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# The Framework for Project Teams Optimal Assignment Based on Fuzzy Logic

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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 system has been designed to reduce evaluation subjectivity. The developed system, further on, serves to constitute project teams, by choosing a particular configuration of people within a team considering their knowledge and skills. The framework for project teams optimal assignment has been developed, based on usage of a fuzzy system together with an AHP decision making support system.


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

## 1. 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 is not available in exact, mathematic form, so judgement must be made with certain percentage of uncertainty. Such reflections have resulted in the development of fuzzy sets theory, which according to Zadeh [7, p. 24] differs from classical theory in one key standpoint: An element can belong to the fuzzy set, be completely excluded from the fuzzy set, or it can belong to the fuzzy set to any intermediate degree 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 categories leads to, if we apply classical sets theory, inconsistency.

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].

## 2. Necessity to evaluate project teams members performance

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 to 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 possible to shape it and thus reduce its influence on decision making and management.

### 2.1. Project team members performance

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 about 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.

### 2.2. 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.

## 3. 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.

### 3.1. 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:

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

$$UN \triangleq unsatisfying, SA \triangleq satisfying, SU \triangleq successful, VS \triangleq very\ successful.$$

Fuzzy sets are almost always presented by triangle membership function, which is the most appropriate [8, 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:

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

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

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

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

### 3.2. 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 [9, 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.

### 3.3. 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 to 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.

Fuzzy 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 1 shows the process flow within the fuzzy evaluation system and its basic parts. The project manager, based on available information, inputs the values into the input modules of the linguistic variable information system, in which the quantitative values are transformed into quality - the values of fuzzy sets of linguistic variables. They, as input values, present inputs for a module for fuzzy deduction of a production rules database of the «IF-THEN» structure. On the causal parts of the production rules a chosen logical operator is used (in Fuzzy Knowledge Builder™ this is Zadeh's minimum logic operator). Next an implication is executed from the cause to the consequential part of the rule, and next the consequential parts of the activated rules are joined. The result of the aggregation of the activated rules is a fuzzy set of the output linguistic variable, where the transformation from the quality value into a quantity value is executed. The created output values are used by the project manager as a basis to take appropriate actions, in order to catalyze positive changes and occurrences coming from the actions of individuals that constitute a team.

