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FUZZY TECHNIQUES USED FOR SOUND POLLUTION EVALUATION

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Abstract: *The work presents the theoretical appropriateness for the application of Fuzzy techniques into two different Romanian towns, the steps necessary to apply it, the program for the application of this technique, but also the computerized results obtained by application of the new method, for the assessment of sound pollution by Fuzzy techniques. This work intended to demonstrate that the Fuzzy techniques can be successful use for the evaluation of sound pollution in urban agglomerations. Implementation of a study from municipal area, with the evaluation system based on Fuzzy crowd is a rapid method, noninvasive, and has been obtained from the indicator of the impact on an intense inhabited road and powerful intense polluted from the movement of motor vehicles. Results of the study obtained from the application of Fuzzy techniques, compared with the ordinary measurement results in the same places, have proved viable and thus Fuzzy techniques becomes a useful tool, quick and non-destructive test for the assessment noise pollution in urban agglomerations. The authors applied first this idea for the noise evaluation.*

Key words: *sound pollution, Fuzzy techniques, degree of belonging.*

1. GENERAL THEORY

The concept of the vague crowd was introduced in 1965 under the name of the crowd "fuzzy", which in translation means many unclear, grayed out and be used with the vague, imprecise. And in general about Fuzzy concepts occurred from the need to be expressed quantitatively "the vague", "the imprecision". Although there are many branches of mathematics theory no one older than Fuzzy, which are concerned with the study processes random in nature: likelihood theory, statistics mathematics, information theory and others, may not be substituted produced between them and no one fuzzy theory.

Starting from the classical design of the crowd and an element of a crowd, it may be argued that the concept of fuzzy crowd an approach from a different angle to the concept of the crowd, more precisely, between an element to become as membership to a crowd and not membership there are a number of transitional situations, such as continuous, characterized by so-called degrees of membership.

For the description of fuzzy phenomena and processes, applications MF(x) function can accept different analytical expressions. A few of these are designated in applications due to facilities related to the computability deployment and ease-of-hardware/software implementation.

Fuzzy logic is an extension of classical logic by replacing discrete character divalent thereof (0-1) with one of a kind. The foundation of Fuzzy logic is the so-called polyvalent logic. Assuming that V_1, V_2, ..., V_n are variables in Fuzzy logic, they take values in the range [0, 1]. Using the definition: Any variable V_i is a *Fuzzy formula*.

If $P, Q, \ldots$ are formulas in Fuzzy logic, logical values (truth) of $P \vee Q, P \wedge Q, \overline{P}$ compounds shall be determined as follows:

$$A(P \vee Q) = max(A(P), A(Q)) \qquad (1)$$

$$A(P \wedge Q) = min(A(P), A(Q)) \quad (2)$$

$$A(\overline{P}) = 1 - A(P) \quad (3)$$

$$A(P \rightarrow Q) = min(1 - A(P) + A(Q), 1) \quad (4)$$

There is an important observation: It is obvious that this way of seeing things is the same as in the divalent logic, where, $A(P) \in \{0, 1\}$ whatever will be the P sentence.

2. FUZZY LOGIC APPLIED TO NOISE POLLUTION

Fuzzy logic is a type of logic continues, because the logical variables take values of truth in the interval [0, 1]. This draws the existence of particular elements of the *language variables*: the relationship of *fuzzy implication* and the notion of *fuzzy inference*. To apply the Fuzzy logic to the sound pollution need to follow the relations:

$$A(P \vee Q) = A(P) + A(Q) - A(P) \cdot A(Q) \quad (5)$$

$$A(P \wedge Q) = A(P) \cdot A(Q) \quad (6)$$

$$A(\overline{P}) = 1 - A(P) \quad (7)$$

$$A(P \rightarrow Q) = 1 - A(P) + A(P) \cdot A(Q) \quad (8)$$

Fuzzy variables are associated with the deterministic fuzzy sizes. The equivalent amount of deterministic sense is scaling for a variable fuzzy linguistic degree (label, attribute) associated with it. So, as for divalent, the deterministic logic "1" is assigned the attribute to TRUE, and the "0" label, in fuzzy logic FALS, for deterministic variable *positive real number* variable can be associated with language, for example, the *distance* between two points, which can have language degrees, SMALL, MEDIUM, LARGE or VERY SMALL, SMALL, MEDIUM, LARGE, EXTRA LARGE. The values of the size of the corresponding are called deterministic *universe of discourse*.

