Irena BACH-DĄBROWSKA[1]

FUZZY MODEL FOR STRUCTURING PROJECT TEAMS

Abstract

The aim of this paper is to present the new approach to process of project team structuring. This approach contains proposition of reference model for selection process, formulated in terms of fuzzy logic theory. The model allows formalising in mathematical way linguistic, rough assessment of human behaviour, competency, and psychological profile according to vacant posts, project and team requirements.

1. INTRODUCTION

It is common knowledge for human resource (HR) leaders that wrong decisions of a few people can bring down a crucial project or even a major company. The human factor is the most flexible, adaptable and valuable part of the project team, but also is the most vulnerable to human relation influences that can adversely affect its performance.

It means that only project team with accurate competencies and a good leader, well matched to the project nature/subject and to the psychological profile of the team, can guarantee the success of the project implementation. Moreover, to increase chance of venture success, it is necessary to provide cross-functional team, engaging people that possess the collective knowledge needed to make decisions on nontrivial issues connected to project tasks execution [3].

Nevertheless, looking through the techniques dedicated to project management, most of them focus on approaches to selecting projects, networking projects tasks or estimating cost rather than on minimizing the human risk factor.

According to the foregoing, it is necessary to develop formalized methods and tools allowing to select the best adjusted (fulfilling conditions such as competencies level, experience, availability, and wages) candidates from set of applicants for project team.

2. METHODS AND MODELS APPLIED IN STRUCTURING PROCESS

Recruitment and selection refers to the chain and sequence of activities pertaining to recruitment and selection of employable candidates and job seekers for a project. Every enterprise, business, start-up and entrepreneurial firm has some well-defined employment and

[1]Ph.D. Bach-Dąbrowska Irena, Technical University of Koszalin, Electronics and Computer Science Department, bach@ie.tu.koszalin.pl

recruitment policies and hiring procedures [14]. Methods and soft tools implemented in hiring process can be categorized to one from four groups:

- Assessment of application forms: curriculum vitae, covering letter, personal questionnaire, certificates and diplomas, education rankings;
- Inspection of references: written references, verbal references;
- Interviews: formalized proceedings, informal/easy conversations;
- Tests: skills/competency tests, samples and simulations of work, medical tests, psychological tests.

Some of employers also use of Assessment Center/Development Center services that guarantee professional and complex performance of recruitment process.

When there is a need to hire professional staff for crucial project, it is necessary to employ all named methods and tools. The most important are those, which allow to asses adjustment of each applicant in respect to psychological profile of whole project team. On the HR management target, there exist wide ranges of special psychological test that recruitment personnel can apply in hiring process.

As an example the Thomas-Kilmann Conflict Mode Instrument [15] measures how much people display competing, collaborating, compromising, avoiding, and accommodating behavior in conflict situations. The T-P (Task-People) Leadership Questionnaire [10] examines the extent to which individuals focus on tasks versus people in work situations. The FIRO-B Awareness Scale [6] examines people along three dimensions: inclusion ("Do you desire strongly to be included in group activities? Do you like to include others?"), control ("Do you prefer being in situations that are well under control? Do you feel a strong need to take control of situations?"), and affection ("Is it important to you to be liked? Do you express affection toward others?") [3].

The most popular and adaptable method is however the Myers-Briggs Test Indication (MBTI) [7], [8] which allow to determine and categorized people to one from sixteen possible psychological types. This typology is simple, practical and reliable tool, which is used to precise requirements for specify functions or work post and in respect of applicants applied for this post. It is also helpful in searching for complementary types of leaders and subordinates as well as in optimizing project teams. Reliability and accuracy of MBTI method has been confirm thru review millions of tests carried out on employees from large business companies such as Apple Computer, Exxon, AT&T, CityCrop, General Electric, Honeywell, McDonald's or 3M. It has been estimated that only in 1986 in United States this test has been carried out on over one and a half million of people [5]. From that time MBTI and other popular psychological test like Belbin Team Roles [1], [2] becomes a standard in recruitment and selection process.

All of mentioned methods apart from good points have also bad one that significantly affects on selecting quality. Main disadvantages of described methods are as follow:

- carry out and verify tests for all applicants require great cost of time and labor, thus in situation of large amount of applications there exist a suspicion of unconscientiously work performance,
- assessment of application forms and the review process carried out by human resource can be exposing on lack of impartiality.

It is easy to notice that there is a need to develop one general model and solving method of structuring project team process, implementation of which ensue:

- impartial and non emotional, thus a fair assessment of each candidate,
- uniform procedure of verification for all applicants.

The class of problem described in the next paragraph will be formulated by the defined reference model.

3. PROBLEM STATEMENT

Given is a project, characterized by its complexity, specific/required character of management and time window for its execution.

Given is a set of vacancies necessary to fill in a project team, characterized by required competency level, experience, availability, MBTI profile.

Given is a set of candidates for vacant posts, characterized by their competencies, work experience, psychological profile and availability.

Information about project, vacancies and candidates are formulated in linguistic way. Values of decision variables are defined in both precise (crisp) and imprecise (fuzzy) way and can take a form of numbers as well as words.

The following questions are considered:

- Does there exist a project team (set of alternative projects teams) allowing to achieve assumed project objectives?
  If YES:
- Which combination of candidates (alternative sets) allow to achieve assumed project objectives?
- Does there exist a candidate, who fulfils given set of the basic criteria and is well adjusted to the project team?
  If YES:
- Which of candidates is best adjusted to vacant post and to project team?

This paper presents a proposition of general reference model based on fuzzy set theory, model that allows defining and resolving structuring project teams decision problems. Proposed model combine precise and imprecise values of decision variables.

4. FUZZY MODEL

In the situation where the quality assessment is needed and there are no measuring devices able to carry out measurement – for example stress resistance level, force of pressure, intuition level, chance of getting promotion in given workplace, people usually do not have any problems with evaluation. They use of linguistic values based on rough, fuzzy evaluation.

In 1965, Lotfi Zadeh formalized this approach as Fuzzy Logic theory.

Fuzzy logic is a form of many-valued logic, based on imprecise data implementing approximate rather than fixed and exact reasoning. In contrast with traditional logic theory, where binary sets have two-valued logic: true or false, fuzzy logic variables may have a truth-value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth-value may range between completely true and completely false. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions [4].

