APPLICATION OF THE FUZZY LOGIC IN THE EVALUATION OF SOLUTION VARIANTS IN THE PRODUCT DEVELOPMENT PROCESS

Mihai Robert VLADU[1], George DOBRE[2], Radu Florin MIRICĂ[3]

Logica fuzzy reprezintă un instrument excelent pentru a se ocupa de incertitudinile şi informaţiile incomplete care apar în procesul de evaluare şi pentru determinarea soluţiei optime. Luând în considerare această idee, lucrarea prezintă aplicarea logicii fuzzy în evaluarea variantelor de soluţii din cadrul procesului de dezvoltare de produs pentru diminuarea subiectivităţii în procesul de evaluare şi de stabilire astfel a soluţiei optime. Prin generarea automată a bazei de reguli fuzzy este diminuată subiectivitatea stabilirii valorilor unor mărimi specifice (factori de pondere şi criterii de evaluare).

The fuzzy logic represents an excellent instrument to deal with the uncertainty and incomplete information that appear in the evaluation process and to establish the optimal solution. Taking into account this idea, the paper presents the application of fuzzy logic in the evaluation of the solution variants in the product development process to diminish the subjectivity in evaluation process and to establish thus the optimal solution. Generating automatically a fuzzy rule base, the subjectivity of establishing values of specific quantities (weighting factors and evaluation criteria) is diminished.

Keywords: fuzzy logic; product development; subjectivity in evaluation process; fuzzy rule base; weighting factors; evaluation criteria

1. Introduction

Considering the needs of the companies to achieve low-cost and high-quality products that must be reliable throughout their life cycle and to fully satisfy the customers' needs and wants it is very important that the product development process to be continuously improved.

[1] PhD Student, Department of Machine Elements and Tribology, University POLITEHNICA of Bucharest, Romania, e-mail: mvladu@omtr.pub.ro
[2] Prof. Dr., Department of Machine Elements and Tribology, University POLITEHNICA of Bucharest, Romania, e-mail: G.Dobre@gmail.com
[3] Assoc. Prof. Dr., Department of Machine Elements and Tribology, University POLITEHNICA of Bucharest, Romania, e-mail: mirica@meca.omtr.pub.ro

The analysis and evaluation of different conceptual or embodiment solution variants of a product and the establishing of the optimal solution in order to be widely produced in accordance with customer requirements is a current issue in the product development process. The decision to establish the optimal product solution in product development process is difficult and raises many questions; thus the importance of this decision is extremely high. The actual and most known evaluation method is proposed by Pahl et al. [1] which combines two types of approaches recommended: cost-benefit-analysis [2] and technical and economic evaluation [3] derived from [4]. From these approaching the following conclusions could be extracted:

- the evaluation methods are subjective and depend on the human experts who realized the evaluation;
- diminishing this subjectivity in this evaluation process represents another important problem.

Taking into account the benefits of fuzzy logic [5] to deal with the uncertain, imprecise and inexact information a fuzzy logic approach in the evaluation of solution variants it is necessary to resolve the problems presented above.

In the literature, the fuzzy logic approach in the product development process helped:

- to develop an intelligent knowledge-based system for the estimation of the product manufacturing cost which included material, processing, machine set-up and non-productive costs in the stage of the conceptual design [6];
- to optimize the manufacturability, reliability and quality of the modular architecture of the product during the concept development stage and to minimize the cost of modularization using a proposed intelligent knowledge-based system [7];
- to realize a prototype system which can assist inexperienced users to perform the failure mode and effects analysis for quality and reliability improvement, alternative design evaluation, materials selection and cost assessment [8];
- to deal with the problems of heterogeneous information and information loss during the processes of subjective evaluation and to measure the performance of new product development [9];
- to develop a risk analysis model which is possible to determine the risk degrees of the risk factors from the product development process [10];
- to improve the failure mode and effects analysis in order to deal with the acquirement of the members' team diversity opinions and to determinate the risk priorities of the failure modes that have been identified [11].

After this analysis of the state of the art in field it is visible that the approach of fuzzy logic in the evaluation of solution variants in product development process was not an aim of study.

The paper exposes the application of fuzzy logic in the evaluation of the solution variants of a product used before or after the conceptual design in the product development process. This approach offers the possibility to diminish the subjectivity of the values of weighting factors and evaluation criteria.