Each attribute of a variable that is assigned to a function whose membership (in the sense deterministic) indicates the level of confidence with which deterministic values of it can assign the variable attribute.

2.1 Implication in the Fuzzy Logic Regarding the Sound Pollution

In the Fuzzy logic, the implication is an operation of the formula (variables) Fuzzy, meaning a correlation of two categories of events, referred to as the premise, and the consequences. Fuzzy implication is similar, but does not fully function in the case of deterministic and refers to the assessment of degrees of linguistic Fuzzy subsets, which is the logical consequence of functional or Fuzzy subsets. The result of Fuzzy implications is also fuzzy subsets noted:

$$Q' \equiv P \rightarrow Q \quad (9)$$

This has the same language degrees as well as Q, but its membership, functions that express the degree of truth:

$$A(Q') = A(P \rightarrow Q) \quad (10)$$

Results from algebraic calculations performed on values of corresponding membership degrees of which linguistic fuzzy implication. Therefore, considering the fuzzy formulas:

$$P : x \text{ is LARGE, } Q : y \text{ is SMALL} \quad (11)$$

Where x, and y, are deterministic variable belonging to the universe of discourse of the subset P, or Q, it expresses the Fuzzy implication:

$$Q' \equiv P \rightarrow Q \Leftrightarrow \underbrace{\text{IF } x \text{ is LARGE,}}_{\textit{CONDITION}} \underbrace{\text{THEN } y \text{ is SMALL}}_{\textit{THEREFOR}} \quad (12)$$

Considering $m_P(x)$ and $m_Q(y)$ the membership functions that characterize fuzzy crowds P and Q, the question arises of determining the membership function:

$$m_Q(x, y) = m_{P \rightarrow Q}(x, y) \quad (13)$$

For the study of sound pollution application is the implication for the purposes of Mamdani, expressed through the relation:

$$m_{P \rightarrow Q}(x, y) = \text{MIN}\left[m_P(x), m_Q(y)\right] \quad (14)$$

In this paper, the relationship (14) will be used in two different cases studies, which are

been in the city of Oradea and in the city of Bistrița.

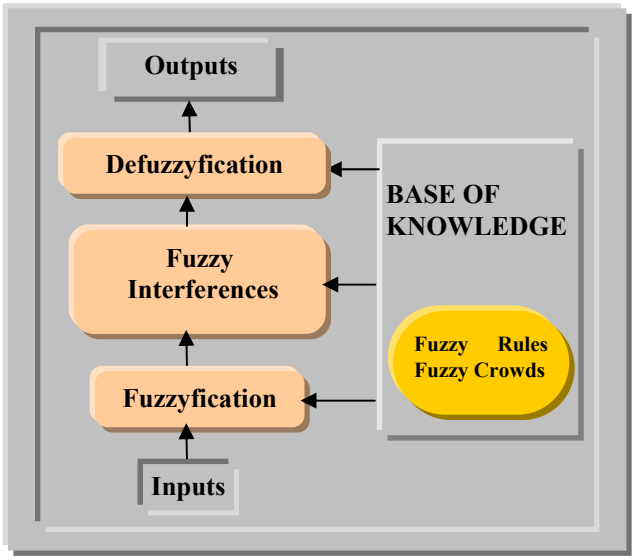

Fig. 1. Fuzzy decision - making system.

2.2. Algorithm of Fuzzy Modelling

Fuzzy modeling is characterized by a specific algorithm for the treatment of information, which forms the basis for the synthesis of a decision-making system based on Fuzzy set. In figure 1 is given the work of a decision-making system based on Fuzzy concepts.

The majority of works in this field adopted the following stages of the algorithm of Fuzzy modelling:

1. description heuristic base of the problem;
2. the choice variables to input - output;
3. establishing the Fuzzy crowd language and values associated with them;
4. making databases of rules for Fuzzy interferences;
5. establish processes of fuzzyfication, realise the logical inferences and defuzzyfication of outputs;
6. adopting the mechanism of defuzzyfication;
7. description of the system of adaptation and of the schemes for learning;
8. in the final form, fuzzy systems can be deployed in the wired form (hardware) in bodies dedicated or general-purpose programmable.

