Fuzzy Approach for Project Team Members Work Evaluation

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Abstract: *Project team work depends considerably on the contribution of its members and its management as well. Cooperation among members depends on the leader who is supposed to encourage interactions, growth and knowledge exchange among members. To identify the importance of each individual, a leader/manager must evaluate individual contributions. On the basis of such assessments, necessary and possible actions will be undertaken to improve the achievements of the team as a whole. A leader usually has defective and incomplete information at his disposal and, besides, is subjective. To solve the aforesaid problem, fuzzy approach and fuzzy logic are used. Fuzzy logic, as a method for soft computing, as input values employs data with the following features; uncertainty and partial verity, indistinctive borders among particular categories. Fuzzy evaluation model has been designed to reduce evaluation subjectivity.*

Keywords: *evaluation, fuzzy approach, fuzzy logic, project team, uncertainty*

1. INTRODUCTION

Everyday working life brings different problem situations and it is not easy to find and choose right procedures and define rules to solve them. In spite of formal education and experience, attained solutions frequently are not satisfactory. Apart from particular complexity of a problem which is the rub in itself, problem solution is made even more difficult because of numerous entities existing in problem vicinity. They are interconnected, they have influence upon the problem itself and interact by means of numerous heterogeneous connections of different importance, quality and frequency. On the other hand, an individual who must solve the problem is under the influence of the aforementioned factors and his judgment ability is subject to judgment subjectivity. For high quality evaluation, on which depends success of a particular work, this fact represents additional difficulty influence of which should be completely eliminated or, at least, reduced as much as possible.

2. CLASSICAL AND FUZZY APPROACH TO CLASSIFICATION

Classical theory of sets has considerably contributed to the development of numerous scientific program solutions designed for decision making where phenomena can be precisely measured. In problem fields where there are no such measuring possibilities, classical set theory does not render good results. Employment of classical sets theory can lead to misinterpretation of data and knowledge. Sometimes transfer from one set to another is not precise but gradual. In such cases, to classify members into well defined groups, it is necessary to define arbitrary boundaries among sets. The problem is even bigger when information needed for decision making are not available in exact, mathematic form, so judgment must be made with certain percentage of uncertainty. Such reflections have resulted in the development of fuzzy sets theory, which differs from classical theory in one key standpoint: a member can belong to a fuzzy set, not belong to it, or belong to it in a certain degree - value of which is somewhere between these two extremes. Membership or not to a fuzzy set and its presentation through certain values makes classical theory a special case of fuzzy set theory. In classical sets theory a member can belong to a set if, and only if, it fulfils all conditions of the membership, otherwise it doesn't belong to the set. If, for example, the set "satisfying" contains the values from 8 to 14, an individual to get such a mark must have at least 8 and at the most 14 points. If he/she has 7.9 points, he/she will not belong to the set "satisfying". Since there are no indicators showing how close an eliminated individual is to a set membership, an individual having only 1 point will be eliminated from the set "satisfying" (and ranged, put into the set "unsatisfying") as well as an individual having 7.9 points. Classifying the one having only 1 point and the one having 7.9 points into the same category, i.e. ranging the persons having 7.9 and 8 points into different categ ories leads to, if we apply classical sets theory, inconsistency.

Since the creation of logic rule that every statement is at the same time true and false, there have been some doubts about that [1, p. 41]. Although the roots of such reflections can be found in Aristotel, Bool, Peirce, Vasiliev, in contemporary sense we must consider Lukasiewicz's and Post's early works. Independently from each other, these authors have systematically defined multi-valued logic systems, Lukasiewicz being motivated by philosophical reasons and Post by mathematic ones. Lukasiewiscz in his work "On determinism" states if allegations about future events are true (sign 1) or false (sign 0), then the future is as much determined as the past, the only difference is that the future has not happened yet [3, p. 72]. The ancient Epicurus teaching supported indeterminism and rejected the principle of logic bivalence, while the Stoics accepted it and strongly advocated determinism [4, p. 8]. To overcome the dead end of determinism, Lukasiewicz abandoned the traditional rule on the elimination of the third one, which reads: "every allegation is whether true or false in the same sense, i.e. every allegation must be assigned one and only one value - truth or untruth." He added the third value - possible (sign ½) and thus introduced the principle of logic three-valence. Later on he widened the set of possible values permitting number of values n = 3 from [0, 1], introducing n-valued or multi-valued logic by means of infinite and countable set of rational numbers Q. If truth values are represented by all real numbers in [0, 1], i.e. truth set is $T_\infty = [0, 1]$ the set of real numbers is infinite and uncountable) then multi-valued logic is logic where judgments can assume infinite number of values (infinite valued logic) or standard Lukasiewicz logic. There is correspondence between fuzzy sets and infinite valued logic. Complement, intersection and union of fuzzy sets correspond respectively to negation, conjunction and disjunction of infinite valued logic. Fuzzy logic uses fuzzy sets theory as a main tool, basic mathematic ideas of fuzzy logic originated from infinite valued logic, and that's the connection between these two logics. Fuzzy logic can be considered an extension of infinite valued logic since it incorporates fuzzy sets and fuzzy relations [1, p. 43].