2. Subjective aspects in the evaluation of solution variants in product development

At it was mentioned, the most known evaluation method is proposed by Pahl et al. [1]. The method consists in the establishment of a tree network of technical and economic criteria arranged on levels of dependence and which are mainly derived from the requirements list and from general constraints; such a tree network with four levels of dependency is presented in Fig. 1. The criterion 1 from the first level is detailed using the criteria 11 and 12 from the level 2, each of those two criteria are further detailed until the criteria from the last level are established. Thus, the criteria are arranged into levels of decreasing complexity. The criteria with the lowest complexity form the evaluation criteria used for the assessment of the solutions.

"For the quantitative appreciation of each criterion are used two weighting factor. A weighting factor is a real, positive number ranging on a scale from 0 to 1 (or the scale can be chosen from 0 to 100). In the paper will be used the scale from 0 to 1. The two factors are the node weighting factor, n, which indicate the relative contribution of the criterion to the associated sub-group with respect to the superior criterion and the level weighting factor, l, which indicates the relative importance of a criterion at a particular level with respect to the criterion from the first level (for example, Criterion 1 in Fig. 1).

The node weighting factors are determinate by human experts. The sum of the node weighting factors of a sub-group at any level must always be equal to 1. For example, at the level 2 the sub-group associated to the criterion from the first level: $n_{11} + n_{12} = 0.8 + 0.2 = 1$; at the level 3 the first sub-group associated to the first criterion of the level 2: $n_{111} + n_{112} + n_{113} + n_{114} = 0.3 + 0.2 +0.2 + 0.3 = 1$ and so on.

The level weighting factor is determined by the product between the node weighting factor of the considered criterion and the level weighting factor of the superior associated criterion.

The sum of the level weighting factors of all evaluation criteria (at the lowest levels) is equal to 1 ($\Sigma l_i = 1$). Thus, a percentage weighting can be attached to all of the evaluation criteria."

The evaluation of the solution variants consists in (details in [1] and [12]):

1. analysis of each solution variant:
   a) for each evaluation criterion will be assigned a chosen assessing value according to a value scale, usually from 0 to 10 (Table 1) by the human experts;

