to the sharp value of the weight. It results the asymmetric fuzzy digits creation:

$$w_{wj}^{FS}(x) = \begin{cases} 0 & \Leftrightarrow x \le lrs \vee x \ge rrs \\ \dfrac{x - lrs}{lrk - lrs} & \Leftrightarrow lrs < x \le lrk \\ \dfrac{rrs - x}{rrs - lrk} & \Leftrightarrow lrk < x < rrs \end{cases} \tag{14}$$

where:

$w_{wj}^{FS}(x)$ – member function of *wj* feature weight fuzzy set,

lrk – the lowest value of the fuzzy set kernel,

lrs – the lowest value of the fuzzy set support,

rrs – the biggest value of the fuzzy set support.

Having respective degrees of fulfilment of each of the criteria by the system and their validity for the final evaluation, it is possible to determine a resultant form of the operation quality of the analysed system.

3 Graphic interpretation of the system operation quality assessment

The quality of the system operation estimated on the basis of the features significant in the time t, $t \in < t_0, t_k >$ could be described using so called *Multidimensional Quality Vector*. The set of the features creates the p - dimensional assessment space. The values of the features determined for time t creates the point M'. The coordinates of the point are expressed by the vector $[k'_{x_1(t)}, k'_{x_2(t)}, \ldots, k'_{x_p(t)}]$. In the multidimensional space the point is the end of the vector $\overline{WWJ}$. The vector begins in the point $[0,0,\ldots,0]$ (Fig. 3).

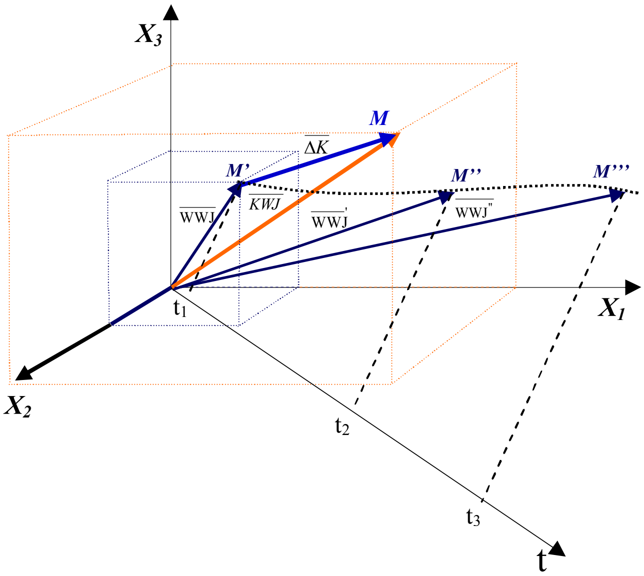

Fig. 3 Graphic interpretation of $\overline{\Delta K}$ *vector in* R^3 *space*

It describes the quality of the system operation in time t. Similarly, the desired values of the features construct the M point. The coordinates of the point M are expressed by the vector $[k_{x_1}, k_{x_2}, ..., k_{x_p}]$. So in the assessment space the *Model Quality Vector* $\overline{KWJ}$ could be defined. The vector starts in the point $[0,0,...,0]$ and ends in the point M. The distance between the ends of the vectors is interpreted as a quality of the system operation $\overline{\Delta K}$.

$$\overline{\Delta K} = \overline{KWJ} - \overline{WWJ} \tag{15}$$

The wear factors change the values of the system features. So, the values of the features change in time. It could be observed as an M' point motion in period of time Δt. It means that the quality of system operation changes in time because the components of $\overline{WWJ}$ vector change on each axis in p-dimensional space in time period (t+Δt) (Woropay & Muślewski, 2005).
The multidimensional and the model quality vectors are defined on the basis of the system features. The sharp real and the optimal values of the features determine the position of the ends of the quality vectors. In case of fuzzy interpretation of the features values the situation changes. The value of each feature is expressed by the fuzzy set defined in different domain.

$$
\begin{aligned}
&FS_1 = \int_{X_1} \mu_{FS_1}(X_1) \,|\, (X_1) \\
&FS_2 = \int_{X_2} \mu_{FS_2}(X_2) \,|\, (X_2) \\
&\vdots \\
&FS_n = \int_{X_n} \mu_{FSn}(X_n) \,|\, (X_n)
\end{aligned}
\tag{16}
$$

where:

FS_i - fuzzy value of the feature no. *i*,

X_i - *i* feature of the system,

μ_{FS_i} - member function of the fuzzy set no. *i*.