Noise pollution is an important feature of urban areas with harmful effects on humans. Assessment of the degree of noise pollution has become a major there will for local authorities to take measures for the reduction of acoustic pollution.

3. FUZZY CROWDS IN THE POLLUTANT AUDIBLE IMPACT ON THE MAN

The Government of Romania, by Order no 678/2006, adopted the methods for the calculation of noise indicators, for the noise caused by road traffic, rail, air and industrial activities, methods recommended by the European Union. Also are given guidelines for the attainment of strategic noise maps. In this context is placed and the problem estimate number of people exposed to different levels of noise. Not shown but a method allowing assessment of the impact of noise on residents from the affected areas.

In this context it is proposed a method for the evaluation of the impact noise pollution on human, method, which uses specific techniques of the Fuzzy crowds.

Crowds fuzzy give the ability to define the type of decision-making systems multi-attribute which may take into account several factors (criteria) which shows a high degree of uncertainty. In our case these factors are: *traffic intensity* and *population density*. Also there is a possibility they are connected by the operators specific fuzzy masses in such a way that the outlet from the decision-making, *the indicator of impact* and to reflect cumulative influence of the quantities of entry.

3.1. Evaluation of the Impact Pollutant Sound by Fuzzy Techniques Steps

Steps that must be covered for the deployment decision-making process based on fuzzy crowd will be described in the following.

1. *The magnitudes of entry (criteria) in relation to that will be determining Impact Indicator (II)*

Inputs sizes in relation to which carry out the determination Impact indicator are: *Intensity of*

Traffic (IT) and *Density of Population* (DP). They form the crowd of the assessment criteria.

$$IN = \{IT\ DP\} \quad (15)$$

2. *Definition of the scope values for each evaluation criteria*

Each input sizes is teaming up a range of variation, within which can be restored to the values specific to it. These areas of values will be:

$$IT : D_{IT} = [\, L_{IT}^{inf}, L_{IT}^{sup}\,]$$
$$DP : D_{DP} = [\, L_{DP}^{inf}, L_{DP}^{sup}\,] \quad (16)$$

Where: L^{inf}, L^{sup} are low limits or high limits of the field of values associated with each input sizes, which will be presented in case study.

3. *Definition of linguistic variable associated with each input size*

Each input sizes is associated a linguistic variable. For simplification, the linguistic variable will have same name as the input size. Such sizes IT, DP become input linguistic variables.

4. *Establishing the linguistic grades associated with each linguistic variable*

For each variable linguistic output levels are to be defined linguistic (they have established 6 language degrees, it is considered encrypted [6]) or linguistic terms (were established 5 linguistic terms, it is considered encrypted [5]). They will also serve to characterize as "vague" of firm information**.**

5. *Definition of the output size in decision-making process*

The size of the output decision-making process is Indicator of Impact (II).

6. *Setting the range of values of the output size*

Range in values for the output size of Impact Indicator (II) is the following:

$$II : D_{II} = [\, L_{II}^{inf}, L_{II}^{sup}\,] \quad (17)$$

7. *Definition of linguistic variable associated with output size*

The output size of Impact Indicator (II) is associated a linguistic variable named Indicator of Impact (II).

8. *Establishing the linguistic grades associated with each variables corresponding to output linguistic size*

For the variable language associated with the output size to define language degrees (5 linguistic degrees, it is considered encrypted [5]) or terms linguistic (5 linguistic terms, it is considered encrypted [5]). They will characterize "vague" the output of the procedures for inference as the definition from Mamdari method adopted.

9. *Establishing the method to connect various values of membership functions. Inference Machine*

The crowds of linguistic variables of linguistic grades, which have been associated with functions of membership, characterize "vague", the firm values of the input sizes, respectively of the output sizes. Inference machine consists of a set of rules having the form:

IF (*premise*) THEN (*conclusion*) (18)

Premise - it is a owned by noted [5, 5] resulting from connecting, through specific procedures of fuzzy crowd theory, of the various degrees linguistic variables associated with appropriate linguistic input sizes. In the event of decision to be described has used the connector AND [5,5]. *Conclusion* - is the property affirmed and it will be expressed in degrees linguistic of associated variables with appropriate of output linguistic sizes.

10. *Establishing the method of defuzzyfication*

By defuzzyfication means the operation for obtaining of a firm values ("crisp") of the output sizes, on the basis of the function of membership "result" of Fuzzy inferences [5]. From a number of existing methods of defuzzyfication [5, 5], it will use the center of gravity, the most applied in practice, the Mamdari method.