The reasoning in fuzzy logic is similar to human reasoning. It allows for approximate values and inferences as well as incomplete or ambiguous data (fuzzy data) as opposed to only

relying on crisp data (binary yes/no choices). Fuzzy logic is able to process incomplete data and provide approximate solutions to problems other methods find difficult to solve.

As this article is not dedicated to explain the basics of fuzzy logic theory, in following book positions [9], [12], interested readers can find detailed description of this theory. Therefore only the most important definitions, needed to understand and define of fuzzy set, are given below (Def. 1 based on [13], [11], Def. 2 ÷ 5 based on [9]).

Definition 1.: ***Linguistic variable*** is a variable whose values are words or sentences instead of numbers and that is characterized by a quadruple [L, $T(L)$, Ω, M] in which L is the name of the variable, $T(L)$ is a countable term set of labels or words (i.e. the linguistic values), Ω is a universe of discourse and M is a semantic rule.

***Example*:**
X is variable with values in Ω [0, 10]
[L, $T(L)$, Ω, M] is a linguistic variable labeling X, where:
T(L): {very small, small, medium, large, very large},
M (very small) = [0:1 2:1 3:0],
M (small) = [1:0 2:1 4:1 5:0],
M (medium) = [3:0 4:1 6:1 7:0],
M (large) = [5:0 6:1 8:1 9:0],
M (very large) = [7:0 8:1 10:1].

Definition 2: ***Linguistic value*** is a words assessment of linguistic variable.

Example:
L: Speed
Linguistic values: high, medium, low

Definition 3: ***Fuzzy Set*** is any set that allows its members to have different degree of membership, called membership function, in the interval [0 - 1].

Fuzzy set A, defined in the numerical universal of discourse Ω, is a set of pairs:

$$A= \{(\mu_A^*(q), q)\}, \forall q \in \Omega. \quad (1)$$

Where:
μ_A is a membership function of fuzzy set A,
$\mu_A^*(q)$ is membership grade of the element q in a fuzzy set A, while $\mu_A(q) \in [0,1]$.

Membership function implements representation of numerical universe of discourse for given variable to the range [0,1]:

$$\mu_A: \Omega \rightarrow [0,1].$$

Definition 4: ***Membership function. Grade of membership.***
The membership function associates to each element q of given variable a certain value from range [0,1]:

$$\mu_A(q): \Omega \rightarrow [0,1], \forall q \in \Omega. \quad (2)$$

This value, named *grade of membership* informs in what grade element q belongs to the fuzzy set A.

Definition 5: ***Singleton*** is a set with exactly one element and one membership grade. For example set {0} is singleton and $\mu_A^*(0) = 1$.

Basing on above-mentioned definitions, general assumptions to the reference model and fuzzy model for structuring project teams are presented.

4.1. General assumptions for reference model

VARIABLES

Given is a set of linguistics variables $V_i = \{V_1, \ldots, V_n\}$, $i \in$ N - {0}, defining input and output criteria of candidates assessment in structuring process of project team. Linguistic variable V_i is characterized by a quadruple $[L_i, T_i(L), \Omega_i, M_i]$, where:

$L_i = \{L_1, \ldots, L_n\}$, $i \in$ N - {0} – set of names of linguistic variables;
$T_i(L_i) = \{T_1(L_1), \ldots, T_n(L_n)\}$, $i \in$ N - {0} – set of countable term set of labels or the linguistic values;
$t_{ij} = \{t_{11}, t_{12}, \ldots, t_{nm}\}$, $i,j \in$ N - {0}, $t_{ij} \subset T_i(L_i)$ – set of the linguistic values of linguistic variable;
$\Omega_i = \{ \Omega_1, \ldots, \Omega_n\}$, $i \in$ N - {0} – set of a universes of discourse of linguistic variable V_i;
$M_i = \{M_1, \ldots, M_n\}$, $i \in$ N - {0} – set of semantic rules;
$m_{ij} = \{m_{11}, m_{12}, \ldots, m_{nm}\}$, $i,j \in$ N - {0}, $m_{ij} \subset M_i$ – variability range for linguistic value t_{ij} with grade of membership equal 0 or 1.

MEMBERSHIP FUNCTIONS

Given are standard, piecewise linear shapes of membership functions (MBF) represents the degree to which the crisp value of linguistic variables V_i belong to a fuzzy set. In other words, MBF represents terms describing linguistic variables.

Although scientific publications have suggested many different types of MBF for fuzzy logic, standard MBF are used in most practical applications. Great value of piecewise linear type of MBF is the fact, that only minimum information is necessary to define them. For example to define triangular MBF it is enough to define three values: most typical value as a middle of variability range also maximum and minimum values for that range.

Reference model assume using of following MBF shapes (Dig. 1):

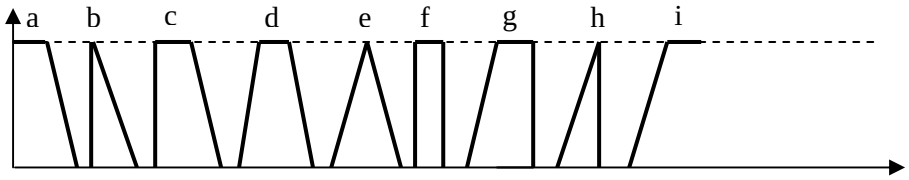

Diagram 1 Shapes of most common piecewise linear membership functions

- (a) Left external (LE),
- (b, h) Triangular asymmetrical (TA),
- (c, g) trapezoidal asymmetrical (TRA),
- (d) trapezoidal symmetrical (TRS),
- (e) triangular symmetrical (TS),
- (f) rectangular (R),
- (i) right external (RE).

The assumption is made that structuring process of project team includes three stages:

- Stage 1 – Defining of project requirements:
  a) determination of expected competency level for each post in project,
  b) determination of behavioral type for each post in project,
  c) project complexity,
  d) project character;
- Stage 2 – Preliminary verification process: analyzing of application forms and selection of candidates fulfils:
  a) given set of basic criteria,
  b) given set of required competency,
  c) adjustment to Myers-Briggs Type Indicator (MBTI) for chosen posts in project team,
  d) availability criteria for given period of time;
- Stage 3 – Final selection:
  a) determination of final set of candidates and reserve list, depending on output variables ranges obtained on previous stages,
  b) grouping chosen set of candidates into alternative project teams, according to psychological profile of group conformity.