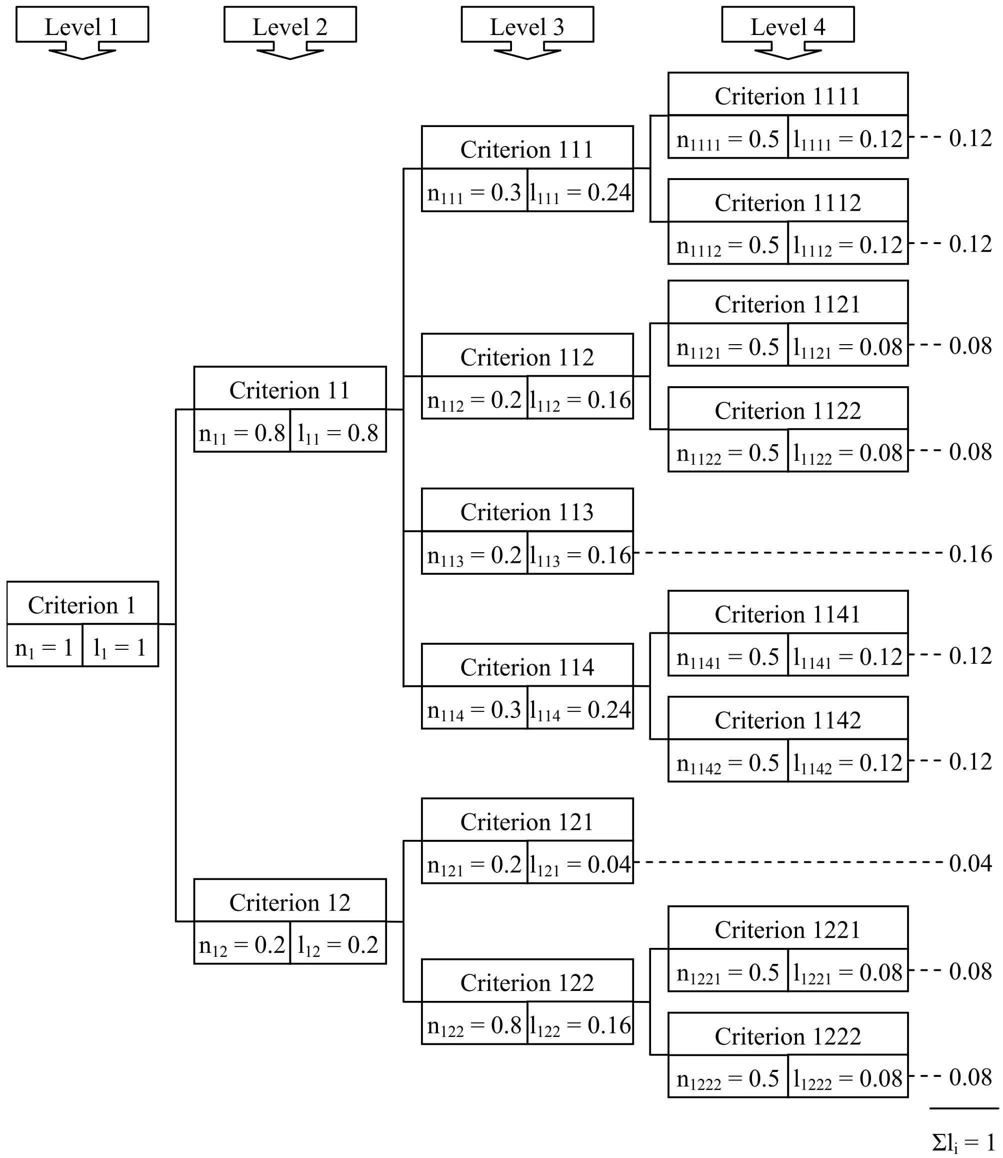

Fig. 1. Example of tree network criteria with weighting factors [1]

   b) calculation of the final overall values (unweighted and weighted);
2. comparison of the solution variants. The solution variant with the highest overall values (unweighted and weighted) will be the optimal solution.

The unweighted overall value will be calculated with the equation (1):

$$v_{\Sigma} = \sum_{i=1}^{n} v_i \,, \tag{1}$$

where: v_{Σ} is unweighted overall value of the solution variant; v_i - chosen assessing value of the evaluation criterion i.

Table 1

Recommended assessing value scale for evaluation criteria [1]

Chosen assessing value	Signification	Chosen assessing value	Signification
0	Absolutely useless	6	Good with few drawbacks
1	Very inadequate	7	Good
2	Weak	8	Very good
3	Tolerable	9	Exceeding the requirement
4	Adequate	10	Ideal
5	Satisfactory		

The weighted overall value will be calculated with the equation (2):

$$(lv)_{\Sigma} = \sum_{i=1}^{n} l_i v_i \,, \tag{2}$$

where: $(lv)_{\Sigma}$ - weighted overall value of the solution variant; l_i - level weighting factor of the evaluation criterion i.

3. Application of fuzzy logic in the evaluation method

The chosen assessing values of the node weighting factors are imprecise, uncertain, inexact, ambiguous, in other words, vague. This fact gives the subjective character of these factors. Thus, the subjective character of node weighting factors (or all types of weighting factors) represents an actual problem in the evaluation of the solution variants because these have a high influence in the determination of the optimal solution. A small variation of these factors can significantly change the results of the evaluation. Therefore, the diminishing of the node weighting factors subjectivity is an important and actual problem.

The presented evaluation method doesn't have the possibility to deal with these types of vague values of the node weighting factors. The applicability of the fuzzy logic (which is usually used to approach the imprecise, uncertain or vague information) in the evaluation method represents an efficient solution to this problem. Thus, the proposed approach suggest that instead of using the equation

(1) and (2) to calculate the overall values for each solution variant will be used fuzzy logic to determine an assessing weighting global value for each solution variant.

The fuzzy logic will be applied for each sub-group of criteria (starting with the sub-groups from the lowest level) and for the associated superior criterion creating in this way a network tree of fuzzy logic systems which will be used to calculated the assessing weighting global value for each solution variant. The sub-group of criteria will represent the input variables of the fuzzy logic system and the associated superior criterion will be the output variable.

For simplifying the explanation of the proposed approach will be presented the applicability of the fuzzy logic only for a sub-group of criteria. Thus, will be taken as example the first sub-group of criteria from the level 3 presented in the Fig. 1 (Criterion 111…Criterion 114) together with the associated superior criterion (Criterion 11); creating in this way a fuzzy logic system.

To create the fuzzy logic system for the above example must be define four important steps:

1. The type of the fuzzy inference system (Mamdani type [13]) and the defuzzification method (centroid method);
2. The input and output variables (four input variables and one output variable);
3. The membership functions attached to each variable (all the input variables will have five triangular membership functions represented in Fig. 2 and the output variable will have eleven triangular membership functions represented in Fig. 3);
4. The rule base of the system which contains all the fuzzy rules.
5.