3.2. Sound Pollution Evaluation by Fuzzy Techniques

The rating system based on fuzzy crowd, which is implemented in *Toolbox Fuzzy Logic* in *MatLab* programming environment, is the one shown in figure 2.

The Input Sizes are: Intensity of Traffic (IT) and Density of Population (DP). Areas in which two sizes take values are:

$$IT : D_{IT} = [0,4500] \qquad DP : D_{DP} = [0,1000] \tag{19}$$

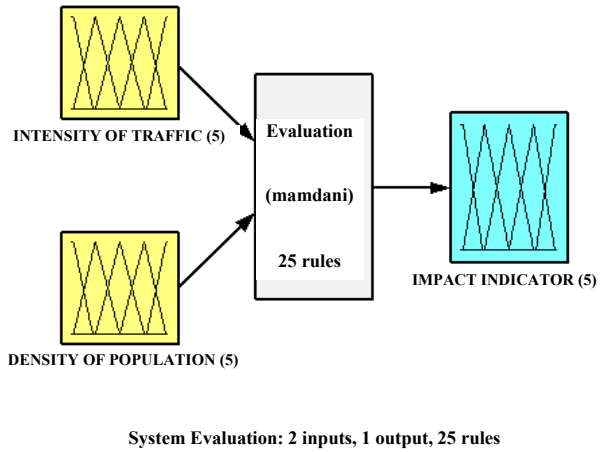

Fig. 2. Evaluation System of Sound Pollution, Based on Fuzzy Technique

Language variables associated with the two sizes are *Intensity of Traffic* (IT) and *Density of Population* (DP). Linguistic variable (IT) has associated language following degrees: Very small (fm); Small (m); Medium (Md); Intense (I); Very intense (FI). Linguistic variable (DP) has associated language following degrees: Very low (fm); Low (m); Average (Md); High (M); Very high (FM).

Variable output Impact Indicator (II) correspond the linguistic degrees and membership functions associated with each linguistic degree. Language degrees are: Very small (fm); Small (m); Medium (Md); High (M); Very high (FM).

Input sizes are to be found in figure 3, and the output size is located in figure 4, for which they have used triangular, which is perfect suitable in the study.

The inference motor is composed of 25 rules of the form:

1. If (Intensity of Traffic is fm) and (Density of Population is fm) then (Impact is fm)
2. If (Intensity of Traffic is fm) and (Density of Population is m) then (Impact is fm)
3. If (Intensity of Traffic is fm) and (Density of Population is Md) then (Impact is m)
4. If (Intensity of Traffic is fm) and (Density of Population is M) then (Impact is m)
5. If (Intensity of Traffic is fm) and (Density of Population is FM) then (Impact is Md)
6. If (Intensity of Traffic is m) and (Density of Population is fm) then (Impact is fm)
7. If (Intensity of Traffic is m) and (Density of Population is m) then (Impact is m)
8. If (Intensity of Traffic is m) and (Density of Population is Md) then (Impact is Md)
9. If (Intensity of Traffic is m) and (Density of Population is M) then (Impact is Md)
10. If (Intensity of Traffic is m) and (Density of Population is FM) then (Impact is M)
11. If (Intensity of Traffic is Md) and (Density of Population is fm) then (Impact is m)
12. If (Intensity of Traffic is Md) and (Density of Population is m) then (Impact is Md)
13. If (Intensity of Traffic is Md) and (Density of Population is Md) then (Impact is Md)
14. If (Intensity of Traffic is Md) and (Density of Population is M) then (Impact is M)
15. If (Intensity of Traffic is Md) and (Density of Population is FM) then (Impact is M)
16. If (Intensity of Traffic is I) and (Density of Population is fm) then (Impact is m)
17. If (Intensity of Traffic is I) and (Density of Population is m) then (Impact is Md)
18. If (Intensity of Traffic is I) and (Density of Population is Md) then (Impact is M)
19. If (Intensity of Traffic is I) and (Density of Population is M) then (Impact is FM)
20. If (Intensity of Traffic is I) and (Density of Population is FM) then (Impact is FM)
21. If (Intensity of Traffic is FI) and (Density of Population is fm) then (Impact is Md)
22. If (Intensity of Traffic is FI) and (Density of Population is m) then (Impact is M)
23. If (Intensity of Traffic is FI) and (Density of Population is Md) then (Impact is M)
24. If (Intensity of Traffic is FI) and (Density of Population is M) then (Impact is FM)
25. If (Intensity of Traffic is FI) and (Density of Population is FM) then (Impact is FM)