Reference model based on fuzzy logic theory is divided according too above named three stages:

- project requirements reference model,

- preliminary verification reference model,
- final selection reference model.

Particular models are shown in tabular presentations Tab1., Tab2., Tab3.
In these models following symbols occur:

- "*u*" – "units" for universe of discourse *Ω*,
- for MBTI profiles combination of following symbols:
  - *E* – Extraversion,
  - *I* – Introversion,
  - *S* – Sensing,
  - *N* – Intuition,
  - *T* – Thinking,
  - *F* – Feeling,
  - *J* – Judging,
  - *P* – Perceiving.

4.1.1. Project requirement reference model

Project requirements reference model is multiply input – multiply output (MIMO) type, where project complexity and project character are input variables while expected competency level for post and expected MBTI profile for post are output variables (Dig. 2).

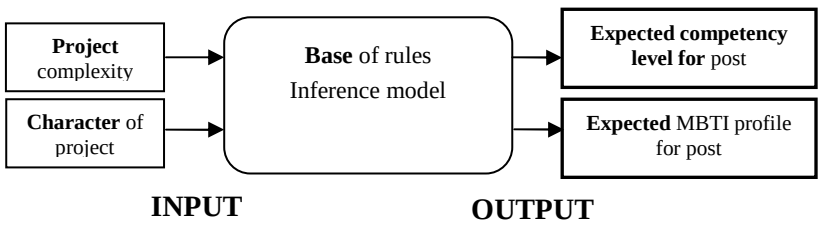

Diagram 2. Multiply input-Multiply output model

The first stage allows identify the main requirements following from project specification. Table 1 shows fuzzy model for this stage based on definition presented on the beginning of this chapter.

Table 1. Project requirements reference model (Stage 1)

PROJECT REQURIMENTS REFERENCE MODEL						
V_i	**L_i**	**$T_i(L_i)$**	**t_{ij}**	**Ω_i**	**M_i**	**m_{ij}**
V_1	Project complexity level	$T_1(L_1)$	t_{11}(low) t_{12}(medium) t_{13}(high)	[0 ÷ 6] *u: points*	M_1	m_{11}[0:1 1:1 2:0] LE m_{12}[1:0 3:1 4:0] TA m_{13} [3:0 5:1 6:1] TRA
V_2	Project character	$T_2(L_2)$	t_{21}(technical) t_{22}(technical/soft) t_{23}(soft)	[0 ÷ 6] *u: points*	M_2	m_{21}[0:1 3:0] TA m_{22}[2:0 3:1 4:1 5:0] TRS m_{23} [4:0 6:1] TA
V_3	Expected competency level for post	$T_3(L_3)$	t_{31}(medium) t_{32}(medium high) t_{33}(high)	[0 ÷ 6] *u: points*	M_3	m_{31}[0:1 3:0] TA m_{32}[2:0 3:1 4:1 5:0] TRS m_{33} [4:0 6:1] TA
V_4	Expected MBTI profile for post	$T_4(L_4)$	t_{41}(ISTJ) t_{42}(ISTP) t_{43}(ESTP) t_{44}(ESTJ) t_{45}(ISFJ) t_{46}(ISFP) t_{47}(ESFP) t_{48}(ESFJ) t_{49}(INFP) t_{410}(ENFP) t_{411}(ENFJ) t_{412}(INTJ) t_{413}(INTP) t_{414}(ENTP) t_{415}(ENTJ) t_{416} (INFJ)	[1÷16] *u: points*	M_4	m_{41} [1:1] Singleton (S) m_{42} [2:1] S m_{43} [3:1] S m_{44} [4:1] S m_{45} [5:1] S m_{46} [6:1] S m_{47} [7:1] S m_{48} [8:1] S m_{49} [9:1] S m_{410} [10:1] S m_{411} [11:1] S m_{412} [12:1] S m_{413} [13:1] S m_{414} [14:1] S m_{415} [15:1] S m_{416} [16:1] S

Reading key:

Variable V_1
Name L_1: project complexity level
Set of linguistic values $T_1(L_1)$: {low, medium, high}
The universe of discourse of V_1, Ω_1: [0÷6]
Terms for linguistic values:
m_{11}[0:1 1:1 2:0] LE,
m_{12}[1:0 3:1 4:0] TA,
m_{13} [**3:0 5:1 6:1**] TRA,

Graphical representation:

Obtained in Stage 1 requirements for vacant posts forms ground for expected candidates profile determination in the Stage 2.

4.1.2. Preliminary selection reference model (Stage 2)

Preliminary selection reference model is multiply input – single output (MISO) type. Implementation of this model is additionally divided into four steps (Dig. 4). First step includes all applicants and on every subsequent step the number of candidates is reduce to successful ones from previously stage, that mean candidates with *sufficient adjustment to the post* without constraint of grade of membership level. On the last, fourth step of verification, the output list of successful candidates is sort according to grade of membership. In that way the final set of verified candidates can be placed under final verification process on Stage 3.