In such situation the ends of the multidimensional and the model quality vectors are the results of the relation of the p-dimensional extension of the flat fuzzy sets (Łachwa, 2001). It could be expressed by the formula (17). The result of the relation constructs the area in multidimensional space. The shape of the area depends on used *T-norm* operator. The minimum and the algebraic multiplication operators are proposed as the optimal ones.

$$
\begin{aligned}
&ce(FS_1; X_1 \times X_2 \times \cdots \times X_n) = \int_{X_1 \times X_2 \times \cdots \times X_n} \mu_{FS_1}(X_1) \,|\, (X_1, X_2, \cdots, X_n) \\
&ce(FS_2; X_1 \times X_2 \times \cdots \times X_n) = \int_{X_1 \times X_2 \times \cdots \times X_n} \mu_{FS_2}(X_2) \,|\, (X_1, X_2, \cdots, X_n) \\
&\vdots \\
&ce(FS_n; X_1 \times X_2 \times \cdots \times X_n) = \int_{X_1 \times X_2 \times \cdots \times X_n} \mu_{FSn}(X_n) \,|\, (X_1, X_2, \cdots, X_n)
\end{aligned}
\tag{17}
$$

where:

$ce(FS_i; X_1 \times X_2 \times \cdots \times X_n)$ - n-dimensional extension of the fuzzy set no i

The fuzzy sets implementation implicates the transformation of model and real quality vectors to *p-dimensional* areas. So, it is necessary to define the *p-dimensional* method of estimation of system operation quality.

Looking at the graphical form of the method it is possible to distinguish three cases of relative location of real system quality and model system quality areas. These areas could overlap each other, could be contiguous or separated. Obviously the biggest quality value is represented by overlapping areas and in decreasing order contiguous and separated ones. But it is necessary to develop the method of solutions ordering within each case.

In case of overlapping areas the method based on the size of the intersection volume was proposed. In case of separated areas the quality value is proportional to distance between the fuzzy sets.

4 Example of applying elements of fuzzy logic to evaluate transport system operation quality

An example of applying the presented method is verification of the evaluation model built.

In the process of evaluation of the system operation quality one of the essential problems is to determine, out of the set of the analysed features only those which affect most extensively the evaluation being carried out. A set of seventeen features was selected in the created resultant model of quality evaluation of the executive subsystem of a transport system. Taking into consideration verification of the model built and especially checking excessiveness of the adopted set of the features and determination of their significance, the elements of fuzzy logic were applied.

A method of the fuzzy average graphs was used for that purpose. The process of the fuzzy modelling was done on the basis of the feature value analysis, determined due to the operation and maintenance investigations, describing a transport system from the point of view of it's operation quality. For the selected values of each of the adopted features, a cross-section through a surface was determined for the adopted variable value (Woropay & Muślewski, 2005).

In order to analyse the real data, it is needed to fuzzy the value determined for the cross-section with the measurement spots. It eliminates the problems related to the irregular and non-continuous coverage of the solution space, Membership of a measurement spot to a respective cross-section was adopted in a form of the Gauss function:

$$\mu(X_i^*) = \exp(-(\frac{X_i^* - X_i}{b})^2) \tag{18}$$

where:

- $\mu(X_i^*)$ – membership function for the value determined for the i-th system feature,
- X_i^* – determined value of the i-th system feature,
- b – membership function opening width.

A weighted average value was calculated for each cross-section:

$$Z_{śr}(X_i) = \frac{\sum_{k=1}^{nwp} \mu(X_k) \cdot Z(wp_k)}{\sum_{k=1}^{nwp} \mu(X_k)} \tag{19}$$

where:

nwp – number of measurement vectors,

wp – measurement vector.

The dependency stated above may be used when applying the method of fuzzy average graphs (Piegat, 1999), it is intended to model influence of each real measurement on the closest fuzzy cross-sections determined.

The cross-section average values create a curve whose dispersion is a measure of the dependence degree between the model output value and the input value. During realization of the works, some analysis were performed, and a 20% coefficient of the membership function range was adopted. The number of the fuzzy cross-sections equal to 10 was determined and a method to calculate the dispersion was elaborated as an average square value (Pająk & Muślewski, 2005). On the basis of the performed analysis of the gradient representation of the fuzzy average values (Fig. 4), the value equal to 0.01 was adopted as a significance limit.

