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ASSESSMENT OF FACTORS OF ECOLOGICAL ACCEPTABILITY AS A CRITERION WHEN DECIDING ON CONSTRUCTION MATERIAL

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ABSTRACT
The application of efficient methodology when choosing the construction materials is one of the essential assumptions for optimizing of designer demands and financial limitations when planning the construction of any kind of objects. Various factors, such as spans, bearing capacity, isolation, costs, durability, etc influence the decision regarding the construction materials. There are also meeting the aesthetic and environmental demands. Therefore, the process of deciding upon the construction material is a complex problem of determining the alternative choice based on several criteria – decision influencing factors. The issue of global warming and worrying effect of the human actions on nature is increasingly directed as addressing the individual that needs to change his living habits and a way of life that includes energy saving. Energy saving is becoming a standard and the assessment of factors of ecological acceptability and its ranking as a criterion when deciding on construction material is thereby more important. For the assessment of ecological acceptability and based on the amount of the energy used for the production of materials and prices of materials, this paper proposes the application of Method of fuzzy logical conclusion (Mamdani) with two input variable and one output variable.
Key words: Decision criterion, construction material, fuzzy logic, environment, ecological acceptability.

1. INTRODUCTION
This paper will propose form of fuzzy clusters (triangle) that leads to usage of fuzzy logic when assessing factors the ecological acceptability of the construction material. Emission of CO_2, consumption of energy in the process of production of construction material, index of emission into water, solid waste, electrostatic characteristics will be used as an input variable and other input variable will be cost price.
With fuzzy logic deduction for the assessment of ecological acceptability factors, we will use two inputs and one output variable as well as the procedure of defuzzyfication.

2. APPLICATION OF FUZZY CLUSTERS TO MATERIAL CLASSIFICATION ACCORDING TO ECOLOGICAL ACCEPTABILITY

2.1. Consumption of energy for the production of materials, the fuzzyfication procedure
The fuzzyfication procedure (procedure of transition from unambiguous to fuzzy clusters), classification of material classes according to their ecological acceptability will be here presented on the example of energy consumption. Analogically, procedure can be implemented also for other aspects of ecological acceptability.
Fuzzyfication of construction material classification according to consumption of energy in the process of production according to APA (Association of wood engineering, USA), in the form of

unambiguous clusters – relative quantities of energy consumption was implemented by defining the membership function for "*Consumption of energy*" and according to the rules of overlapping of fuzzy clusters. Numerical interval from 0 to 32 represents relative quantities of energy consumption for GLULAM, steel and cement taken from APA. Linguistic form of fuzzy sub clusters for "*Energy consumption" is*:

$$EC = \{VSec, Sec, Aec, Hec, VHec\} = \{very\ small, small, average, high, very\ high\}$$

Analytical forms for membership functions of triangle fuzzy clusters are:

$$\mu_{VSec}(x_1) = \begin{cases} \frac{8 - x_1}{8} & za \quad 0 \le x_1 \le 8 \end{cases} \quad \mu_{Sec}(x_1) = \begin{cases} \frac{x_1}{8} & za \quad 0 \le x_1 \le 8 \\ \frac{16 - x_1}{8} & za \quad 8 \le x_1 \le 16 \end{cases} \quad \mu_{Aec}(x_1) = \begin{cases} \frac{x_1 - 8}{8} & za \quad 8 \le x_1 \le 16 \\ \frac{24 - x_1}{8} & za \quad 16 \le x_1 \le 24 \end{cases}$$

$$\mu_{Hec}(x_1) = \begin{cases} \frac{x_1 - 16}{8} & za \quad 16 \le x_1 \le 24 \\ \frac{32 - x_1}{8} & za \quad 24 \le x_1 \le 32 \end{cases} \quad \mu_{VHec}(x_1) = \begin{cases} \frac{x_1 - 24}{8} & za \quad 24 \le x_1 \le 32 \end{cases} \qquad \text{... (1)}$$