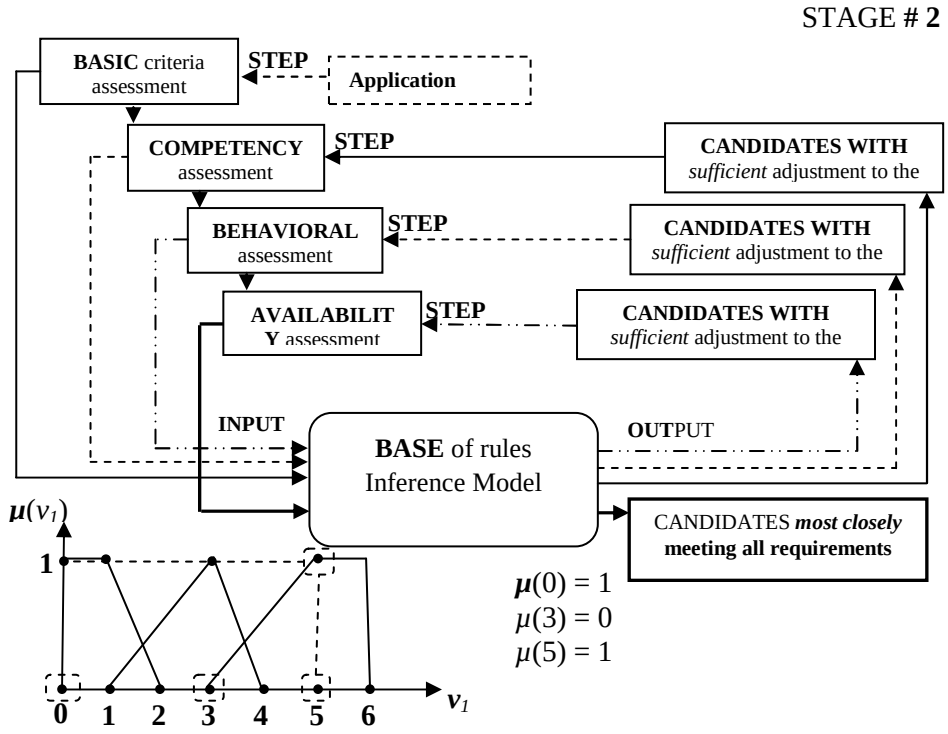

Diagram 3. Graphical representation of fuzzy definition for variable V_1

Diagram 4. Four steps of preliminary selection process (own analysis)

Table 2 presents the whole reference model for Stage 2.

Table 2. Preliminary verification reference model

PRELIMINARY VERIFICATION REFENRECE MODEL						
V_i	**L_i**	**$T_i(L_i)$**	**t_{ij}**	**Ω_i**	**M_i**	**m_{ij}**
V_5	Practice on independently post	$T_5(L_5)$	t_{51}(low) t_{52}(medium low) t_{53}(medium high) t_{54}(high)	[0 ÷ 10] *u: years*	M_5	m_{51}[0:1 1:1 2:0] LE m_{52}[1:0 3:1 4:0]TA m_{53}[3:0 5:1 6:0]TA m_{54}[5:0 7:1 10:1] TRA
V_6	Participation in project teams	$T_6(L_6)$	t_{61}(small) t_{62}(medium) t_{63}(high)	[0 ÷ 8] *u: numbers of projects*	M_6	m_{61}[0:1 1:1 2:0] LE m_{62}[1:0 3:1 5:0]TS m_{63}[4:0 6:1 8:1] TRA
V_7	Candidate competency level	$T_7(L_7)$	t_{71}(low) t_{72}(medium) t_{73}(high)	[0 ÷ 6] *u: points*	M_7	m_{71}[0:1 3:0] TA m_{72}[2:0 3:1 4:1 5:0] TRS m_{73} [4:0 6:1] TA
V_8	MBTI profile	$T_8(L_8)$	t_{81}(ISTJ) t_{82}(ISTP) t_{83}(ESTP) t_{84}(ESTJ) t_{85}(ISFJ) t_{86}(ISFP) t_{87}(ESFP) t_{88}(ESFJ) t_{89}(INFP) t_{810}(ENFP) t_{811}(ENFJ) t_{812}(INTJ) t_{813}(INTP) t_{814}(ENTP) t_{815}(ENTJ) t_{816} (INFJ)	[1÷16] *u: points*	M_8	m_{81} [1:1] S m_{82} [2:1] S m_{83} [3:1] S m_{84} [4:1] S m_{85} [5:1] S m_{86} [6:1] S m_{87} [7:1] S m_{88} [8:1] S m_{89} [9:1] S m_{810} [10:1] S m_{811} [11:1] S m_{812} [12:1] S m_{813} [13:1] S m_{814} [14:1] S m_{815} [15:1] S m_{816} [16:1] S
V_9	Availability	$T_9(L_9)$	t_{91}(consistent) t_{92}(inconsistent)	[0÷4] *u: points*	M_9	m_{91}[0:1 3:0] TA m_{92}[2:0 4:1] TA
V_{10}	Post character	$T_{10}(L_{10})$	t_{101}(independent) t_{102}(dependent)	[0÷4] *u: points*	M_{10}	m_{101}[0:1 3:0] TA m_{102}[2:0 4:1] TA
V_{11}	Post adjustment	$T_{11}(L_{11})$	t_{111}(sufficient) t_{112}(insufficient)	[0÷2] *u: points*	M_{11}	m_{111}[0:1 1.5:0] TA m_{112}[1:0 2:1] TA

Each step has assigned input and output variables according to Table 3.

Table 3. Input and output variables for preliminary selection reference model

STEP	Input variables	Output variables
1	V_5, V_6, V_{10}	V_{11}
2	V_7, V_{10}	V_{11}
3	V_8, V_{10}	V_{11}
4	V_9, V_{10}	V_{11}

As the results of Stage 2 obtained is a set of candidates fulfill with at least 0.5 grade of membership all basic criteria. On this stage however candidates are not jet categorized according to their achieved results, and also are not 'confront whit each other'. That mean the competencies of candidates are enough for the posts, but there is no guarantee of effective, peaceable cooperation with others team members. Those two important elements are obtained and verified on Stage 3.

4.1.3. Final selection reference model

The final selection process, as in the case of the second Stage, is divided in to two steps. The first step allows categorizing selected on Stage 2 candidates according to the results achievements. That allows creating a list of basic candidates for project team, and two additional reserve lists.

The second step of final selection process allows checking adjustment of chosen candidates according to their MBTI profile, and ability to work in selected team. It is crucial stage, as it is know that even the best specialist, when are unable to work with each other, can bring undertaken project to failure.

The reference model for step one in final selection process is MISO type, where V_7,V_8,V_{11}, are input variables and V_{12} is output variable.