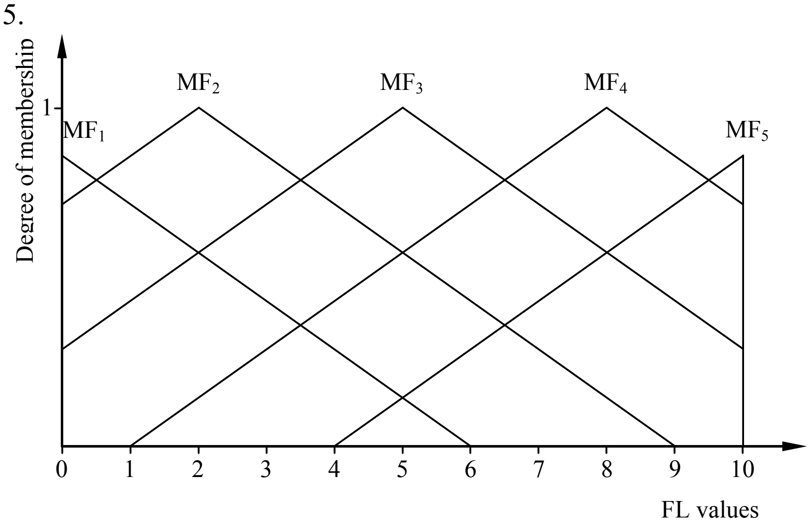

Fig. 2. Representation of the five triangular membership functions for the input variables

The classical forms of the triangular membership functions have leaded to inconclusive results. Really, a logical aspect to evaluate the solution variants is that if two solution variants are distinguished by the assessing value of a single criterion (the assessing values of others criteria are identically for both solution variants), then the solution variant with the highest assessing value is the best solution. In some cases, the classical representation does not fulfill this characteristic. Thus, particularly forms of triangular membership functions have been determined to accomplish this logical aspect. The determination process was based on the study and simulation of the influence of the membership functions on the results.

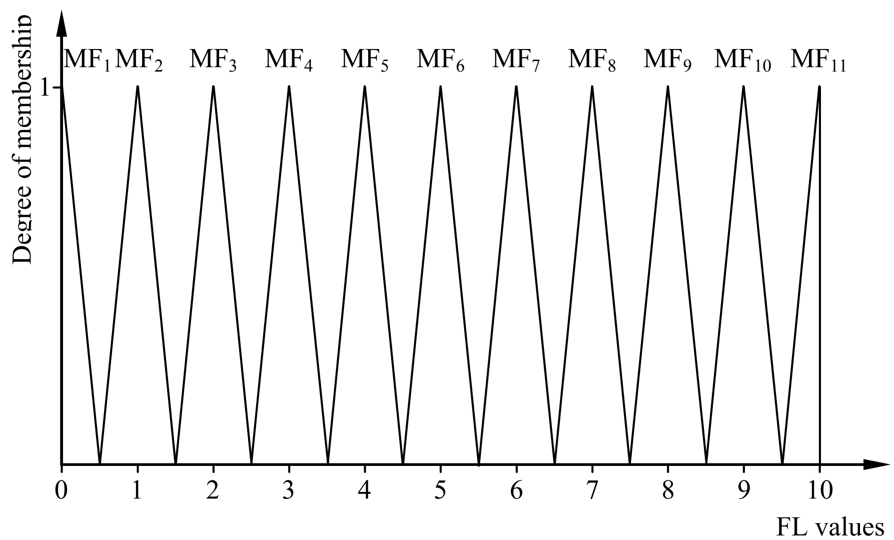

Fig. 3. Representation of the eleven triangular membership functions for the output variable

The fuzzy rules are expressed in the form of "If-Then" rules (If x is A Then y is B, where A and B are linguistic values defined by fuzzy sets on the universes of discourse X and Y). Such rules are usually formulated more conveniently in linguistic terms than in numerical terms.

The "If-Then" rules have two parts: the "If" part of the rule (If x is A) called the antecedent or premise, while the "Then" part of the rule (Then y is B) is called the consequence or conclusion.

The rule base used for this application is a complete rule base and the number of fuzzy rules is given by the product between the numbers of membership functions of each input variables of the fuzzy logic system [14]. For the above example the complete rule base have 625 fuzzy rules (four input variables with five membership functions for each, $5 \cdot 5 \cdot 5 \cdot 5 = 625$).

The complete rule base of a fuzzy logic system can be seen as a structure in which the columns represent the inputs and outputs variables and the rows are the fuzzy rules (Fig. 4). Thus, for the above example the complete rule base will be a structure with 5 columns (four input variables and one output variable) and 625 rows (number of fuzzy rules). The membership functions of the input or output variables will be represented by numbers. For the first membership function of a variable the number will be 1, for the second membership function will be 2 and so on to the last membership function (which is 5 in the case of the input variables and 11 for the output variable).