3. NECESSITY TO EVALUATE PROJECT TEAM MEMBERS WORK

Organizational, financial, human and material resources are requisite for the information system development. According to this paper, human resources are in the centre of a star, other resources being points around it. Professional profile of the necessary staff belongs mainly to informatics field, minor part relating to the clerical staff. A project leader, the one who is the most responsible for the plan realization, must have possibility to evaluate to the utmost the contribution and reliability of each member, so that each member could be managed in a way that leads to success - successful termination of the project. In this way behaviour and matter of fact contribution of each individual will be determined, as well as favourable moment and the ways suitable for the application of available mechanisms for human resources management. Because of impossibility to evaluate contribution of each individual (which is immanent to evaluation process), i.e. inability to define and determine precise and strict bounds between possible evaluation grades for an individual, with a view to find the adequate way to solve the problem, grades in this work are represented as fuzzy sets. Their mutual bounds are not strictly defined, changes are gradual, common part being maintained. Due to complexity, numerous problem situations can not be solved in a distinctive way. To resolve real problems, like project team leadership and management of human resources, financial, and organizational resources, as well as the tracking of their development, we lack timely and reliable data. Reasons are numerous and can be found inside (inadequate competency and too small a staff, interpersonal relations, motivation, decision making in connection with priorities and necessary financial support, planning and acquisition of necessary equipment) and outside (political decisions, economic measures, economic stability, international situation etc.). If, in a better case, there are data, they are late, incomplete, indefinite, not precise, in short, doubtful and because of that considerably subject to subjective assessments of an individual or a group resolving the problem. In spite of the aforesaid, it is necessary to create the best possible basis for rational decision making and problem elaboration, calculate the parameters value and create solution rules. It is not possible to eliminate completely assessment subjectivity, but it is possib le to shape it and thus reduce its influence on decision making and management.

3.1. PROJECT TEAM MEMBERS WORK

To obtain synergetic staff efficiency and rise in proficiency it is necessary, apart from material and financial resources, to provide for the other prerequisites. They are reflected in providing pleasant working environment, possibility to discuss assigned duties, expressing opinion on problems in good faith, respecting individual opinions, views and ideas, solution of possible conflicts on the basis of analysis and arguments, getting familiar with assigned duties and unambiguous assignment to a particular team member. Problems in connection with duties and related risks should be foreseen and actions should be undertaken to prevent problem occurrence. If such actions are not possible, problems must be solved without delay to minimize bad consequences.

3.2. PROJECT MANAGEMENT

Project management involves planning, organizing and control of a system development. Project leading relates more to the prediction of possible events and less to the analysis of the present facts. It represents coordination of the tasks assigned to the team members, its basic duty being restraint of changes. Efficient leadership is the result of actions taken by the leader and led team members and actual work situation. Very often such a situation is not simple - it depends on the number and complexity of the influencing factors. It is very difficult, sometimes even impossible, to overcome them all. So, it is necessary to identify the most important ones, which in a particular case have the biggest influence.

As for the project leader, amongst all project factors, the most appreciated factor is the staff. The staff should be managed in a way which will provide for the best results and insure success of the work. In this connection he/she must be able to accelerate the accomplishment of the assigned tasks, on the assumption that there’s no one and the same way to manage and lead a team, a way which will be suitable for all problem situations. Because of the aforementioned restrictions - subjectivity which is immanent quality of a human being, leader can develop fuzzy evaluation models in order to minimize subjectivity and to make his assessment objective as much as possible, using imprecise and uncertain values - the only ones at his disposal. A possible evaluation model is represented in this work.

4. FUZZY EVALUATION MODEL

Since different kinds of uncertainty can be well explored and described within theory of fuzzy sets, instead of insisting upon precise and sharp bounds, necessary linguistic expressions are formalized by fuzzy sets with overlapping possibilities.

In “Outline of a New Approach to the Analysis of Complex Systems and Decision Processes” Zadeh states in his principle of incompatibility: As the complexity of system increases, our ability to make precise and yet significant statement about its behaviour diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics.

4.1. LINGUISTIC VARIABLE AND MEMBERSHIP FUNCTION

As for fuzzy logic, expression used in natural language to describe some phenomena having fuzzy value is called a linguistic variable. A linguistic variable is often described in terms of its fuzzy space.