Table 4 Final selection reference model

FINAL SELECTION REFERENCE MODEL						
V_i	**L_i**	**$T_i(L_i)$**	**t_{ij}**	**Ω_i**	**M_i**	**m_{ij}**
V_7	Competency level	$T_7(L_7)$	t_{72}(medium) t_{73}(high)	[0 ÷ 6] *u: points*	M_7	m_{72}[2:0 3:1 4:1 5:0] TRS m_{73} [4:0 6:1] TA
V_8	MBTI profile	$T_8(L_8)$	t_{81}(ISTJ) t_{82}(ISTP) t_{83}(ESTP) t_{84}(ESTJ) t_{85}(ISFJ) t_{86}(ISFP) t_{87}(ESFP) t_{88}(ESFJ)	[1÷16] *u: points*	M_8	m_{81} [1:1] S m_{82} [2:1] S m_{83} [3:1] S m_{84} [4:1] S m_{85} [5:1] S m_{86} [6:1] S m_{87} [7:1] S m_{88} [8:1] S

			t_{89}(INFP) t_{810}(ENFP) t_{811}(ENFJ) t_{812}(INTJ) t_{813}(INTP) t_{814}(ENTP) t_{815}(ENTJ) t_{816} (INFJ)			m_{89} [9:1] S m_{810} [10:1] S m_{811} [11:1] S m_{812} [12:1] S m_{813} [13:1] S m_{814} [14:1] S m_{815} [15:1] S m_{816} [16:1] S
V_{11}	Post adjustment	$T_{11}(L_{11})$	t_{111}(sufficient) t_{112}(insufficient)	[0÷2] *u: points*	M_{11}	m_{111}[0:1 1.5:0] TA m_{112}[1:0 2:1] TA
V_{12}	Assignment	$T_{20}(L_{20})$	T_{201}(basic) T_{202} (reserveA) T_{203}(reserveB)	[0 ÷ 5] *u: points*	M_{20}	M_{201}[3:0 5:1]TA M_{202}[2:0 3:1 4:0] TS M_{203}[0:1 3:0] TA

As the result of this process three list of candidates are prepared:

- Basic list – includes candidates who assignment to the vacant post is not les than 0.8 grade of membership,
- Reserve A list – includes candidates who assignment to the vacant post is between 0.6÷ 0.8 grade of membership,
- Reserve B list – includes candidates who assignment to the vacant post is between 0.5 ÷ 0.6 grades of membership.

In the second step of the final selection process, occurs comparison of chosen candidates according to the posts and relation occurring between those posts and to MBTI profile of candidates.

Table 5. Reference model of team adjustment

TEAM ADJUSTMENT REFERENCE MODEL						
V_i	**L_i**	**$T_i(L_i)$**	**t_{ij}**	**Ω_i**	**M_i**	**m_{ij}**
V_{13}	Post A character	$T_{13}(L_{13})$	$t_{13,1}$(executive) $t_{13,2}$(subsidiary)	[0 ÷ 4] *u: points*	M_{13}	$m_{13,1}$[0:1 3:0] TA $m_{13,2}$[2:0 4:1] TA
$V_{13'}$	Post B character	$T_{13'}(L_{13'})$	$t_{13',1}$(executive) $t_{13',2}$(subsidiary)	[0 ÷ 4] *u: points*	M_{14}	$m_{13',1}$[0:1 3:0] TA $m_{13',2}$[2:0 4:1] TA
V_8	MBTI profile	$T_8(L_8)$	$t_{8,1}$(ISTJ) $t_{8,2}$(ISTP) $t_{8,3}$(ESTP) $t_{8,4}$(ESTJ) $t_{8,5}$(ISFJ) $t_{8,6}$(ISFP) $t_{8,7}$(ESFP) $t_{8,8}$(ESFJ) $t_{8,9}$(INFP) $t_{8,10}$(ENFP) $t_{8,11}$(ENFJ) $t_{8,12}$(INTJ)	[1÷16] *u: points*	M_8	$m_{8,1}$ [1:1] S $m_{8,2}$ [2:1] S $m_{8,3}$ [3:1] S $m_{8,4}$ [4:1] S $m_{8,5}$ [5:1] S $m_{8,6}$ [6:1] S $m_{8,7}$ [7:1] S $m_{8,8}$ [8:1] S $m_{8,9}$ [9:1] S $m_{8,10}$ [10:1] S $m_{8,11}$ [11:1] S $m_{8,12}$ [12:1] S

			$t_{8,13}$(INTP) $t_{8,14}$(ENTP) $t_{8,15}$(ENTJ) $t_{8,16}$ (INFJ)			$m_{8,13}$ [13:1] S $m_{8,14}$ [14:1] S $m_{8,15}$ [15:1] S $m_{8,16}$ [16:1] S
$V_{8'}$	MBTI profile	$T_8(L_8)$	$t_{8,1}$(ISTJ) $t_{8,2}$(ISTP) $t_{8,3}$(ESTP) $t_{8,4}$(ESTJ) $t_{8,5}$(ISFJ) $t_{8,6}$(ISFP) $t_{8,7}$(ESFP) $t_{8,8}$(ESFJ) $t_{8,9}$(INFP) $t_{8,10}$(ENFP) $t_{8,11}$(ENFJ) $t_{8,12}$(INTJ) $t_{8,13}$(INTP) $t_{8,14}$(ENTP) $t_{8,15}$(ENTJ) $t_{8,16}$ (INFJ)	[1÷16] *u: points*	$M_{8'}$	$m_{8,1}$ [1:1] S $m_{8,2}$ [2:1] S $m_{8,3}$ [3:1] S $m_{8,4}$ [4:1] S $m_{8,5}$ [5:1] S $m_{8,6}$ [6:1] S $m_{8,7}$ [7:1] S $m_{8,8}$ [8:1] S $m_{8,9}$ [9:1] S $m_{8,10}$ [10:1] S $m_{8,11}$ [11:1] S $m_{8,12}$ [12:1] S $m_{8,13}$ [13:1] S $m_{8,14}$ [14:1] S $m_{8,15}$ [15:1] S $m_{8,16}$ [16:1] S
V_{14}	Effectiveness of cooperation	$T_{14}(L_{14})$	t_{14}(low) t_{14}(medium) t_{14}(high)	[0 ÷ 6] *u: points*	M_{14}	$m_{14,1}$ [0:1 3:0] TA $m_{14,2}$ [2:0 3:1 4:1 5:0] TRS $m_{14,3}$ [4:0 6:1] TA

As the result of the last step of selecting process the alternative sets of team, fulfilling given assessment criteria, are generated.

To conduct the structuring process basing on presented reference models it is necessary to implement this model in fuzzy system.

5. IMPLEMENTATION – DECISION MAKING

Fuzzy logic systems are build form three main blocs (Dig. 5): Fuzzification, Inference, and Defuzzification.

In FUZZIFICATION, crisp input values are translated into linguistic concepts, which are represented by fuzzy sets. These concepts are called linguistic variables. Degrees of membership for all input values are assigned.