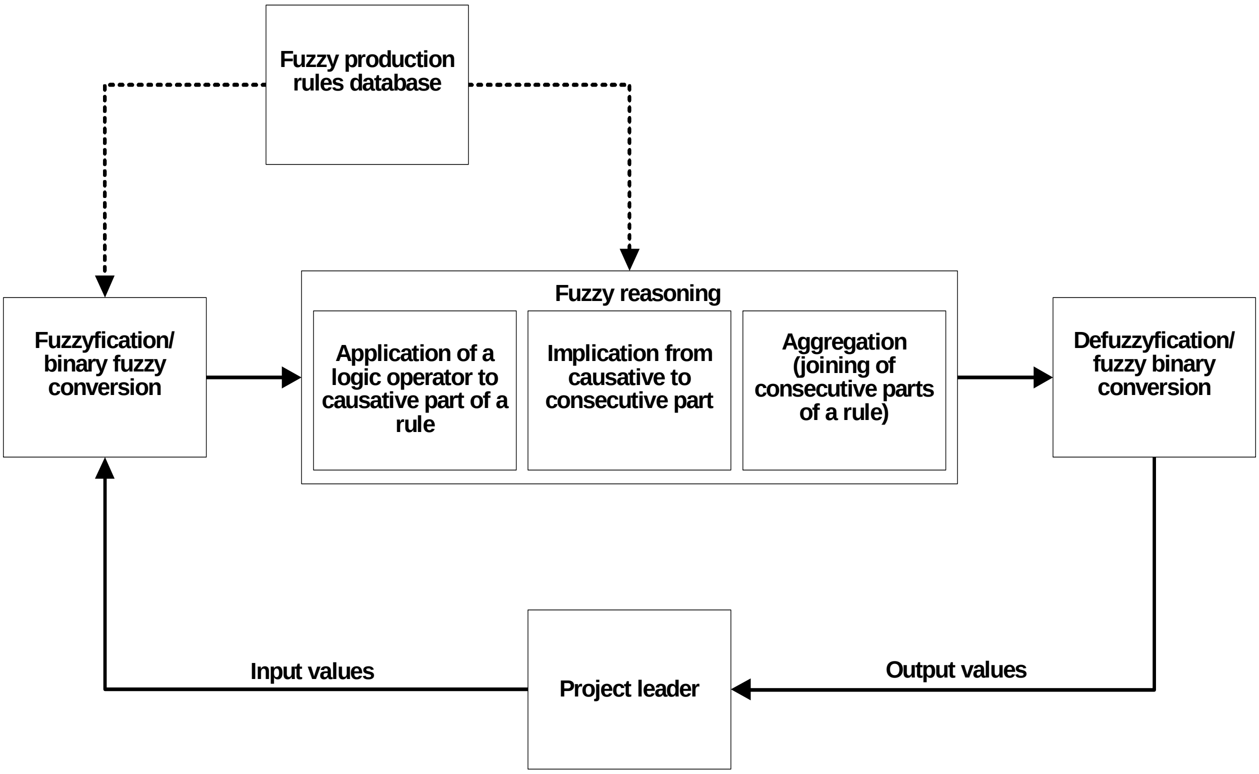


**Figure 1: Model of fuzzy evaluation system**

Figure 2 displays input and output originally developed linguistic variables of a fuzzy system model. The first input module contains the input linguistic variable «competence» which refers to the level of knowledge and expertise in the problem area referring to the project team's work, and is a result of the formal education of the team members, including completed courses and training. «Efficiency» represents the rate of produced effect of an individual measured by the volume and quality of the execution of the assigned tasks. Both dimensions of the project team member affect the level of his «ability», which is a linguistic variable that represents the first output value of the model. The other linguistic variable input module includes «responsibility» as a measure of gravity and excellence of task execution performance, and «management» that acknowledges the fact that within the modern organization forms nowadays the prevailing opinion is that all members of the team are management oriented - managers, regardless whether they have subordinates or not. If the latter is the case, they are managers of their own tasks only. The output linguistic variable that is created within this module is «reliability», and as a result of the two input variables it represents the measure of certainty with which the project manager can rely on the person in question, in order to maintain the quality and the dynamics of the work. The third module uses output values of the previous two modules as its input values, and its goal is to put together the level of quality of «ability» and «reliability» of a specific individual, so that it could, based on the derived «resulting value», finally be decided on his or her future, form and type of cooperation in the common work.

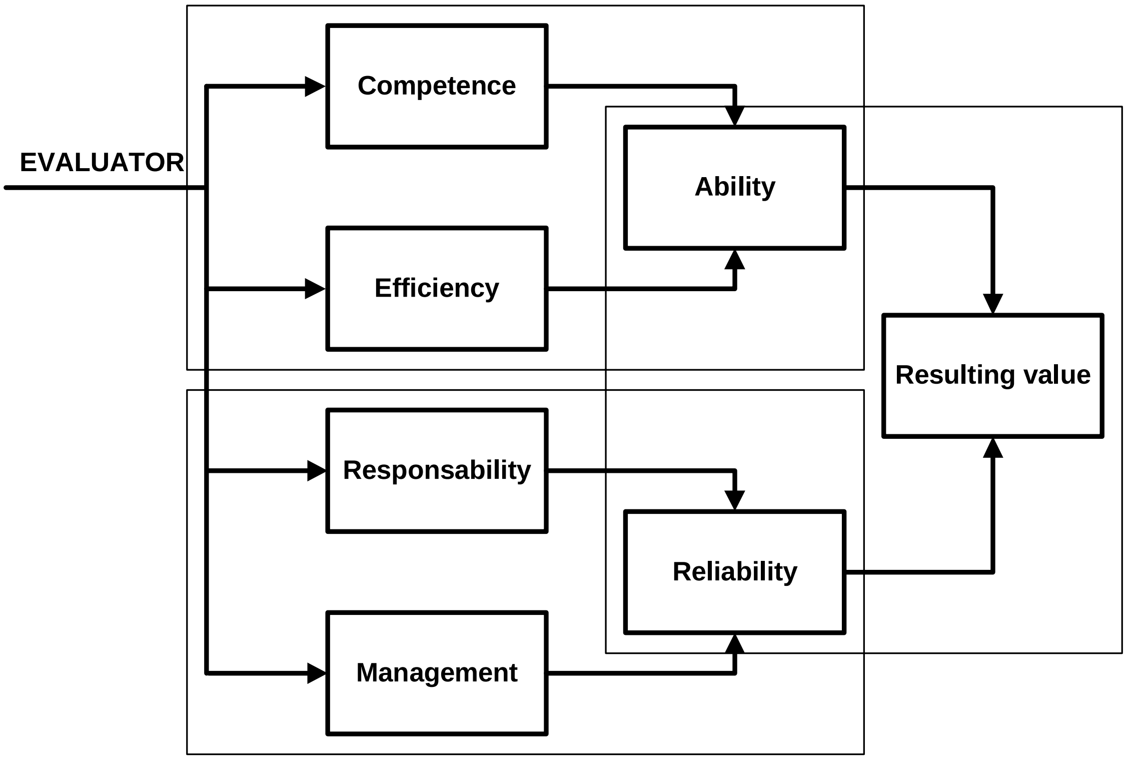


**Figure 2: The structure of modules**

The model is shaped and implemented by using the Fuzzy Knowledge Builder™ tool programming system, which was used to enter, process and display data. On the basis of phenomena described by linguistic variables the bases of fuzzy rules are made. Figure 3 presents basis of 2nd module fuzzy rules, needed to calculate the value of linguistic variable «reliability»

| Management \ Responsibility | UN | SA | SU | VS |
|---|---|---|---|---|
| VS | UN | SA | SU | VS |
| SU | UN | SA | SU | SU |
| SA | UN | SA | SA | SA |
| UN | UN | UN | UN | UN |