This space is generally composed of multiple, overlapping fuzzy sets, each fuzzy set describing a semantic partition of the variable's allowable problem state [2, p. 40].
For example, the linguistic variable "responsibility" is broken down into four fuzzy sets: unsatisfying (UN), satisfying (SA) successful (SU) very successful (VS). This total problem space, from the smallest to the largest allowable value, is called the universe of discourse. The universe of discourse for the linguistic variable "responsibility" is 1 to 16 measurement units - points in our example.
Linguistic variable ability, reliability, and resulting value can be modelled by means of sets ABI, REL, REV containing certain number of values:

$$ability \,\underline{\underline{\Delta}}\, ABI = \{ABI_1, ABI_2, ABI_3, ABI_4\} = \{UN, SA, SU, VS\},$$
$$reliability \,\underline{\Delta}\, REL = \{REL_1, REL_2, REL_3, REL_4\} = \{UN, SA, SU, VS\},$$
$$resulting\ value \,\underline{\underline{\Delta}}\, REL = \{REV_1, REV_2, REV_3, REV_4\} = \{UN, SA, SU, VS\},$$

$$UN \,\underline{\Delta}\, unsatisfying, SA \,\underline{\Delta}\, satisfying, SU \,\underline{\Delta}\, successful, VS \,\underline{\Delta}\, very\ successful.$$

Fuzzy sets are almost always presented by triangle membership function, which is the most appropriate [5, p. 33]. It is very often used in fuzzy applications for fuzzy controller, managerial decision making, business and finance, social sciences, etc. It can be created in a simple way, on the basis of small amount of information [1, pp. 22-23].
The terms of linguistic variables ability, reliability, and resulting value have the same membership functions presented analytically below:

$$m_{UN}(v) = \begin{cases} 1, 1 \le v \le 4, \\ \dfrac{7-v}{3}, 4 \le v \le 7, \end{cases}$$

$$m_{SA}(v) = \begin{cases} \dfrac{v-4}{3}, 4 \le v \le 7, \\ \dfrac{10-v}{3}, 7 \le v \le 10, \end{cases}$$

$$m_{SU}(v) = \begin{cases} \dfrac{v-7}{3}, 7 \le v \le 10, \\ \dfrac{13-v}{3}, 10 \le v \le 13, \end{cases}$$

$$m_{VS}(v) = \begin{cases} \dfrac{v-10}{3}, 10 \le v \le 13, \\ 1, 13 \le v \le 16. \end{cases}$$

4.2. FUZZY RULES AND LOGIC OPERATIONS

Preconditions and conclusions about phenomena can be found within fuzzy rules which create the knowledge basis on a certain phenomenon. Knowledge is presented as the following rule: "If P then C", P represents rule precondition and C its conclusion. Rule precondition consists of clauses mutually connected with logic operators. Conclusion consists of truth statement. Creation of fuzzy rules basis presents the most complex part of the work since collected knowledge about systems behaviour is presented in a formal shape, thus containing the elements of artificial intelligence.

Membership function which refers to a fuzzy set joins degree of membership to set members. Membership to a certain fuzzy set is described as a degree of membership or grade of membership and refers to precondition on phenomenon. Certainty factor, CF, which refers to the conclusion on phenomenon is calculated for each decision making process and represents degree of belief that decision is correct. Although certainty factor can use the values from any interval, it is usually normalized on the interval [0, 1].

True value reaching procedure by means of fuzzy reasoning includes implicitly elaboration of all activated rules together. Each of the aforesaid rules contributes to the conclusion in a certain degree, that degree being equal to the degree to which is satisfied the portion of the rule referring to the precondition. Such an imitation process resembles to human deduction - a man making decisions takes into account different facts, each of them having particular influence on the final decision. The choice of appropriate logic operator represents an important part of a fuzzy system design. Originally, theory of fuzzy sets formulates standard Zadeh's minimum, maximum and complement operations.

Since 1965 a few classes of logic operators satisfying corresponding axioms have been introduced for each of the aforementioned operations [6, p. 1]. By acceptance of some basic conditions, by means of t-operators, a huge class of operation sets for union and section has been created. T-norm concept and t-co-norm has been originally developed by Menger in 1942 within theory of probabilistic metric spaces. Since then, numerous types of t-operators have been developed. In many applications, such common operators are not efficient, so there are demands for compensational behaviour [1]. Because of the aforesaid, compensation operators are introduced.

4.3. MODEL BEHAVIOUR

Model behaviour and fuzzy deduction procedure can be described in a few successive steps. First of all, an evaluator must assess the value of input linguistic model variables. Values found are turned into fuzzy sets to show assessment uncertainty - that's called fuzzyfication. Then logic operators are applied on the causative portion of the rule, after that implication procedure from causative to consecutive portion of the rule is made. On the basis of fuzzy rules, the values of output linguistic variables - fuzzy set for each variable - are calculated. Obtained fuzzy sets are aggregated - resulting in a fuzzy set. Finally, on the basis of output fuzzy set, one, precise value of linguistic variable is calculated. It represents the best assessment – defuzzyfication is being implemented.