Decision making process in fuzzy logic systems is rule-based. Linguistic rules are formed using operators that represent linguistic AND and OR. Finally, a computation of the applicability of the rules themselves – represented by a linguistic IF...THEN expression – is performed. The inference is a calculus consisting of the steps: aggregation, composition and, if necessary, result aggregation.

Diagram 5. Fuzzy logic system blocks

The first step of the fuzzy inference, aggregation, determines the degree to which the complete IF part of the rule is fulfilled. Special fuzzy operators are used to aggregate the degrees of support of the various preconditions. Finally, if more than one rule produces the same consequence, an operation must aggregate the results of these rules. A result aggregation step determines the maximum degree of support for each consequence, which is used for all further processing. This step is called fuzzy INFERENCE.

In DEFUZZIFICATION block, the result of the fuzzy inference is modified from a linguistic concept to a crisp output value.

The diagram 6. shows the inference process.

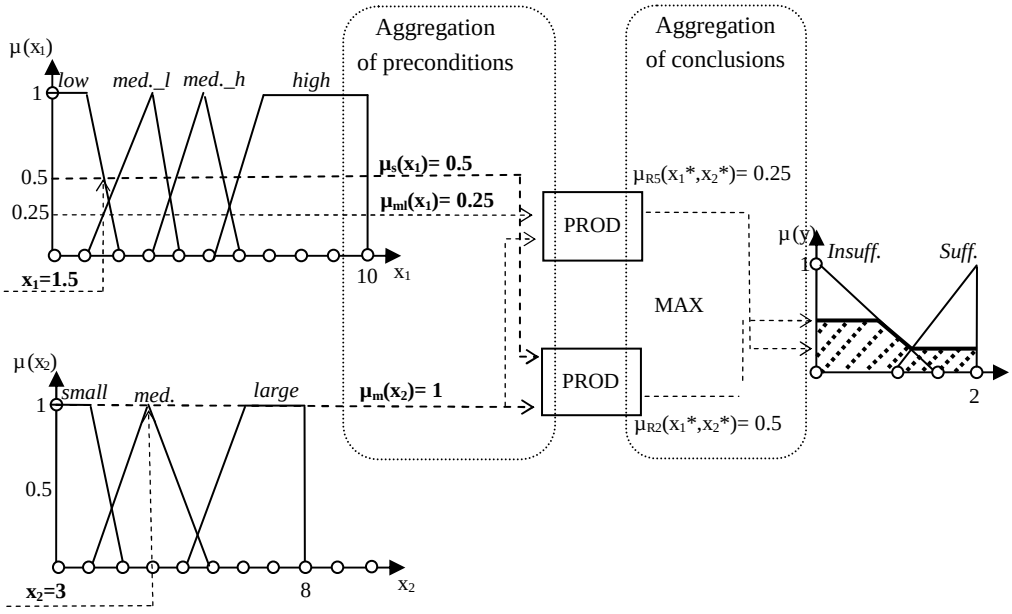

Diagram 6. Example of inference process

Fuzzy system implementing proposed in chapter 4 reference model is presented on diagram 7. This system includes all divided reference models from Stage 1 to Stage 3.

It can be notice that designed system structure includes seven rule bases. This solution follows from two main reasons:

- Process of candidates verification is divided on stages and steps, which means, that on each step different criteria's are checked; this allow on gradual selection of candidates; from this reason output values form one stage are implemented as an input values for next stage.

- Divided rule bases allow to minimize number of rules taking part in inference process; for example if on stage 2 instead of four different rule blocks with total number of rules equal 66, only one rule block would be design, the number of rules would increase to 1536. Rule base with so many rules is difficult to design and to guarantee correctness of its implementation. Moreover computation of the results would require more time

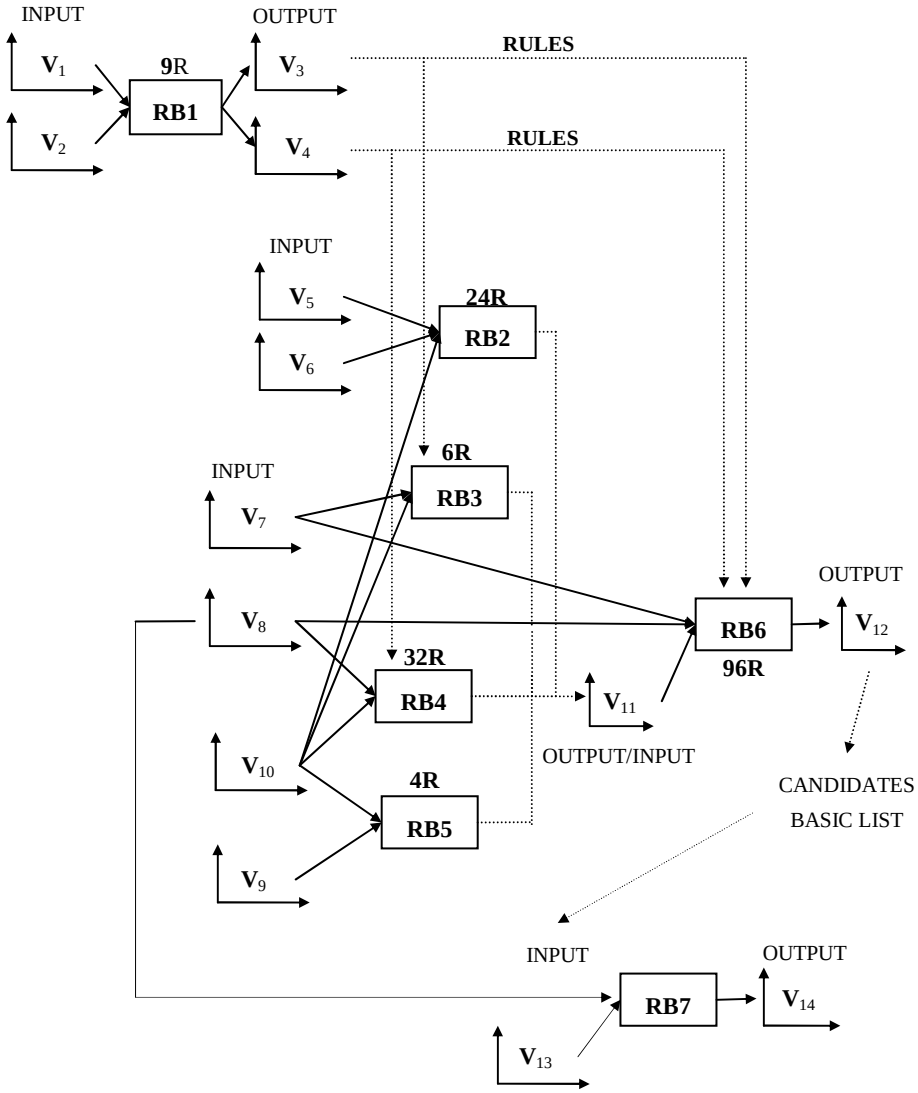

Diagram 7. Design fuzzy system structure

According to presented diagram 7, rule base number 1 applies on Stage 1 in project's requirements specification. Output information form this stage constitutes input project criteria defined in rule base on Stage 2.