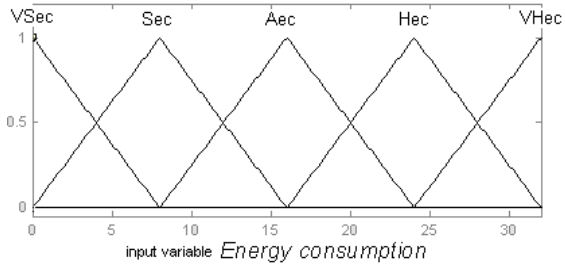

Figure 1. Fuzzy presentation "Energy consumption for material production".

Usually, even though it is not a strict rule, we are striving that the number of fuzzy clusters is equal for all input variables. In the literature we are often using 3, 5 or 7 while fuzzy clusters with 5 for each input variable are dominant. (S. Bojadziev, M. Bojadziev, 2007)

3. APPLICATION OF MAMDANI'S METHOD OF FUZZY LOGIC DEDUCTION WHEN ASSESSING THE FACTOR OF ECOLOGICAL ACCEPTABILITY BASED ON THE ENERGY CONSUMPTION AND PRICE OF THE MATERIAL

In order to assess the factor of ecological acceptability based on the quantity of energy consumption for material production and price, here we are suggesting the application of Mamdani model of deduction with two input variable and one output variable.

After defining fuzzy clusters (fuzzyfication) for energy consumption, classified according to APA, as one input variable (input 1) takes fuzzy cluster: *Consumption of energy* and other input variable (input 2) will be fuzzy cluster *Cost of materials*, which form is suggested as it is illustrated in the Figure 2.

For fuzzy cluster "Cost of materials" linguistic form of fuzzy sub clusters is:

$C = \{S, A, H\} = \{small, average, high\}$, and it is defined by the equations:

$$\mu_{Small}(x_2) = \begin{cases} \frac{0{,}4 - x_2}{0{,}4} & za \quad 0 \le x_2 \le 0{,}4 \end{cases}$$

$$\mu_{Average}(x_2) = \begin{cases} \frac{x_2 - 0{,}1}{0{,}4} & za \quad 0{,}1 \le x_2 \le 0{,}5 \\ \frac{0{,}9 - x_2}{0{,}4} & za \quad 0{,}5 \le x_2 \le 0{,}9 \end{cases} \qquad \text{... (2)}$$

$$\mu_{High}(x_2) = \begin{cases} \frac{x_2 - 0{,}6}{0{,}4} & za \quad 0{,}6 \le x_2 \le 1 \end{cases}$$

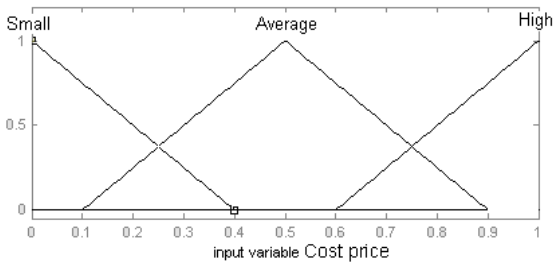

Figure 2. Triangle Fuzzy clusters, defined by terms (5.4) as a general form of input variables. Cost price, normalized to the interval l [0,1].

Therefore, based on the data on energy consumption and Material cost as input variables by using fuzzy (Mamdani) model of deduction we come to the assessment of *Factors of ecological acceptability for energy consumption (FEAec)* in form of fuzzy cluster *(Figure 3)* that represents an input variable of fuzzy deduction procedure.

$$\mu_{Small}(x_3)=\begin{cases}\dfrac{0,4-x_3}{0,4} & za \quad 0\le x_3\le 0,4\end{cases} \qquad \mu_{Average}(x_3)=\begin{cases}\dfrac{x_3-0,1}{0,4} & za \quad 0,1\le x_3\le 0,5\\ \dfrac{0,9-x_3}{0,4} & za \quad 0,5\le x_3\le 0,9\end{cases}$$

$$\mu_{High}(x_3)=\begin{cases}\dfrac{x_3-0,6}{0,4} & za \quad 0,6\le x_3\le 1\end{cases} \qquad \text{... (3)}$$