**Figure 3: Basis of 2nd module fuzzy rules**

Figure 4 represents calculation rules for output linguistic values - 1st and 3rd module «ability» and «resulting value»).

| Efficiency, Reliability \ Competence, Ability | UN | SA | SU | VS |
|---|---|---|---|---|
| VS | UN | SU | VS | VS |
| SU | UN | SA | SU | SU |
| SA | UN | SA | SA | SA |
| UN | UN | UN | UN | UN |

**Figure 4: Calculation rules for output linguistic values**

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

Rules activated within third module are:

1. If $ABI$ is $SU$ and $REL$ is SA then $REV$ is $SA$;
2. If $ABI$ is $S$U and $REL$ is $SU$ then $REV$ is $S$U;
3. If $ABI$ is $V$S and $REL$ is $SA$ then $REV$ is $SA$;
4. If $ABI$ is $V$S and $REL$ is $SU$ then $REV$ is $SU$.

The strength of the rules is calculated as follows:

$$\alpha_{11} = \mu_{SU}(11) \wedge \mu_{SA}(9.1) = \min(0.61, 0.29) = 0.29,$$
$$\alpha_{12} = \mu_{SU}(11) \wedge \mu_{SU}(9.1) = \min(0.61, 0.71) = 0.61,$$
$$\alpha_{21} = \mu_{VS}(11) \wedge \mu_{SA}(9.1) = \min(0.39, 0.29) = 0.29,$$
$$\alpha_{22} = \mu_{VS}(11) \wedge \mu_{SU}(9.1) = \min(0.39, 0.71) = 0.39.$$

All input and output processing values produced during evaluation process have been numerically displayed in Table 1. Finally, following this procedure, the value of output linguistic variable «resulting value» is reached.

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

| 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 |

Figure 4 represents 4 rules activated by input values 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.

Model can be shaped by tools for fuzzy modelling. 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.

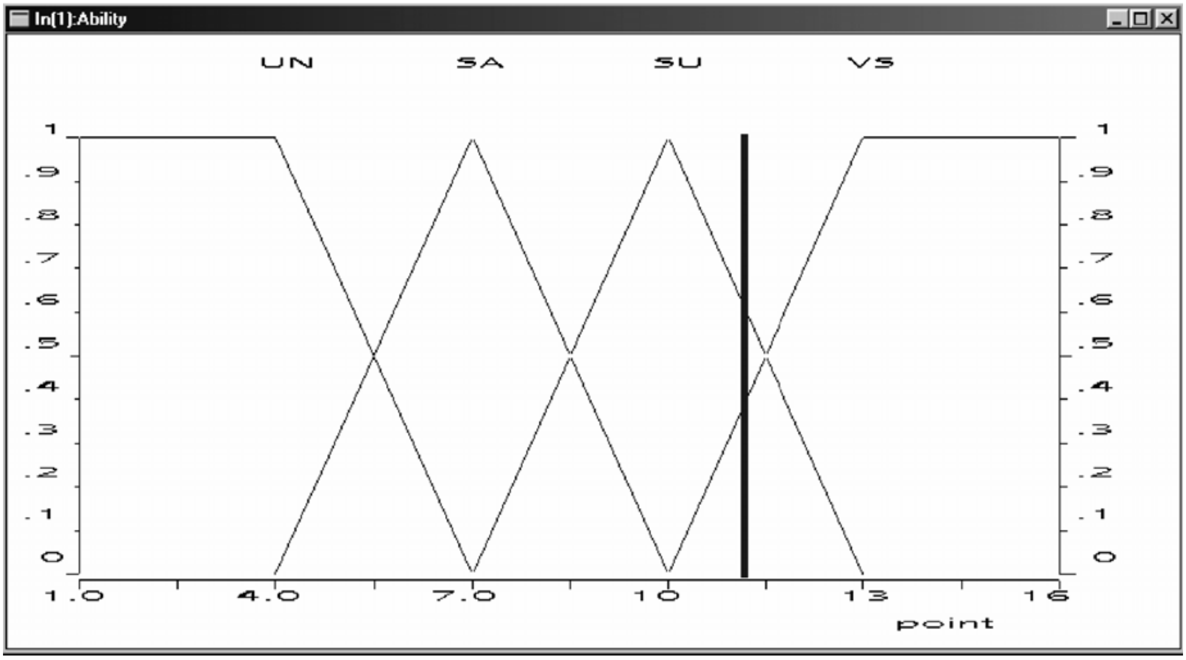


Figure 5: Input linguistic variable «ability»