For Stage 2 four rule bases are defined – number 2, 3, 4 and 5. Output variable V_{11} from this Stage is apply as an input variable for Stage 3 with rule bases number 6 and 7.

As the result of the inference in rule base number 6 obtained is the basic list of best-adjusted candidates, and two additional reserve lists. The candidates form basic list are verify

on next step (rule base number 7) according to their psychological profile and effectiveness of cooperation in given project team. That allow to group chosen candidates in project teams.

Implementation of proposed reference model, and decision-making process is presented in following example, for purpose of which the basic assumption according to fuzzification, inference and defuzzification process are as follows:

- compensatory operators: Min, MAX
- inference mechanism: MAX-PROD
- defuzzification mechanism: Best Compromise.

6. EXAMPLE

This example consider the situation, where given is a team project in which one managerial vacant need to be filled up. Given is a set of six candidates for this post. Known are input values of linguistic variables, defined in reference models form chapter 4. This example shows systematically the verification process in proposed reference model and design fuzzy system structure.

STAGE 1. Project requirements specification

Given is reference model consistent with Table 1, chapter 4, subsection 4.1.1.

Inference process from Stage 1 allows getting the answer to the question:
For given project complexity and project character what is the expected competency level and MBTI profile for the vacant post?

Model: input variables V_1, V_2; output variables V_3, V_4.

Input data:
V_1 – project complexity level: 4 points $\rightarrow t_{12}$ (medium)
V_2 – project character: 3 points $\rightarrow t_{22}$ (technical/soft)
Output:
V_3 – expected competency level
V_4 – expected MBTI profile

Basing on expert knowledge the rule base matrix has been defined.

Reading Key for rule base:
R1: IF $V_1 = t_{11}$ AND $V_2 = t_{21}$ THEN $V_3 = t_{3,1}$ AND $V_4 = t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$
R2: IF $V_1 = t_{12}$ AND $V_2 = t_{21}$ THEN $V_3 = t_{3,2}$ AND $V_4 = t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$
…

Table 6. Rule Base for Stage 1

V_1 / V_2	t_{11}(low)	t_{12}(medium)	t_{13}(high)
t_{21}(technical)	$t_{3,1}$/ $t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$	$t_{3,2}$/ $t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$	$t_{3,3}$/ $t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$
t_{22} (technical/soft)	$t_{3,2}$/ $t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$	$t_{3,2}$/ $t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$	$t_{3,3}$/ $t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$
t_{23} (soft)	$t_{3,3}$/ $t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$	$t_{3,3}$/ $t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$	$t_{3,3}$/ $t_{4,1}$or $t_{4,2}$ or $t_{4,5}$ or $t_{4,6}$ or $t_{4,9}$ or $t_{4,12}$ or $t_{4,13}$ or $t_{4,16}$

INFERENCE PROCESS: only one rule, nr 8 was activate (diagram 8)
R8:

$\mu_{v1/t1,3}(4) = 0.5$
$\mu_{v2/t2,2}(3) = 1$ } $\xrightarrow{\text{MIN}}$ $\mu_{v1/v2}(wyn) = 0.5$

Defuzzification for $\mu_{v1/v2}(wyn) = 0.5$ with Best Compromised method.

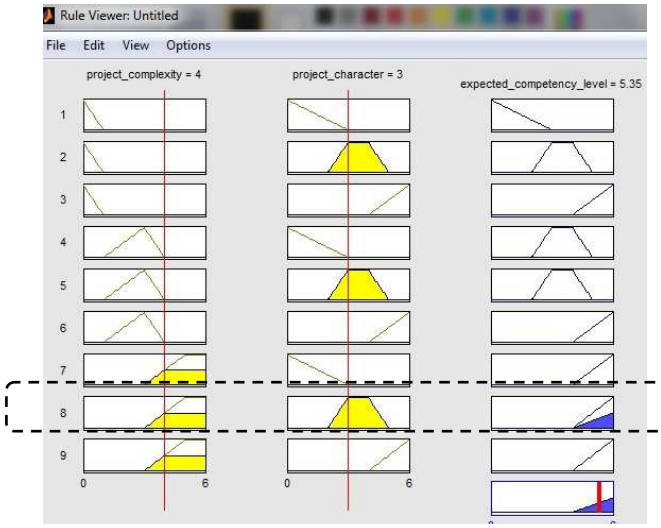

Diagram 8. Inference process in rule viewer

Table 7. Results for Stage 1

Input variable		**Given values**	
V_1	Project complexity level	t_{12} (medium)	4
V_2	Project character	t_{22}(technical/soft)	3
Output variable		**Results**	
V_3	Competency level	5.35 (high)	
V_4	MBTI profile	2 or 3 or 5 or 6 or 9 or 12 or 13 or 16	

The expected competency level for vacant post is equal 5.35 what, according to reference model, give the note 'high'.
The expected MBTI profile for vacant post is one from following psychological profiles: 2(ISTP), 3(ISTJ), 5(ISFJ), 6(ISFP), 9(INFP), 12(INTJ), 13(INTP), 16(INFJ).

Undermentioned tables contain the next Stages of verification process results. Prepared example has been implemented in Fuzzy Toolbox for MatLAB2010 environment. For each Stage proper rule base has been defined.