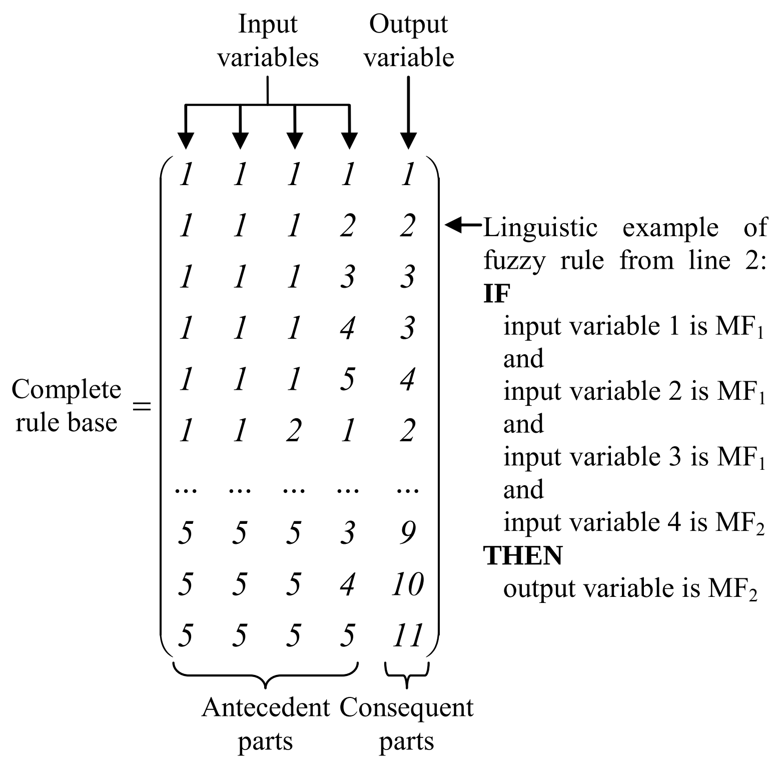

Fig. 4. Structure of complete rule base of the first sub-group of criteria from the level 3 presented in the Fig. 1

The structure from Fig. 4 contains two parts.

1. The first part is formatted by the first four columns (which represent the four input variables) and will contains all the possible combinations of the membership functions of the input variables. Thus, each row symbolizes the antecedent part of a fuzzy rule.
2. The second part is formatted by the last column (representing the output variable) and which contains the membership functions of the output variable corresponding to each antecedent part. Each row symbolizes the consequent part of the fuzzy rule.

The establishment of the second part (last column) of the structure from Fig. 4 will be made using a fuzzy logic sub-system. The sub-system will automate determinate the appropriate membership function of the output variable for all the antecedent parts; obtaining in this way the last column (the consequence parts) of the structure. Also, for the determination of the consequence parts of the fuzzy rules will be taken into account the node weighting factors of the studied sub-group of criteria ($n_{111} = 0.3$, $n_{112} = 0.2$, $n_{113} = 0.2$ and $n_{114} = 0.3$).

Respecting the four steps for defining the fuzzy logic sub-system the next observations can be made:

1. the fuzzy inference system is Mamdani type and the defuzzification method is centroid;
2. the variables of the fuzzy logic sub-system are: four input variables and one output variable;
3. all the input variables will have five triangular membership functions (represented in Fig. 5) and the output variable will have eleven triangular membership functions (represented in Fig. 3);
4. the complete rule base of the fuzzy logic sub-system will be created by applying the same principle of the structure from Fig. 4.

The structure for this complex rule base of the fuzzy logic sub-system (not-represented here) will have 5 columns (four input variables and one output variable) and 625 rows (representing the fuzzy rules).

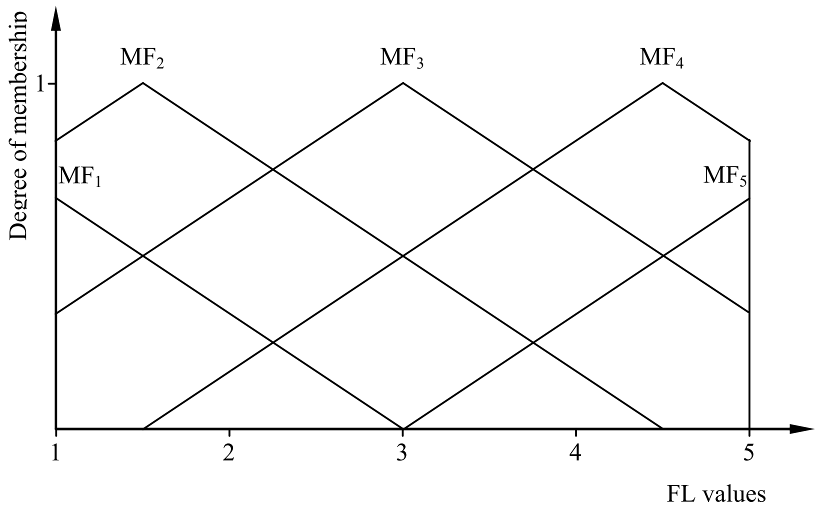

Fig. 5. Representation of the five triangular membership functions for the input variables of the fuzzy logic sub-system