4. STUDY OF CASES REGARDING THE POLLUTANT AUDIBLE IMPACT ON THE MAN

For the demonstration the impact of the Fuzzy techniques on the people in the urban agglomeration, in this paper were used two different municipalities of Romania, and they are: Bistrița and Oradea.

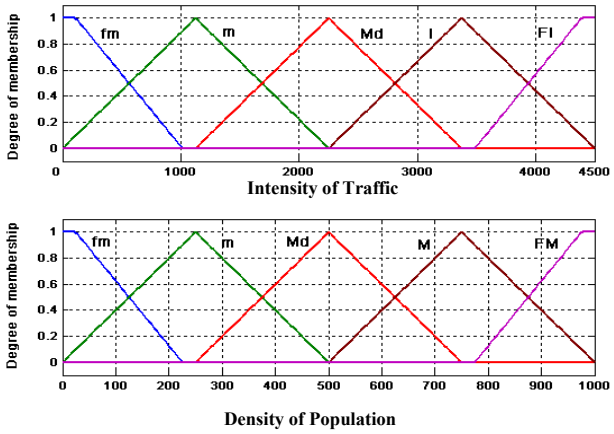

Fig. 3. Input Sizes

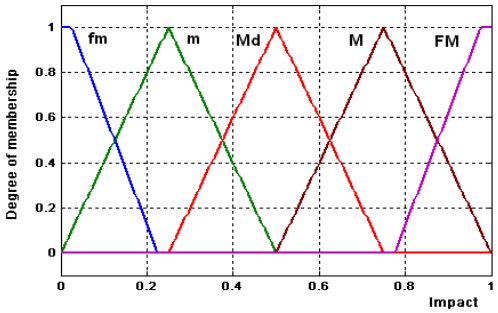

Fig. 4. Output Size

4.1. Implication in the Fuzzy Logic for the Sound Pollution in Oradea

For the assessment itself of the Impact Indicator (II) on it has been 10 points on Oradea city, in which *traffic intensity* was determined by counting vehicles over the course of a day. Also, it has been estimated *density of population* (residents) of the points (areas) in question. These data, the entries in the system of assessment, are shown in table 1. The selected points are the much agglomerated points in the entire town, and were necessary to use them, because the municipality has very strong activities for diminish the sound pollution.

Table 1. The input data in the evaluation system in Oradea

Pt	Name of street	IT	DP
1	Dacia	4236	900
2	Pod Continental	3912	800
3	Calea Aradului	3100	850
4	Decebal	2928	950
5	Nufărului	2863	900
6	Cantemir Dimitrie	2586	850
7	Pod Decebal	2378	700
8	B-Dul Stefan Cel Mare	2252	800
9	Clujului	2132	500
10	1 Decembrie	1664	450

The assessment system is to apply for the thirteen sets of entries and shall be obtained the values Impact indicator, which is presented in Figure 5 and represents the size of the application output Fuzzy crowd. Figure 6 contains rules of interference for IT and DP, and figure 7 has distribution on the surface of the of Impact Indicator corresponding sound pollution inside the Oradea town.