STAGE 2 Preliminary assessment of candidates

STEP 1. Basic criteria assessment

Table 8 Results for step 1

Input variable		**Given values**					
		C1	**C2**	**C3**	**C4**	**C5**	**C6**
			C2	**C3**	**C4**	**C5**	**C6**
V_5	Practice on independently post	2	0	5	4	2	7
V_6	Participation in project teams	1	4	2	6	8	2
V_{10}	Post character	2	2	2	2	2	2
Output variable		**Results**					
V_{11}	Post adjustment		1		0.493		0.493

The results from Step 1 show that only three from six candidates successfully pass verification process for basic criteria. To be successful on this step it is necessary to achieve grade of membership for 'post adjustment' in variability ranger from 0 to 1.5 point, where 0 is the best result, and 1.5 is the weakest acceptable value. Candidates who exceed the scope of given range are rejected from verification process. In given example those candidates are C1, C3 and C5. The others candidates go to the step number 2 – competency assessment.

STEP 2 Competency assessment

Table 9. Results for step 2

Input variable		**Given values**					
			C2		**C4**		**C6**
V_7	Competency level		3.5		5		4.5
V_{10}	Post character		2		2		2
Output variable		**Results**					
V_{11}	Post adjustment				0.49		0.956

To be successful on step two, it is necessary to achieve grade of membership for 'post adjustment' in variability ranger from 0 to 1.5 point. This time candidate number 2 exceed the scope of given range that means the person is rejected from further assessment process. From successful candidates, candidate number 4 has better notes than Candidate number 6. Both of them go to the next step.

STEP 3 Behavioral assessment

Table 10. Results for step 3

Input variable		**Given values**					
					C4		**C6**
V_8	MBTI profile				2		12
V_{10}	Post character				2		2
Output variable		**Results**					
V_{11}	Post adjustment				1		0.493

Behavioral assessment allows determining the MBTI profile adjustment according to post character. As the variability range for V_{11} variable is the same like in preceding steps, it is easy

to notice that candidate C6 obtained better notes than candidate C4, both of them however go to the last step of verification process in this stage.

STEP 4 Availability assessment

Table 11 Results for step 4

Input variable		**Given values**					
					C4		**C6**
V_9	Availability				1		1
V_{10}	Post character				2		2
Output variable		**Results**					
V_{11}	Post adjustment				0.49		0.49

After availability assessment, where both of verified candidates obtained equal, positive notes, the list of preliminary verified candidates is closed.

Now the information from the Stage 2 can be used in final verification process.

As the preliminary assessment has been divided into four steps with one, this same output linguistic variable, it is necessary to calculate the average value of notes obtained by candidates C4 and C6. This calculation allows determining who get the better general note for post adjustment. This note would be a value for an input variable V_{11}.

STAGE 3. Final candidate's assessment.

Table 12 Results for final verification

Input variable		**Given values**					
					C4		**C6**
V_7	Competency level				5		4.5
V_8	MBTI profile				2		12
V_{11}	Post adjustment				0.6182		0.608
Output variable		**Results**					
V_{12}	Assignment				1.75		1.61

After final verification fuzzy system, give the result of candidate's assignment to the vacant post.

According to reference model presented in Table 4, chapter 4, subsection 4.1.1., obtained results place both of verified candidates on reserve list B, while candidate C4 is placed higher

on that list than candidate C6. Of course, if there is no better candidates than those two, reserve list B become basic list, and the final decision need to be taken by hiring manager.

7. CONCLUDING REMARKS

Described proposition of general reference model for recruitment and selection is beginning of the research in area of the multicriteria decision-making in aim of structuring teams for project implementation based on fuzzy logic theory. The next step in this research is to verify and determine membership function shapes implemented for describing linguistic variables variability ranges. Simultaneously undertaken will be tasks allowing defining and solving reverse decision problems in structuring team process, form in examples question: Does there exist such a combination of qualification and competencies for given project team, which guarantee successful implementation of project tasks? And if 'yes' What are the variability ranges of competencies, qualification and psychological profile for particular team members that guarantee undisturbed project execution and achievement of project objectives?

REFERENCES

[1] BELBIN M. R.: *Team Roles at Work*, Butterworth Heinemann, 2nd ed., 2010
[2] BELBIN M. R.: *Management Teams: Why They Succeed or Fail*, Butterworth Heinemann, 3rd ed., 2010
[3] DAVIDSON FRAME J.: *Managing Projects in Organisations*, Jossey-Bass Business & Management Series, San Francisco 2008, str. 51-54
[4] GAUR V.K., SWATI G.: *Use of fuzzy logic and ist implementation in software engineering*, International Journal of Research in Science And Technology, (IJRST) 2011, Vol. No. 1, Issue No. II, July – Sept 2011
[5] GREENBERG J., BARON R.A.: *Behavior in Organizations: Understanding and Managing the Human Side of Word (4th Ed.)*,Needham Heighs, Allyn and Bacon 1993, str. 216.
[6] HAMMER A.L., SCHNELL E.R.: *FIRO-B Technical Guide*.
[7] MYERS, BRIGGS I., MYERS, P. B.: *Gifts Differing: Understanding Personality Type*. Mountain View, CA: Davies-Black Publishing (1980, 1995).
[8] MYERS BRIGGS I., McCAULLEY M. H.; QUENK N. L., HAMMER A. L.: *MBTI Manual (A guide to the development and use of the Myers Briggs type indicator*), Consulting Psychologists Press; 3rd Edition, 1998, str. 131
[9] PIEGAT A., *Modelowanie i sterowanie rozmyte*, Wydawnictwo EXIT, Warszawa 2000.
[10] PFEIFFER W.J., JONES J.E.: *A handbook of structured experiences for human relations training*, University Associates, 1985
[11] RAHEYA S., DHADICH R., RAJPAL S.: *An alternative interpretation of liguistic variables as Linguistic Finite Automata*, Internationa Jurnal of Computer Science & Issues, Vol. 8, Issue 4, No1, July 2011, str. 428 - 432
[12] RUTKOWSKI L.:*Metody i techniki sztucznej inteligencji*, Wydawnictwo Naukowe PWN, Warszawa 2005
[13] ZADEH L.A.: *The concept of a Linguistic Variable and ist Application to Approximate Reasoning – II**, Information Science, No.8, 1975, str. 301-357
[14] www.ehow.com/about_5208890_definition-recruitment-selection.html
[15] www.kilmann.com/conflict.html