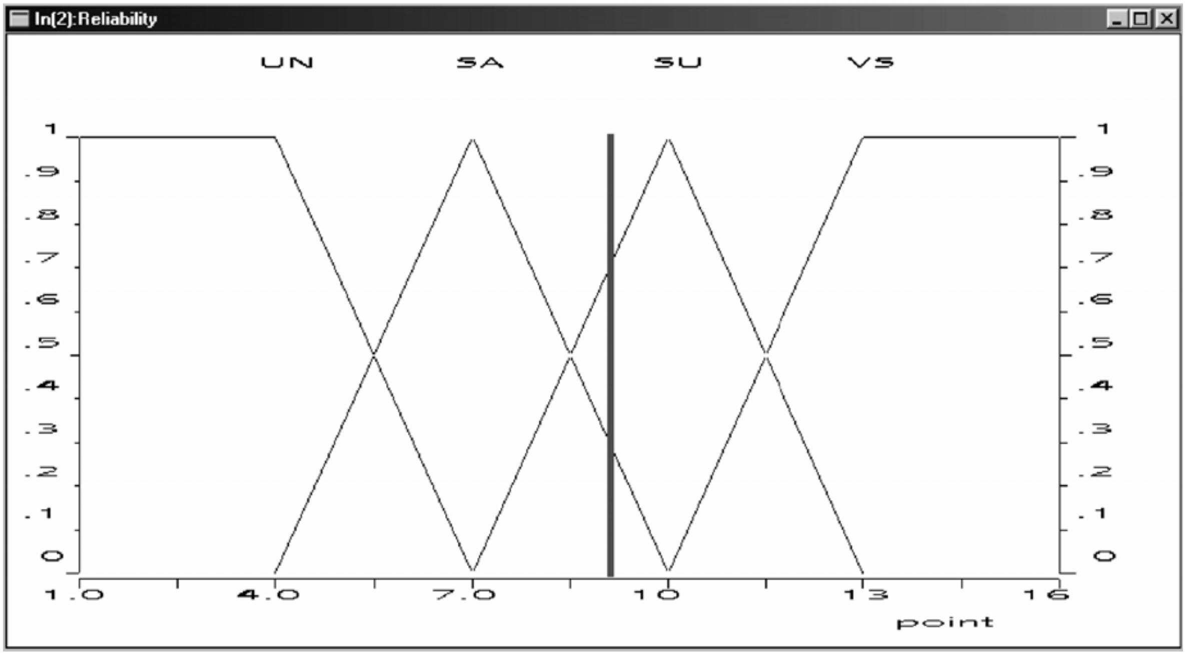


Figure 6: Input linguistic variable «reliability»

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

$$\begin{aligned}
&\text{CO of rule 1: } \alpha_{11} \wedge \mu_{SA}(z) = \min(0.29, \mu_{SA}(z)),\\
&\text{CO of rule 2: } \alpha_{12} \wedge \mu_{SU}(z) = \min(0.61, \mu_{SU}(z)),\\
&\text{CO of rule 3: } \alpha_{21} \wedge \mu_{SA}(z) = \min(0.29, \mu_{SA}(z)),\\
&\text{CO of rule 4: } \alpha_{22} \wedge \mu_{SU}(z) = \min(0.39, \mu_{SU}(z)).
\end{aligned}$$

The aggregated output is:

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

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

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

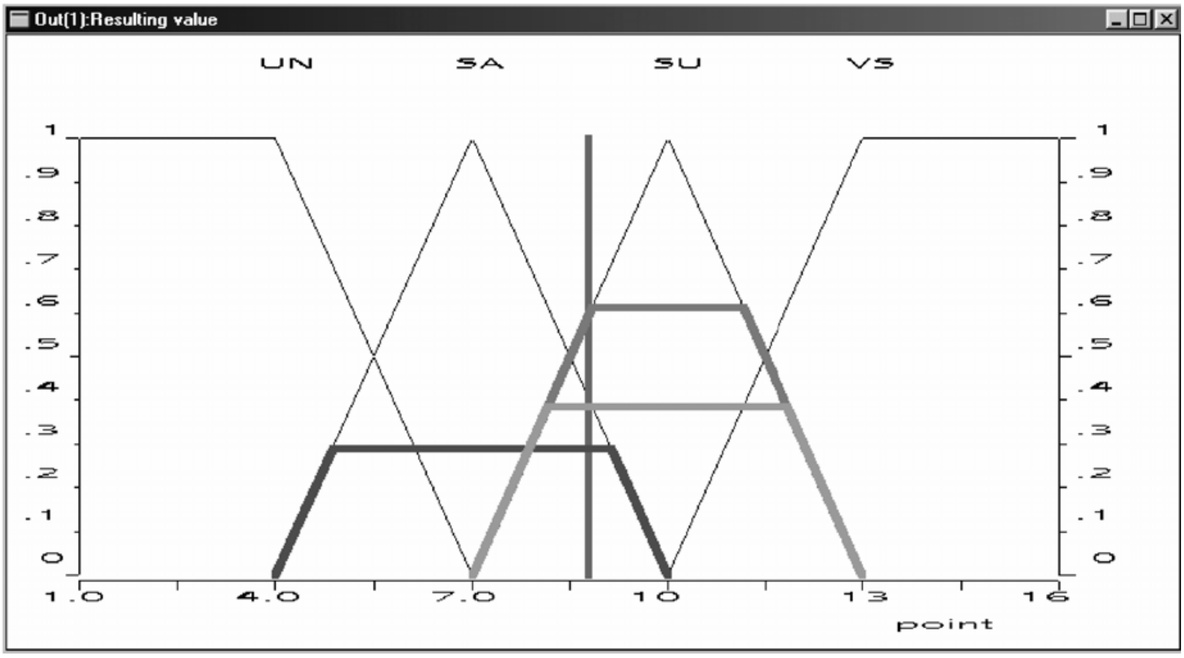


**Figure 7: Output linguistic value «resulting value»**

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 $z_k$.

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

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.

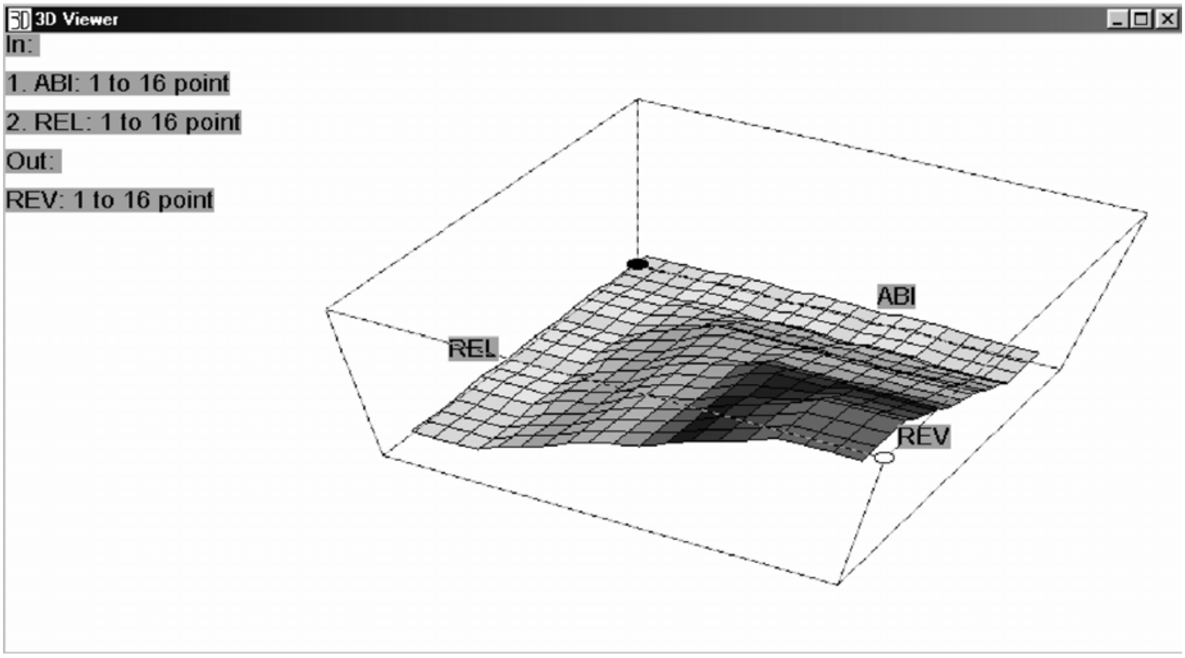


**Figure 8: Action surface**

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

## 4. Configuring project teams

The goal for a role-oriented organization is to move away from traditional notions of how organizations must be structured, while accommodating both data-centric, traditional hierarchies in coexistence with newer, innovative structures. It is not important whether roles are insourced or outsourced. Identifying and staffing individual functions is the consequence of determining whether the roles can be best filled by internal or external resources, and whether it is appropriate to supplement existing personnel with part-time contractors or systems integrators. A role orientation is not a function, it breaks up requirements into a grouping of capabilities that can be fulfilled in several ways, including teams, specialty centers and by individuals assuming more than one function. The emphasis is on communications, process and governance. Each is critical in supporting the flexibility to change as requirements dictate.

The evaluation system is made by defining membership (allocation) functions of linguistic variables, through the research in which authors have shaped and implemented the original fuzzy evaluation system with that kind of internal structure - with original linguistic variables and original business rules - which enables tracking of the level of efficiency of the members of the project team, using incomplete (the only available) input values. It is the result of the execution of the following methodological steps:

1. The choice of the allocation function of form - membership function (triangular)
2. The choice of the number of fuzzy linguistic variable sets (4)
3. The determination of the width of the allocation function interval [1, 7]
4. The construction of fuzzy production rules.