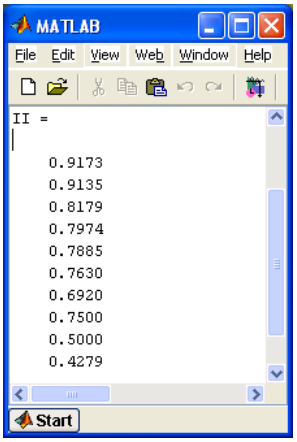

Fig. 5. Values of Impact Indicator for Oradea

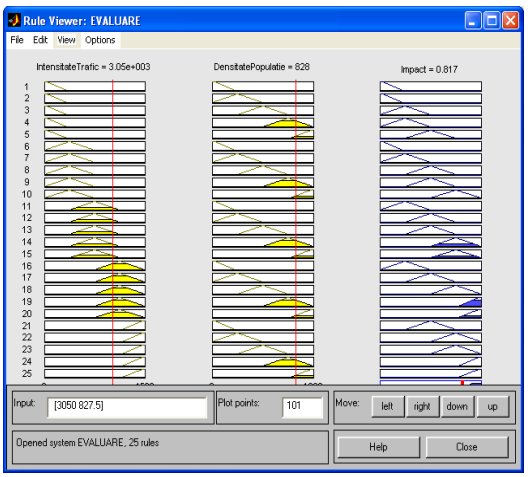

Fig. 6. Interference Rules for Oradea

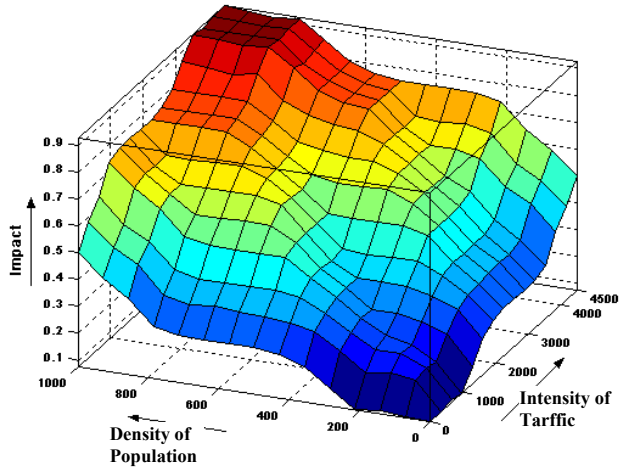

Fig. 7. Surface Variation of Impact Indicator for Oradea

Using all the information presented in this case study the Impact Indicator is not maximum where the DP is greater, this depends of the IT and DP in interference.

4.2. Implication in the Fuzzy Logic for the Sound Pollution in Bistrița

For the assessment itself of the Impact Indicator (II) on it has been 13 points on Bistrita city, in which *traffic intensity* was determined by counting vehicles over the course of a day. Also, it has been estimated *density of population* (residents) of the points (areas) in question. These data, the entries in the system of assessment, are shown in table 2.

For obtaining the real study in the Bistrița municipality, the relation (19) becomes:

$$IT : D_{IT} = [0,90]$$
$$DP : D_{DP} = [0,1000] \qquad (20)$$

Table 2. The input data in the evaluation system in Bistrița

Pt	Name of street	IT	DP
1	Str. Andrei Mureşanu, Int. with str. Năsăudului	63	450
2	Str. Andrei Mureşanu, Vis à vis of Lamă	57	200
3	Str. Andrei Mureşanu, near mag. Ady Lux	48	870
4	Str. Andrei Mureşanu, in front of TBI	82	540
5	Str. Andrei Muresanu, in front of SC Rapid SA	71	245
6	Str. Andrei Mureşanu, int. with Apollo	91	350
7	B-dul Decebal, Vis à vis of Optics	53	720
8	B-dul Decebal, int. at Mag. Motovelo	68	520
9	B-dul Decebal, in front of mag. Caraiman	56	630
10	B-dul Decebal, in front of CAR	44	440
11	B-dul Decebal, int. with str. Lalelelor	54	380
12	B-dul Decebal, in front of Romextera Bank	44	810
13	B-dul Decebal, Vis à vis of Win Markt	30	690

The assessment system is to apply for the thirteen sets of entries and shall be obtained the values Impact indicator, which is presented in Figure 8 and represents the size of the application output Fuzzy crowd. From analysis of the results obtained, it is found that the indicator of the impact of the value of the maximum in point 4, which corresponds to Street Andrei Mureşanu in the face of TBI. Figure 9 contains rules of interference for IT and DP, and figure 10 has distribution on the surface of the of Impact Indicator corresponding sound pollution inside the Bistrița town.

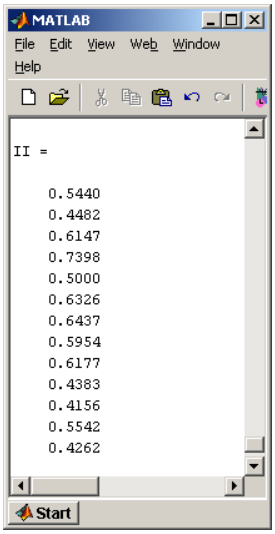

Fig. 8. The Impact Indicator Values for Bistrița

Using the roads Andrei Mureşanu and Decebal, the important traffic inside the town, the Fuzzy techniques demonstrated that, not greater IT or not greater DP gives the maximum II, but interference between them.