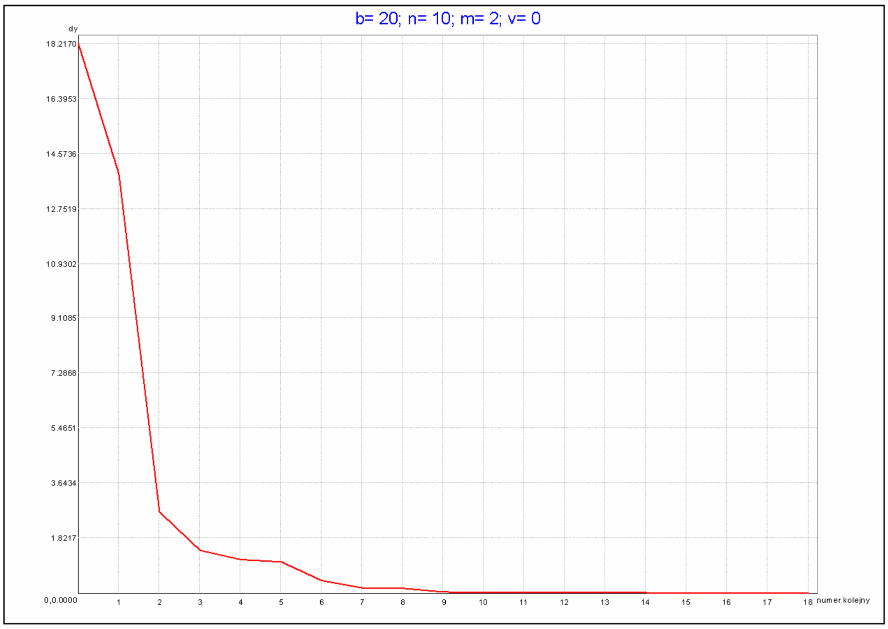

Fig. 4 Gradient representation of the fuzzy average values

However the figure 5, presents a spectral form of the fuzzy average values while the dispersion value of the fuzzy average values.

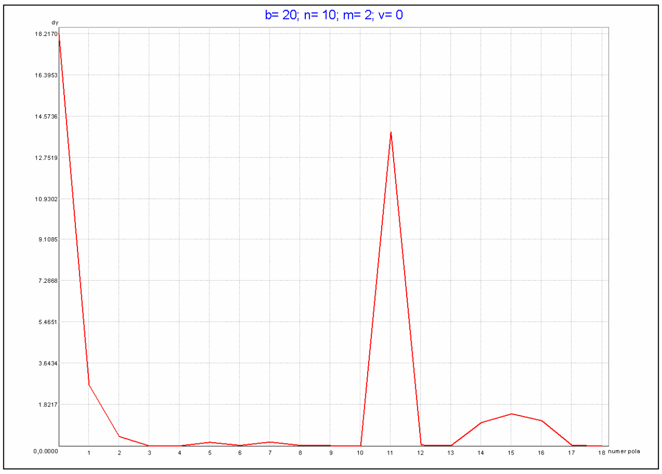

Fig. 5 Spectral representation of the fuzzy average values.

On the basis of the spectral representation of the fuzzy average values and on the dispersion value of the fuzzy average values, nine features characterized by the highest level of significance for the modelled process were selected, as presented in the table 4.

Table 4. Transport system features selected as input parameters of the fuzzy model arranged according to their decreasing significance.

Feature Name	Features	Dispersion value of a fuzzy average value
Faults made by the operators	X_1	18.217
Realization degree of the transport tasks	X_{11}	13.890
Technical condition of the communication routes	X_{15}	1.1820
Visibility level over the respective routes	X_{16}	1.1798
Condition of the elements of the wheels and steering system	X_5	0.1714
Sum of the vehicle operation and maintenance costs	X_7	0.1613
Vehicle ergonomic features	X_8	0,1546
Value of the pollutants emission	X_{12}	0,1429
Value of the emitted noise	X_{13}	0,1411

On the basis of the investigations performed the resultant form of the model to evaluate system operation quality was verified and a set of the nine most significant features was taken into consideration at the further stages of the investigations.

Subsequently, the resultant – considered vector of the quality features $X_i(t)$ takes the following form:

$$X(t) = \langle X_1(t), X_2(t), \ldots X_9(t) \rangle \qquad (20)$$

Reduction of the feature numbers, determined by means of the method of fuzzy average graphs is of great importance for conducting further operation and maintenance investigations. Most of all, the time and the costs to carry out the studies have been reduced, and a resultant model was set to assess the quality of the transport system operation, in which nine most important features affecting its operation quality were distinguished.

It should be emphasized that applying the method presented above and selection of the respective features confirm its adequacy, because on the basis of comparison of the obtained operation and maintenance results and especially the influence (value changes) of the respective features on the system operation quality it turned out that during the previous investigations, in the considered set of seventeen features, the selected nine of them – had the most significant influence on the change of the quality level value of the system under investigation.

5 **Summary**

This paper presents possibilities of application of elements of fuzzy logic for an assessment of a transport system operation quality. In result of experimental tests carried out in a real system, the following conclusions have been formulated

- values of identified features describing the system, reveal a fuzzy character.
- setting the quantity and significance of the features accepted for the assessment of the investigated transport system operation quality is of fuzzy character;
- assessment of the system operation quality with the application of fuzzy modelling, enables acceptance of the process fuzzy character and thus, an increasing accuracy of its projection.

Yet, it should be taken into consideration, that fuzzy logic is one of many existing tools for solving the discussed problems, whereas, purposefulness of its application should depend on optimization and correctness of the obtained solutions.

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