Figure 1 presents fuzzy evaluation system model.

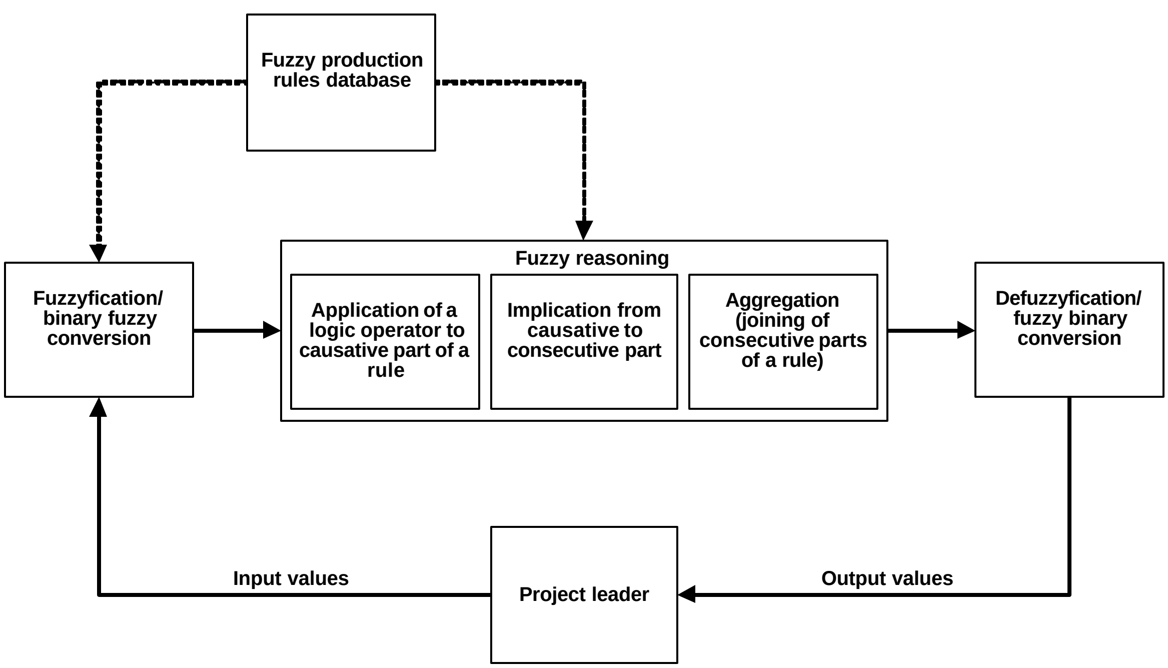

Figure 1: Model of fuzzy evaluation system

Model presented in this work consists of 3 modules: first two having 2 inputs and 1 output. After calculation, outputs of both modules constitute inputs of the third one, output of which represents the required value. This way modelling is possible since mathematic prerequisite has been fulfilled - the following axiom has been fulfilled: chosen logic operations are associative; application of addition when working with chosen logic t-norm and t-co-norm operators makes t-operation extension for more than two arguments unique.
Figure 2 presents the structure of module with input and output linguistic variables of a fuzzy model.