A system like this is meant to increase the level of efficiency of leadership and control, in all project phases, by performing ex-post evaluation of the work contribution of each member. The framework for project teams optimal assignment has also been developed, based on usage of a fuzzy system together with an AHP decision making support system. In this manner ex-ante evaluation of the suitability of an individual to take over a certain role within the project team that is being created is being performed for the configuration of projects and assigning workforce, while the AHP method decides the weighted values of the evaluated roles and projects, which enables setting priorities. This approach is significant for further evaluations of project teams.

Allocation functions of the linguistic variables were created, as were the linguistic variables themselves, based on the results the authors produced by research conducted while leading complex informatics projects. In order to successfully lead team members and control of the proceedings of the whole project, in the authors' opinion, it was necessary to create a system with such a form and width of allocation functions of linguistic variables as to enable the necessary evaluation of the project team members' work. These are the allocation functions used to create the input and output values of the system, in the creation of which the existing working conditions and effectively available information decision making basis were taken into consideration. It consists of incomplete, subjective information which is to be used in the best manner possible, since no other is available. The triangular allocation function has been chosen for reasons stated in the previous part of the paper. (quotes: [8, p. 33] and [1, pp. 22-23]). In its definition the authors took into account that the evaluation interval should neither be too narrow nor too wide. If it were too narrow, with a small number of possible allocation function values (two, for instance), the evaluation criteria would need to be very high, that is, it should be possible to speculate that this is an efficiency evaluation of a team with a high level of excellence. This assumption is hard to accept, because not only the most excellent individuals take part in projects for a certain type of work. If we would, in contrast, use too wide an interval, it would be difficult for the evaluator to conduct the evaluation, since it is hard for a human to decide on a specific value when the granulation level is too high. Therefore each of the allocation functions of linguistic variables has a predetermined evaluation interval [1, 7]. The number of allocation functions for each linguistic variable is 4 and this is not only within previously stated demands, but it also enables the number of fuzzy rules to be neither too big, nor too small (in reality, it equals 16 for calculating each output linguistic variable).

## 4.1. Modelling of the problem and procedure of project configuration

The developed evaluation system should, further on, serve to constitute project teams, by choosing a particular configuration of people within a team considering their knowledge and skills. While up to now the developed fuzzy system was used to evaluate the contribution made by an individual's commitment in the previous time period, now it is used for a priori evaluation of a person's suitableness for a particular job (role in the team). Here it is important that one person can be candidate for several roles in a certain team (be better than others and fit to be assigned to several jobs), while, on the other hand, some jobs in the team may stay vacant because of a lack of appropriate candidates. This is why it is necessary, with the set conditions which are established by types, needs and development simultaneity of the projects by phases, and by the specifics and demands of the jobs in the future project teams, to fuzzy-evaluate an individual's ability for every job in each project and then reach the best combination in a specific moment - to configure the roles of individuals in jobs and project teams and organize undisturbed project realization. Assigning roles to the personnel and their integration in projects is done in each project phase (planning, analysis, design, construction), since in each of the development phases it is necessary to intensify specific (different) knowledge and skills, and then assign the personnel accordingly. It is notable that as a rule the same phases within different projects will not last the same time period (in reality it is common for all project phases, especially the later ones, to be behind schedule), which has a direct effect on the option of assigning personnel according to the needs.

**Approach:**
In order to accomplish a goal thus set, the business system in which the configuration is being done needs to be open and adjustable, while the staff and management need to be flexible. Such an approach includes a specifically developed project team configuration procedure by means of fuzzy evaluation, taking the stated hypotheses and specifics into consideration. All of this points to the fact that a system this complicated can only be optimized by expert and competent staff who know well both business processes and technology, and the people personally. Also, it needs to have a strong decision making support system, so the subjectivity of the decision maker would be modelled and minimized. This is why except for the developed fuzzy system the AHP method for estimating the weighted values of roles and projects considered is also complementarily used.

The Analytic Hierarchy Process (AHP) allows decision makers to model a complex problem in a hierarchical structure showing the relationships of the goal, objectives (criteria), sub-objectives, and alternatives. Uncertainties and other influencing factors can also be included. AHP allows for the application of data, experience, insight, and intuition in a logical and thorough way. AHP enables decision-makers to derive ratio scale priorities or weights as opposed to arbitrarily assigning them. In so doing, AHP not only supports decision-makers by enabling them to structure complexity and exercise judgment, but allows them to incorporate both objective and subjective considerations in the decision process. AHP is a compensatory decision methodology because alternatives that are deficient with respect to one or more objectives can compensate by their performance with respect to other objectives. AHP is composed of several previously existing but unassociated concepts and techniques such as hierarchical structuring of complexity, pairwise comparisons, redundant judgments, an eigenvector method for deriving weights, and consistency considerations.

**Presumption:**
The *m* of roles (tasks, jobs) $R_1 \ldots R_m$, *n* of individuals $M_1 \ldots M_n$ and *l* of projects $P_1 \ldots P_l$ are observed.