The first part of the structure will created in the same way as it was presented above; for the second part (in which will be established the consequence parts for all the fuzzy rules) will be calculated a value for each antecedent part using the equation (3). Also, each membership function of the output variable has attached a range of values (Table 2). After, the value of the antecedent part will be framing in one of the range of values presented in Table 1. Thus, will be established the membership function of the output variable for each antecedent part; in this way will be obtained the last column (consequence parts) of the structure for the fuzzy logic sub-system.

$$r_i = mf_{i1} \cdot n_{111} + mf_{i2} \cdot n_{112} + mf_{i3} \cdot n_{113} + mf_{i4} \cdot n_{114}, \quad (3)$$

where: r_i is the value of the rule i; $mf_{i1} \ldots mf_{i4}$ - elements of columns 1…4 and row i of the structure; $n_{111} \ldots n_{114}$ - node weighting factors of the inputs variable. The expression is valid for i = 1…625.

Table 2

Range of values attached to each membership function of the output variable for the fuzzy logic sub-system

Membership function of the output variable	**Range of values**
MF_1	[1.00 … 1.21]
MF_2	[1.22 … 1.61]
MF_3	[1.62 … 2.01]
MF_4	[2.02 … 2.41]

MF_5	[2.42 … 2.81]
MF_6	[2.82 … 3.19]
MF_7	[3.20 … 3.59]
MF_8	[3.60 … 3.99]
MF_9	[4.00 … 4.39]
MF_{10}	[4.40 … 4.79]
MF_{11}	[4.80 … 5.00]

The fuzzy logic systems for all others sub-groups of criteria used to determine the assessing weighting global value of each solution variant are created in the same way.

4. Case of study

To demonstrate that the applicability of the fuzzy logic in the evaluation method has as effect the diminishing of the node weighting factors subjectivity an example study is proposed. The example presents different cases in which the node weighting factors for some criteria vary slightly and for other ones are constant. The influence of these factors on the evaluation of the different solution variants will be analyzed in comparison with the actual evaluation method.

The first sub-group of criteria from the level 3 (Fig. 1) is taken as example. Table 3 considers two cases (first and second) maintaining the same weighting values for two criterions (112 and 113) and varying slightly the other ones (111 and 114). The values of the node weighing factors are given in Fig. 1 for the first case and in the second case two node weighting factors (randomly chosen) vary slightly in comparison with the first case.

Table 3

Cases of the node weighting factors

Cases	**Node weighting factors**				**Sum of the weighting factors**
	Criterion 111, n_{111}	**Criterion 112, n_{112}**	**Criterion 113, n_{113}**	**Criterion 114, n_{114}**	
First case	0.3	0.2	0.2	0.3	1
Second case	0.35	0.2	0.2	0.25	1

For the analysis of the fuzzy logic influence in the evaluation of different solution variants and the comparison with the actual evaluation method will be considered for both of the cases that the chosen assessing values (see Table 1) for the criteria 112 and 113 as been fixed (the values will be chosen randomly) and for the criteria 111 and 114 (the criteria for which the node weighting factors vary slightly) will be considered all the chosen assessing values shown in Table 1. In this way will be simulated the results for all the created situations.

In the Table 4 or, respectively, in Table 5, the weighting overall evaluation values (calculated with equation 2) are presented for all the situations described above for the node weighting factors of the first case, respective second case. In Table 6 is presented the difference of the weighted overall evaluation values between the two cases.

Table 4

Weighted overall evaluation values for the first case mentioned in Table 3

		Assessing values of the criterion 111										
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Assessing values of the criterion 114	**0**	2.20	2.50	2.80	3.10	3.40	3.70	4.00	4.30	4.60	4.90	5.20
	1	2.50	2.80	3.10	3.40	3.70	4.00	4.30	4.60	4.90	5.20	5.50
	2	2.80	3.10	3.40	3.70	4.00	4.30	4.60	4.90	5.20	5.50	5.80
	3	3.10	3.40	3.70	4.00	4.30	4.60	4.90	5.20	5.50	5.80	6.10
	4	3.40	3.70	4.00	4.30	4.60	4.90	5.20	5.50	5.80	6.10	6.40
	5	3.70	4.00	4.30	4.60	4.90	5.20	5.50	5.80	6.10	6.40	6.70
	6	4.00	4.30	4.60	4.90	5.20	5.50	5.80	6.10	6.40	6.70	7.00
	7	4.30	4.60	4.90	5.20	5.50	5.80	6.10	6.40	6.70	7.00	7.30
	8	4.60	4.90	5.20	5.50	5.80	6.10	6.40	6.70	7.00	7.30	7.60
	9	4.90	5.20	5.50	5.80	6.10	6.40	6.70	7.00	7.30	7.60	7.90
	10	5.20	5.50	5.80	6.10	6.40	6.70	7.00	7.30	7.60	7.90	8.20