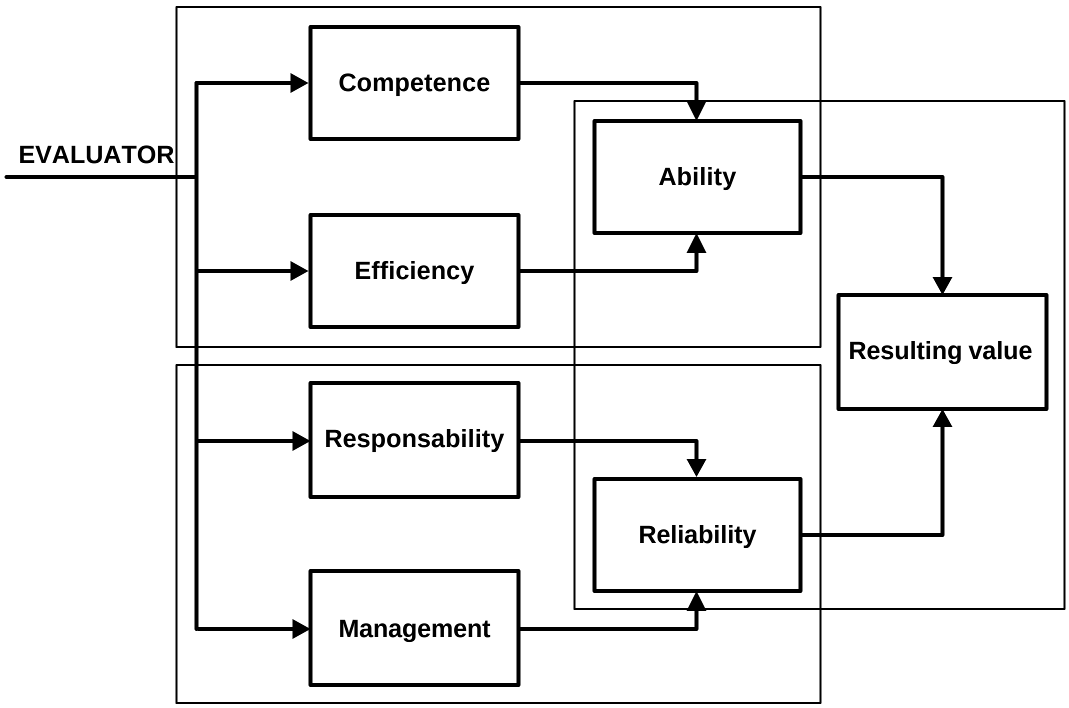

Figure 2: The structure of module

Model can be shaped by Fuzzy Knowledge Builder™ tool. On the basis of phenomena described by linguistic variables the bases of fuzzy rules are made. Figure 3 represents calculation rules for output linguistic values - 1st and 3rd module ("ability" and "resulting value").

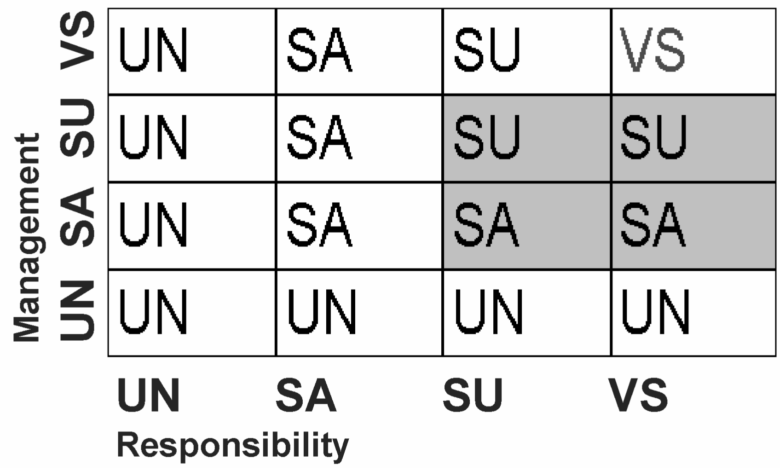

Figure 3: Calculation rules for output linguistic values

Figure 4 presents basis of 2nd module fuzzy rules, needed to calculate the value of linguistic variable "reliability".

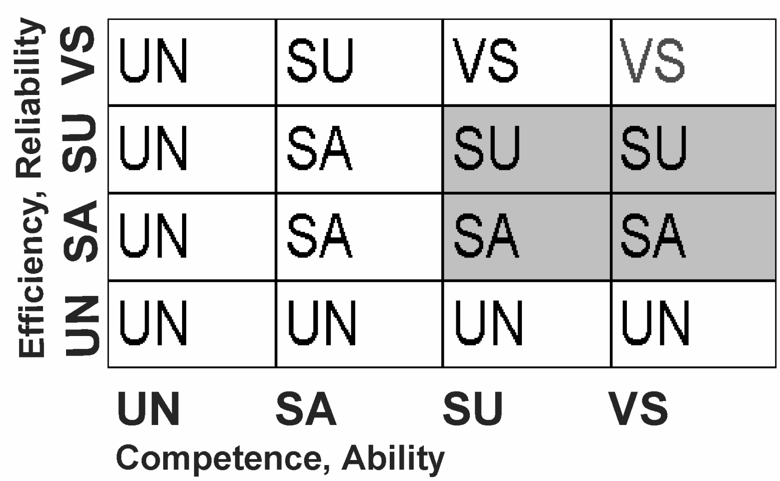

Figure 4: Basis of 2nd module fuzzy rules

$m_{SU}(11)=0.61, m_{VS}(11)=0.39, m_{SU}(9.1)=0.71, m_{SA}(9.1)=0.29.$

Rules activated within third module are:

1. If ABI is SU and REL is SA then REV is SA;
2. If ABI is SU and REL is SU then REV is SU;
3. If ABI is VS and REL is SA then REV is SA;
4. If ABI is VS and REL is SU then REV is SU.