**Specifics:**
- The suitability of person $M_n$ to perform certain roles $R_m$ necessary for the execution of project $P_l$ is evaluated. For each role a grade $V_{min}$ is set, and it represents the acceptability level of a person for assignment. Mark $a_{ij}$, i = 1…*m*, j = 1…*n* is used.
- Roles do not hold the same importance, i.e. each role has its assigned weight, which sets its importance level. The mark used is $p_i$, i = 1…*m.*
- Projects do not hold the same importance, i.e. each project has its assigned weight, which sets its priority level. The mark used is $w_k$, k= 1…*l.*
- The assigning of the evaluated personnel on projects is done according to established priorities. The mark used is $b_{ik}$, i = 1… *m*, k = 1…*l*.

**Optimization criteria:**
What determines the assignment of the evaluated individuals to project jobs is their suitability to perform specific tasks $a_{ij}$ , and project weight $w_k$. This is why there are project precedence constraints determined by their weight. For instance, if project $P_i$ has precedence over $P_k$, this means that assigning to $P_k$ should not be started before $P_i$ is fully assigned ($P_i < P_k$).

- $\max \sum_{k=1}^{l} a_{ij} w_k$ .

**Procedure 1:**
1. By using the fuzzy system the level of assignment appropriateness of each person available to each job in the team is evaluated. If a person is not fit to work in a certain job he or she is excluded from consideration for assigning to this job (the set of possible solutions is reduced).
2. Using the AHP method the weight of each task in the project is determined, as well as the weight of each project.
3. Starting with the most important job the person with the highest grade is chosen for a particular job (the best individuals for the most demanding roles). If the person is able to work on several jobs in the team, he or she is given the job they got the highest grade for. In case several people have the same fuzzy grade for the same job, the choice is made by detailing the grade based on the defuzzyfication conducted.
4. Acceptability threshold is set - the lowest grade an individual can have in order to be assigned to a job in a team. If for a particular job an individual of quality better or the same to the set one cannot be found, new employees need to be acquired. Exceptionally, if a person's grade is below acceptable, but very close to it (if the result of defuzzyfication shows this) the person is included in the candidates for assignment, or the option of re-evaluation is considered.
5. For each project, starting with the one with highest priority, each job is filled with one individual, as long as there is a job unfilled and a suitable individual.
6. Project appointment is analyzed and if there is a disproportion between the projects considering the quality of personnel assigned, personnel reassignment is done between the projects, by mutual agreement of the decision bearers (project manager, members of the organizational unit for decision making and supervision).

Illustration:

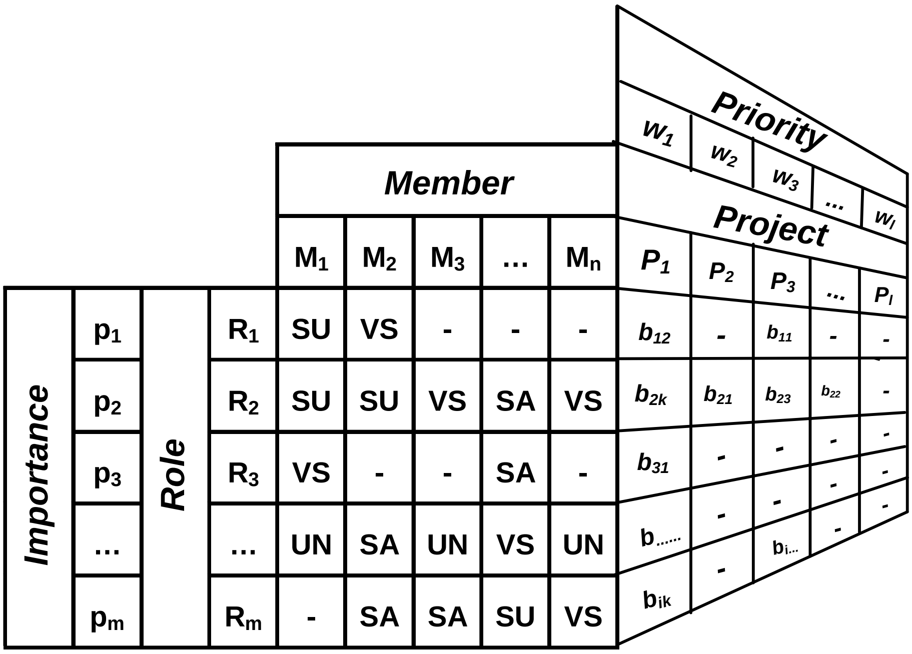


**Figure 9: Teams configuration based on fuzzy evaluation and AHP**

Figure 9 illustrates the procedure. In a case in which persons $M_3$ and $M_n$ were evaluated with the same grade VS for the same role in the team $R_2$, a more detailed insight into the result of the fuzzy evaluation has been performed and thereby established that person $M_n$ is better suited. Assuming that after the weight establishment the projects have been ranked starting with the most important one: $P_1$, $P_3$, $P_2$ … $P_l$, person $M_n$ was assigned to the project team $P_1$ etc. The grade SU has been set as the acceptability threshold for a person's assignment to a particular project. The configuration of personnel by projects has been done as the figure shows. One can note that the formation of project $P_1$ has been finished, project $P_l$ does not have anyone assigned to, while in the other projects the assignment is partial. This points to the fact that, with other conditions unchanged, in this case it was necessary to conduct the procedure of attracting and employing the personnel missing.