Note. The assessing values for the other two criteria are: 7 (criterion 112) and 4 (criterion 113).

Table 5

Weighted overall evaluation values for the second case mentioned in Table 3

		Assessing values of the criterion 111										
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Assessing values of the criterion 114	**0**	2.20	2.55	2.90	3.25	3.60	3.95	4.30	4.65	5.00	5.35	5.70
	1	2.45	2.80	3.15	3.50	3.85	4.20	4.55	4.90	5.25	5.60	5.95
	2	2.70	3.05	3.40	3.75	4.10	4.45	4.80	5.15	5.50	5.85	6.20
	3	2.95	3.30	3.65	4.00	4.35	4.70	5.05	5.40	5.75	6.10	6.45
	4	3.20	3.55	3.90	4.25	4.60	4.95	5.30	5.65	6.00	6.35	6.70
	5	3.45	3.80	4.15	4.50	4.85	5.20	5.55	5.90	6.25	6.60	6.95
	6	3.70	4.05	4.40	4.75	5.10	5.45	5.80	6.15	6.50	6.85	7.20
	7	3.95	4.30	4.65	5.00	5.35	5.70	6.05	6.40	6.75	7.10	7.45
	8	4.20	4.55	4.90	5.25	5.60	5.95	6.30	6.65	7.00	7.35	7.70
	9	4.45	4.80	5.15	5.50	5.85	6.20	6.55	6.90	7.25	7.60	7.95
	10	4.70	5.05	5.40	5.75	6.10	6.45	6.80	7.15	7.50	7.85	8.20

Note. The assessing values for the other two criteria are: 7 (criterion 112) and 4 (criterion 113).

Table 6

The difference of the weighted overall evaluation values between the two cases mentioned in Table 3

		Assessing values of the criterion 111										
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Assessing values of the criterion 114	**0**	0	-0.05	-0.10	-0.15	-0.20	-0.25	-0.30	-0.35	-0.40	-0.45	-0.50
	1	0.05	0	-0.05	-0.10	-0.15	-0.20	-0.25	-0.30	-0.35	-0.40	-0.45
	2	0.10	0.05	0	-0.05	-0.10	-0.15	-0.20	-0.25	-0.30	-0.35	-0.40
	3	0.15	0.10	0.05	0	-0.05	-0.10	-0.15	-0.20	-0.25	-0.30	-0.35
	4	0.20	0.15	0.10	0.05	0	-0.05	-0.10	-0.15	-0.20	-0.25	-0.30
	5	0.25	0.20	0.15	0.10	0.05	0	-0.05	-0.10	-0.15	-0.20	-0.25
	6	0.30	0.25	0.20	0.15	0.10	0.05	0	-0.05	-0.10	-0.15	-0.20
	7	0.35	0.30	0.25	0.20	0.15	0.10	0.05	0	-0.05	-0.10	-0.15
	8	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05	0	-0.05	-0.10
	9	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05	0	-0.05
	10	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05	0

Note. The assessing values for the other two criteria are: 7 (criterion 112) and 4 (criterion 113).

In the Table 7 or, respectively, in Table 8, the assessing weighting global values (calculated using described fuzzy logic system) are presented for all the situations described above for the node weighting factors of the first case, respective second case. In Table 9 is presented the difference of the assessing weighting global values between the two cases.