The strength of the rules is calculated as follows:

$a_{11} = m_{SU}(11) \wedge m_{SA}(9.1) = \min(0.61, 0.29) = 0.29,$

$a_{12} = m_{SU}(11) \wedge m_{SU}(9.1) = \min(0.61, 0.71) = 0.61,$

$a_{21} = m_{VS}(11) \wedge m_{SA}(9.1) = \min(0.39, 0.29) = 0.29,$

$a_{22} = m_{VS}(11) \wedge m_{SU}(9.1) = \min(0.39, 0.71) = 0.39.$

Values of all linguistic variables of a model produced during evaluation process are presented in Table 1. Finally, following this procedure, the value of output linguistic variable “resulting value” is reached.

Linguistic variable	**Point**	**Fuzzy set**	**Grade of membership/ certainty factor**	**Alternative fuzzy set**	**Alternative grade of membership/ certainty factor**
Competence	11	SU	0.56	VS	0.44
Efficiency	12	VS	0.84	SU	0.16
Ability	11	SU	0.61	VS	0.39
Responsibility	12	VS	0.91	SU	0.09
Management	9.5	SU	0.86	SA	0.14
Reliability	9.1	SU	0.71	SA	0.29
Resulting value	8.8	SU	0.60	SA	0.40

Table 1: Linguistic variables of a model with evaluation process values

Figure 3 represents 4 rules activated by input values are presented in grey colour, calculated output values of afore-going modules. As for observed 3rd module, the values of linguistic variable “ability“ are presented on the horizontal axes, while the values of linguistic variable “reliability“ are presented on the vertical one. To calculate the value of output linguistic variable “resulting value“ in the causative part of the rules being activated, Zadeh's minimum logic operator $T_M(x, y) = \min(x, y)$ has been applied, which is one of the basic T-norms.

Figure 5 and 6 represent input linguistic variables of the 3rd module with values awarded to a team member according to the assessment of the team leader.

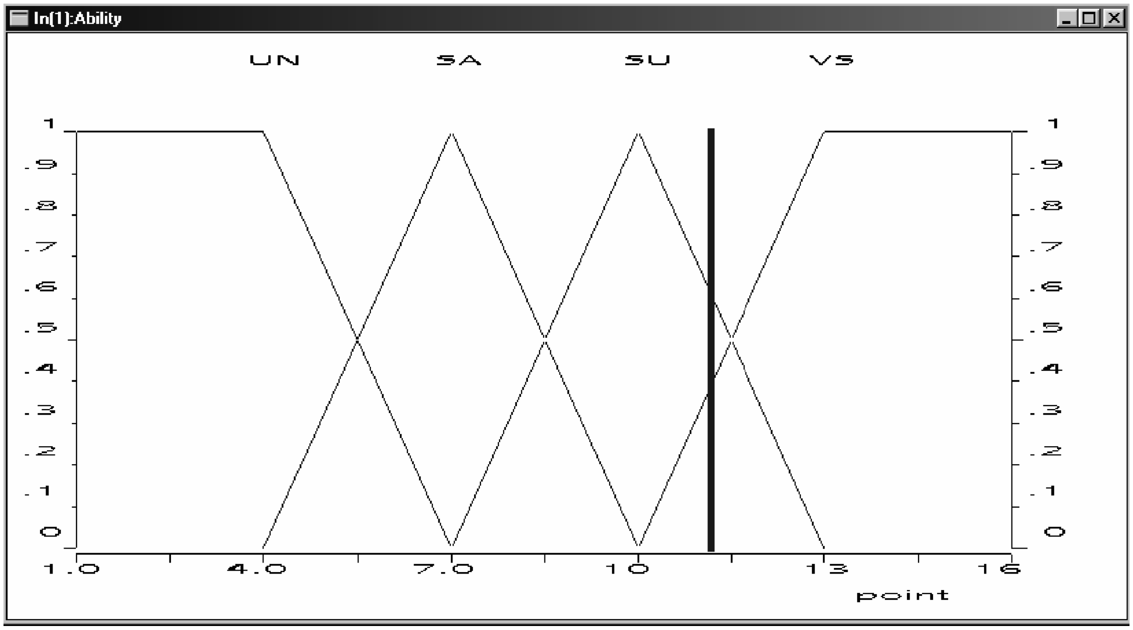

Figure 5: Input linguistic variable "ability"