5. CONCLUSIONS

Regarding the cases studied in this paper can be considered that the Fuzzy Techniques,

being non-destructive method, it can be successful use for the evaluation of sound pollution in urban agglomerations. The conclusions are:

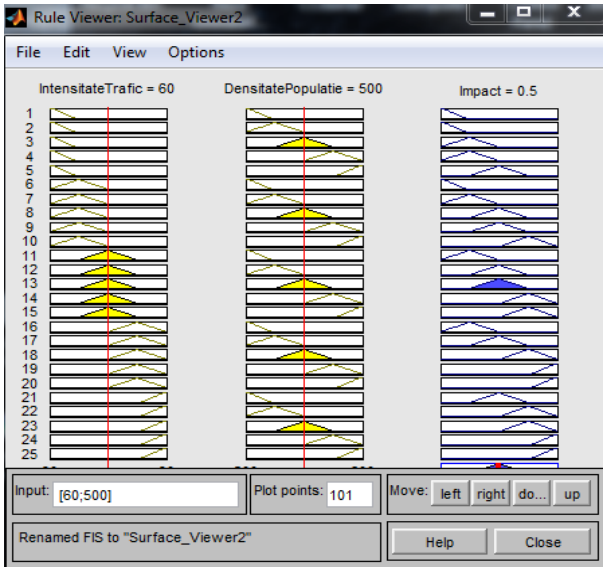

Fig. 9. Interference Rules for Bistrița

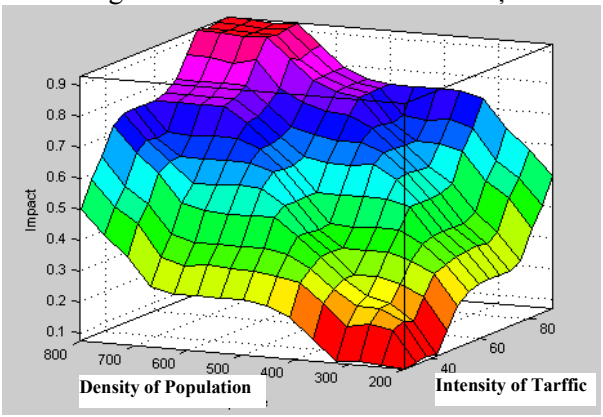

Fig. 10. The Variation Surface of the Impact Indicator in Bistrița

1. Using Fuzzy crowd for to study noise pollutant with impact on the population is a new procedure, but it is very efficient in this study, as resulting from those presented above.
2. Proposed method can provide useful information to the decision makers to identify urban areas with high degree of noise pollution and the risk that it may affect population.
3. Further developing of the method will take into account "refining" the input sizes: of differentiation type traffic (hard, easy), differentiation of population (residents, persons on the workplace). These will able to increase accuracy of results.
4. Method indicated in this paper is a quick and very efficient to set out how noise pollution affect population in a given area of municipality and the way in which traffic more intensely or with less intensity may contribute to a considerable discomfort**.**

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Tehnicile Fuzzy folosite pentru evaluarea poluării sonore

Rezumat: *Lucrarea prezintă aproximarea teoretică pentru aplicarea tehnicilor Fuzzy în două oraşe diferite ale României, paşii necesari în vederea aplicării, program de aplicare, dar şi rezultatele obţinute prin aplicarea metodei. Prin această lucrare se intenţionează să se demonstreze că tehnica Fuzzy poate fi folosită cu succes în evaluarea poluării sonore în aglomerările urbane. Implementarea acestui studiu în aria municipală, cu evaluarea prin tehnica Fuzzy, care este o metodă neinvazivă, şi care se obţine prin determinarea factorului de impact asupra populaţiei ce locuieşte în zone cu trafic intens, poate fi folosită cu succes, pentru că rezultatele obţinute sunt comparabile cu cele rezultate prin metodele clasice de evaluare stabilite în aceleaşi amplasamente. Tehnicile Fuzzy devin o sculă utilă, rapidă şi nondistructivăpentru evaluarea poluări sonore. Aautorii au aplicat primii această idee la evaluarea sonoră.*

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