Table 7

Assessing weighting global values for the first case mentioned in Table 3

		Assessing values of the criterion 111										
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Assessing values of the criterion 114	**0**	3.54	3.62	3.71	3.80	3.91	4.18	4.41	4.59	4.76	5.00	5.08
	1	3.62	3.75	3.83	3.92	4.03	4.28	4.51	4.70	4.88	5.12	5.20
	2	3.71	3.83	4.08	4.17	4.28	4.54	4.74	4.93	5.10	5.34	5.42
	3	3.80	3.92	4.17	4.39	4.51	4.74	4.92	5.09	5.27	5.51	5.59
	4	3.91	4.03	4.28	4.51	4.70	4.93	5.09	5.21	5.38	5.62	5.70
	5	4.18	4.28	4.54	4.74	4.93	5.10	5.27	5.38	5.58	5.84	5.93
	6	4.41	4.51	4.74	4.92	5.09	5.27	5.51	5.62	5.84	6.10	6.20
	7	4.59	4.70	4.93	5.09	5.21	5.38	5.62	5.70	5.93	6.20	6.29
	8	4.76	4.88	5.10	5.27	5.38	5.58	5.84	5.93	6.02	6.29	6.39
	9	5.00	5.12	5.34	5.51	5.62	5.84	6.10	6.20	6.29	6.38	6.47
	10	5.08	5.20	5.42	5.59	5.70	5.93	6.20	6.29	6.39	6.47	6.54

Note. The assessing values for the other two criteria are: 7 (criterion 112) and 4 (criterion 113).

Analyzing Table 6 (in which is shown the different of the results between the two cases of weighted overall evaluation values) can be seen the fact that in the actual evaluation method if the node weighting factors vary slightly, this variation is important and affects most of the results, thus the subjective character of the node weighting factors is high. On the other hand, in Table 9 can be observed that using fuzzy logic in the evaluation method most of the results are not affected by the variation of the node weighting factors. Thus, the fuzzy logic approach in the evaluation method offers as advantage the diminishing of the node weighting factors subjectivity.

Table 8

Assessing weighting global values for the second case mentioned in Table 3

		Assessing values of the criterion 111										
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Assessing values of the criterion 114	**0**	3.54	3.62	3.71	3.80	4.02	4.27	4.49	4.69	4.92	5.19	5.28
	1	3.62	3.75	3.83	3.92	4.03	4.28	4.51	4.70	4.93	5.20	5.29
	2	3.71	3.83	4.08	4.17	4.28	4.54	4.74	4.93	5.10	5.37	5.46
	3	3.80	3.92	4.17	4.39	4.51	4.74	4.92	5.09	5.27	5.51	5.60
	4	3.91	4.03	4.28	4.51	4.70	4.93	5.09	5.21	5.38	5.62	5.70
	5	4.18	4.28	4.54	4.74	4.93	5.10	5.27	5.38	5.58	5.84	5.93
	6	4.41	4.51	4.74	4.92	5.09	5.27	5.51	5.62	5.84	6.10	6.20
	7	4.59	4.70	4.93	5.09	5.21	5.38	5.62	5.70	5.93	6.20	6.29
	8	4.73	4.85	5.10	5.27	5.38	5.58	5.84	5.93	6.02	6.29	6.39
	9	4.91	5.03	5.28	5.51	5.62	5.84	6.10	6.20	6.29	6.38	6.47
	10	4.91	5.03	5.28	5.51	5.70	5.93	6.20	6.29	6.39	6.47	6.54

Note. The assessing values for the other two criteria are: 7 (criterion 112) and 4 (criterion 113).

Table 9

The difference of the assessing weighting global values s between the two cases mentioned in Table 3

		Assessing values of the criterion 111										
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Assessing values of the criterion 114	**0**	0	0	0	0	-0.11	-0.09	-0.08	-0.11	-0.16	-0.19	-0.20
	1	0	0	0	0	0	0	0	0	-0.05	-0.08	-0.09
	2	0	0	0	0	0	0	0	0	0	-0.03	-0.04
	3	0	0	0	0	0	0	0	0	0	0	-0.01
	4	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0
	8	0.03	0.03	0	0	0	0	0	0	0	0	0
	9	0.09	0.09	0.06	0	0	0	0	0	0	0	0
	10	0.17	0.17	0.14	0.08	0	0	0	0	0	0	0

Note. The assessing values for the other two criteria are: 7 (criterion 112) and 4 (criterion 113).

5. Conclusions

The paper presents the application of fuzzy logic in the evaluation of the solution variants from the product development process. The application of the fuzzy logic in the evaluation process presents the advantage to deal with the uncertainty and incomplete information that appear in this evaluation procedure. Also, fuzzy logic is used in the decision process to find the optimal solution, which is evidently integrated into the evaluation process of solution variants. The main advantage is represented by the diminishing of the weighting factors and chosen assessing values subjectivity.

In the paper a method to automatically generate a complete fuzzy rule base is also presented. This method simplifies the way of obtaining the fuzzy rules and no limits the number of the input variables (criteria) or the number of membership functions attach to these variables. This represents a very important aspect in the definition of the fuzzy logic systems.

The proposed evaluation method provides an excellent support for the inexperienced users to realize the assessment of the solution variants before or after the conceptual design and to find thus the optimal solutions.

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