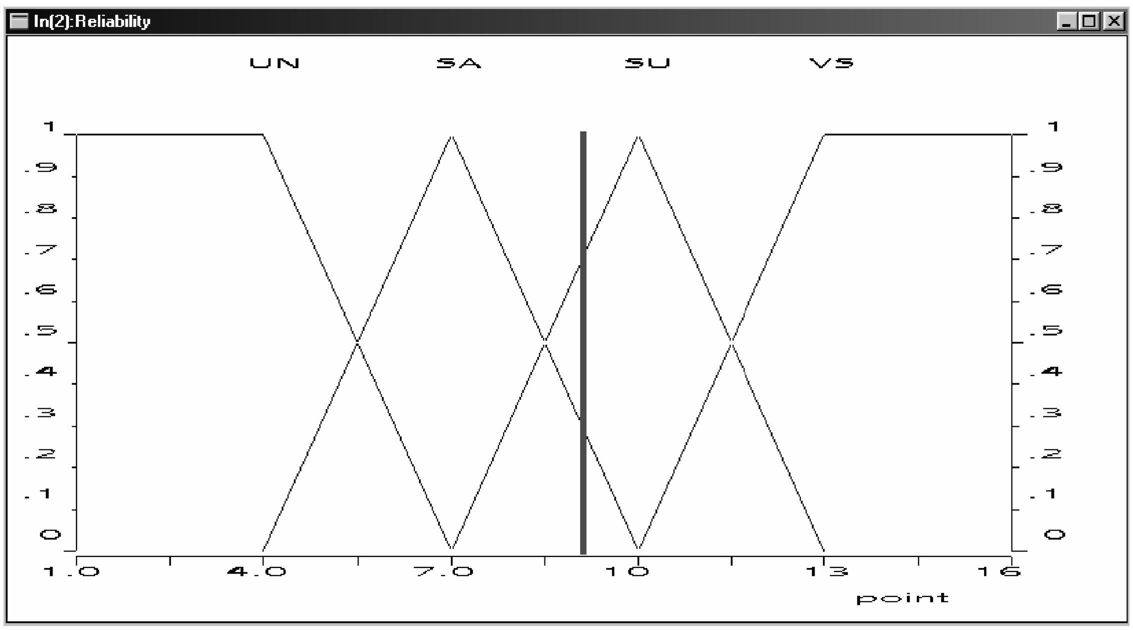

Figure 6: Input linguistic variable "reliability"

Control output (CO) of each rule is defined by operation conjunction applied on its strength and conclusion:

CO of rule 1: $a_{11} \wedge m_{SA}(z) = \min(0.29, m_{SA}(z))$,

CO of rule 2: $a_{12} \wedge m_{SU}(z) = \min(0.61, m_{SU}(z))$,

CO of rule 3: $a_{21} \wedge m_{SA}(z) = \min(0.29, m_{SA}(z))$,

CO of rule 4: $a_{22} \wedge m_{SU}(z) = \min(0.39, m_{SU}(z))$.

The aggregated output is:

$$m_{agg}(z) = \max(\min(0.29, m_{SA}(z)), \min(0.61, m_{SU}(z))).$$

$$m_{agg}(z) = \begin{cases} 0, & 1 \le z \le 4, \\ \dfrac{z-4}{3}, & 4 \le v \le 5, \\ 0.29, & 5 \le z \le 8, \\ \dfrac{z-7}{3}, & 8 \le v \le 9, \\ 0.61, & 9 \le z \le 11, \\ \dfrac{13-z}{3}, & 11 \le v \le 13. \end{cases}$$

Figure 7 represents output linguistic value, calculation of which brings evaluation procedure to an end.