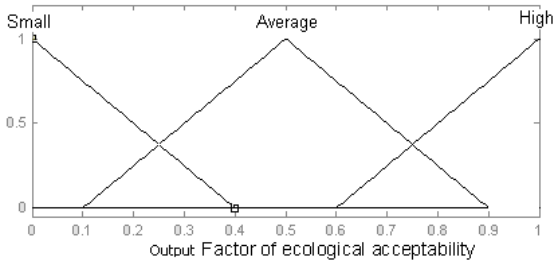

Figure 3. Triangle Fuzzy clusters defined by terms (3) as a general form of output variable Factor of ecological acceptability for energy consumption, normalized to interval [0,1].

Figure 4 illustrates the scheme of application of Mamdani's model o fuzzy deduction with two input variables *energy consumption and Material costs* and one output variable *Factor's of ecological acceptability for energy consumption (FEPue).*

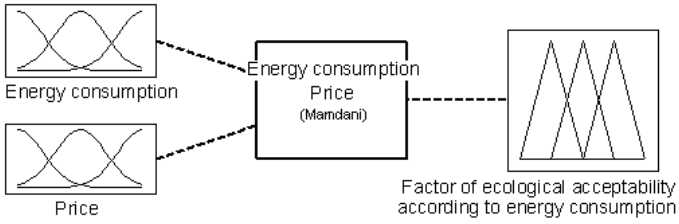

Figure 4. Scheme of decision making by Mamdani method with two inputs "Energy consumption" and "Price" and one output "Factor of ecological acceptability according to energy consumption"

Next step with the application of Mamdani model is forming of decision making rules basis. Number of rules is a product of number of fuzzy sub clusters of input variables (*nxm*) and in this case is 3x5=15. Rules are formed based on the application of table of deduction rules (*Table No. 1*).

Table 1. Cluster of fuzzy rules for input variables "energy consumption" and "Price" and one output ""Factor of ecological acceptability according to energy consumption" ".

	PRICE	Small	Average	High
ENERGY CONSUMPTI	Very small	High	High	Average
	Average	High	Average	Average
	Average	Average	Average	Average
	High	Average	Average	Small
	Very high	Average	Small	Small

For the cluster of rules given in the Table. 1, spatial diagrams are given in the Figure 5.

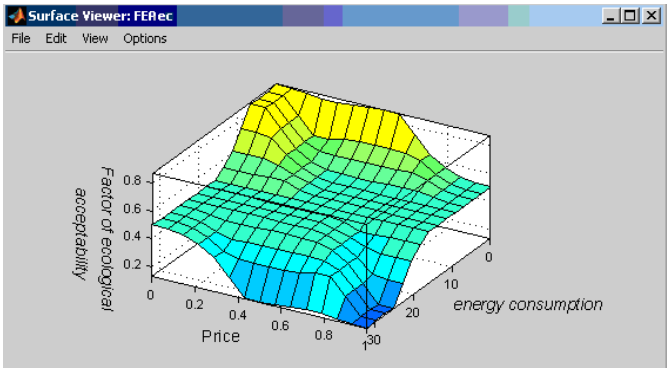

Figure 5. Surface viewer, spatial diagram(MatLab, FL tools) for the Factor of ecological acceptability for energy consumption.

4. CONCLUSIONS

Interpretation and presentation of the indicators of ecological acceptability of materials as input information into models of decision making on choosing the construction materials is subjective and inaccurate.

Therefore, when the input variables are inaccurate or they are the result of subjective opinion, introduction of fuzzy theory i.e. fuzzy logic is a suitable concept and its application (Mamdani method) with elaborated procedure for specific example is given as one of the results of this paper.

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