## 4.2. Methodological framework for evaluation and configuration

Table 2 shows all the steps and phases of a developed framework with input and output values.

Table 2: Methodological procedures for project teams optimal assignment based on fuzzy evaluation of member efficiency

| Methodological unit | Description | Input value | Output value |
|---|---|---|---|
| Phase 1 | Perspective and analysis of the problem as a whole | | |
| Step 1.1 | Setting up goals, limits and limitations of the business system | Initial:<br>Documentation of the business system on a strategic and tactical level (IA1)<br>Individual and group interviewing of key users and business technologists (IA2)<br>System information from the personnel database (IA3)<br>System information from the repository (IA4)<br>Environment information from the database (IA5)<br>Knowledge of individual skills gained based on working together (IA6)<br>Internet, technical literature and other resources (IA7)<br>Procedure 1 (IA8) | Decomposition and contextual diagram (OA1)<br>Technical feasibility, organizational and operational acceptability, economical justification (OA2) |
| Step 1.2 | Making a configuration model with rules and decision making procedures | OA1,<br>OA2 | A model of roles with their importance, persons to be assigned, and priority projects (OA3) |
| Step 1.3 | Setting up the sources and values of data | IA1, IA3, IA4 | Detailed information on individuals and their expertise, jobs and skills demanded, projects, development environment (OA4) |
| Step 1.4 | Choosing the development tool and decision making support tool | IA4, IA5, IA7 | The tool chosen for fuzzy modelling (OA5) |

| | | | |
|---|---|---|---|
| | | | The tool chosen for decision making support (OA6) |
| Step 2 | Design and construction of the fuzzy evaluation system | | |
| Step 2.1 | Determining the number of linguistic variables fuzzy sets | OA4, IA7 | Number of sets (OB1) |
| Step 2.2 | Determining the interval width and shape of the allocation function | OA3, OA4 | Interval width and shape (OB2) |
| Step 2.3 | Development of fuzzy production rules | OA4, IA7 | Production rules (OB3) |
| Step 2.4 | Integration of all elements and creating models | OA5, OA6, OB1, OB2, OB3 | Fuzzy system prototype (OB4) |
| Step 2.5 | Check-up/improvement of the system in accord with the flaws spotted and additional changes | OA3, OA4, OA5, OA6, OB4, | Fuzzy evaluation system (OB5) |
| Phase 3 | Execution of the fuzzy evaluation system and the decision making support system | | |
| Step 3.1 | System input of evaluation values for each person in each role | OB5, IA3, IA6, IA8 (point 1) | Value chart for roles/individuals (OC1) |
| Step 3.2 | Determining the weight measures or roles and projects using the AHP method | OA3, IA8 (point 2), OC1 | Chart for weight measures associated with roles and projects (OC2) |
| Step 3.3 | Configuring the projects by assigning personnel | IA8 (points 3-5) | Project configurations chart (OC3) |
| Phase 4 | Efficiency evaluation | | |
| Step 4.1 | Finding the weak spots coming from the assignment | OC3, IA8 (point 6) | Chart for project jobs to be reconsidered (OD1) |
| Step 4.2 | Analysis of the executed distribution and establishing the option of re-assignment of the current or attracting new personnel | OC3, OD1, IA6 | Chart for jobs to be re-assigned/filled by attracting new personnel (OD2) |
| Step 4.3 | Project configuration after the re-assignment/assignment of the current/attracted personnel | OD2, OB5, OA6, IA7, IA8 (points 1-5) | |

**Restrictions affecting the model:**

Generic qualities of the object system; organizational shape, culture and business rules, knowledge and skills level of the candidates to be assigned and their number, demand level of their roles, competence of the evaluator - the bearer of group decisions, technical-technological level, the money available for salaries, the openness of the system and the ability to react quickly to changes, offer structure at the job market, economical and political stability.

Conditions for development and implementation:

The existence of a team of competent experts for system development and use who know the personnel and their abilities, have a detailed insight into the structure of the conditions set for particular jobs, as well as the existence of a necessary program framework base.

Theories this approach is based on:

General Systems Theory, Fuzzy Logic, Fuzzy Sets Theory, Classical Theory of Decision-making.

Result:

By executing the phases and steps within them and using input/output values the final result is reached - project teams configuration considering the individual/role relations.

## 5. Conclusions

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 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. Furthermore, the framework for project teams optimal assignment has also been developed, based on usage of a fuzzy system together with an AHP decision making support system. In this manner ex-ante evaluation of the suitability of an individual to take over a certain role within the project team that is being created is being performed for the configuration of project teams and assigning workforce, while the AHP method decides the weighted values of the evaluated roles and projects.

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