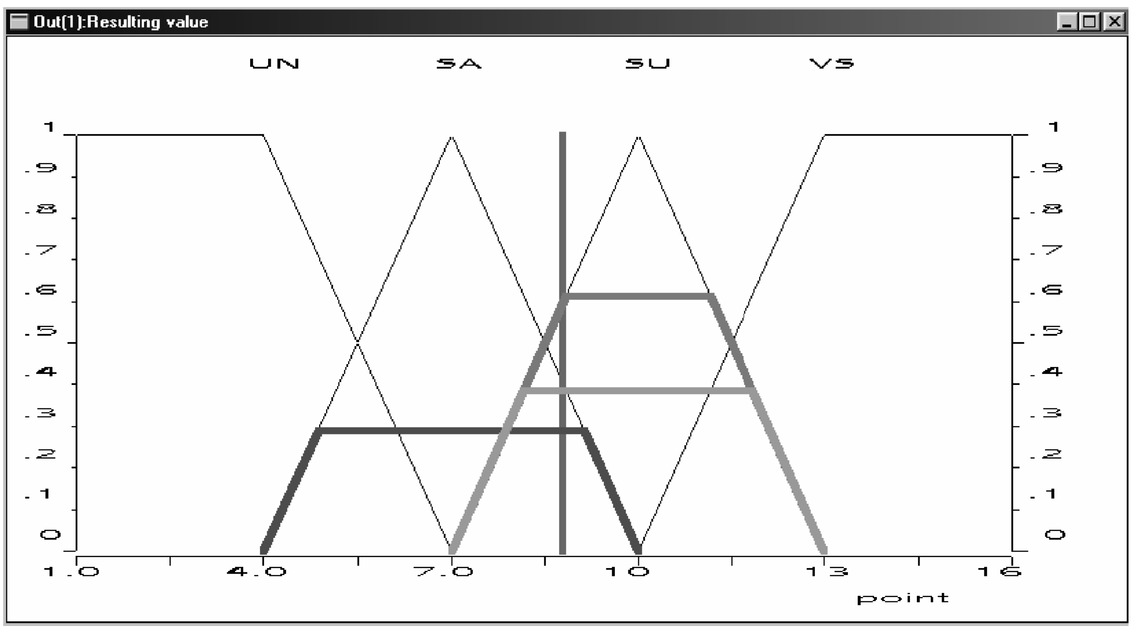

Figure 7: Output linguistic value "resulting value"

The crisp value of an output linguistic variable is reached by the centre of gravity method. The crisp value $\hat{z}_c$ according to this method is the weighted average of the numbers z_k.

$$\hat{z}_c = \frac{\sum_{k=1}^{q-1} z_k m_{agg}(z_k)}{\sum_{k=1}^{q-1} m_{agg}(z_k)}.$$

Centre of gravity calculation leads to the crisp value $\hat{z}_c = 8.8$ which inside fuzzy set “successful” is found on the certainty grade 0.60 while within fuzzy set ”satisfying” is on 0.40.
To get better insight into relations between input variables and output variables three-D graph may be used. Figure 8 presents action surface or estimation surface.

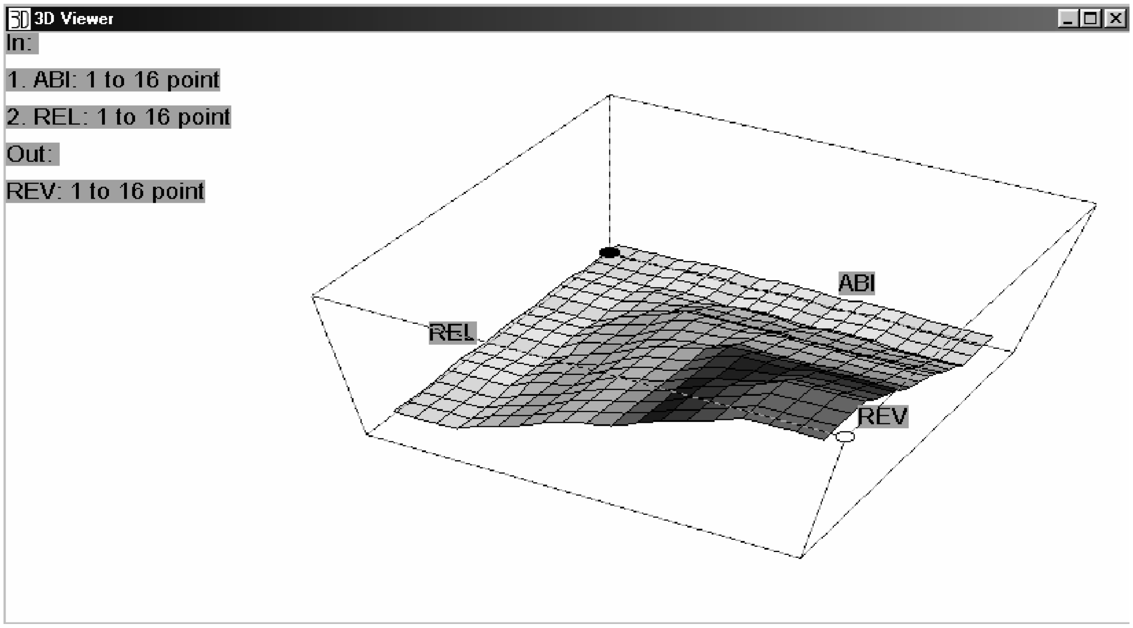

Figure 8: Action surface

The inputs form the base of the graph, and the output is represented by the height of the graph above each input pair.

5. CONCLUSION

A complex work like project elaboration and project management strongly requires qualitative evaluation of human capabilities and capacities in order to manage them. Improvisation and subjective evaluation should be reduced as much as possible. The aforesaid can be achieved by the development and employment of models which will produce decisions made on the basis of more objective assessments. By means of fuzzy approach and fuzzy logic employment, the system model supporting evaluation processes and decision making is rendered possible. Fuzzy evaluation model is complex and structured. According to its modules, fuzzy evaluation of an individual characteristics is made, in conformity with beforehand defined rules modelling relationship among characteristics. On the basis of calculated output module values, the resulting, final evaluation value is reached. Shaped model is adaptable, it can be improved according to the business needs, introducing changes through the selection of features - linguistic variables, their values, and interaction rules as well - until satisfactory shape is achieved.

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