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Contact:	„Applied Computer Science" – Editorial Office 20-618 Lublin, ul. Nadbystrzycka 36, Poland Tel.: (+48 81) 538 42 76 Fax.: (+48 81) 538 44 96 e-mail: wm.itsi@pollub.pl
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CONTENTS

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):

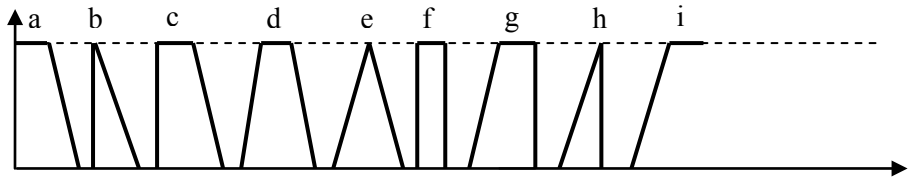

Diagram 1 Shapes of most common piecewise linear membership functions

- (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).

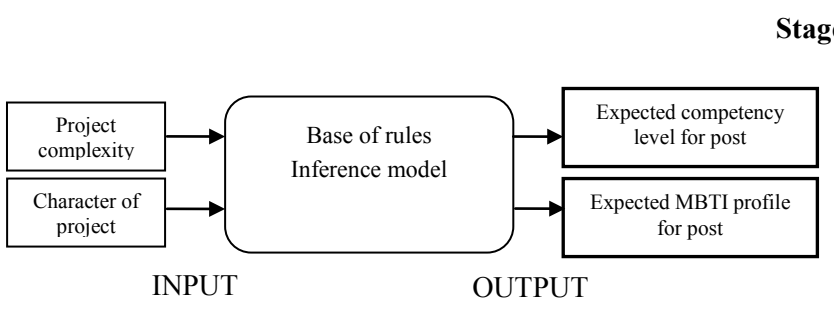

Diagram 2. Multiply input-Multiply output model

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.

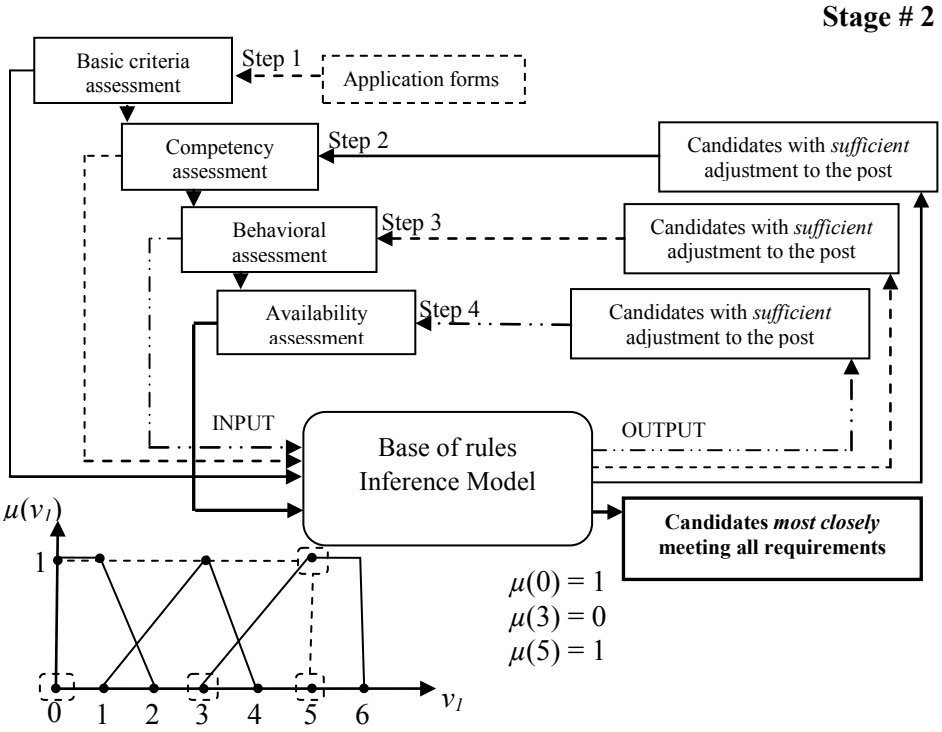

Diagram 3. Graphical representation of fuzzy definition for variable V_1

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_{ii}**	**Ω_i**	**M_i**	**m_{ii}**
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.

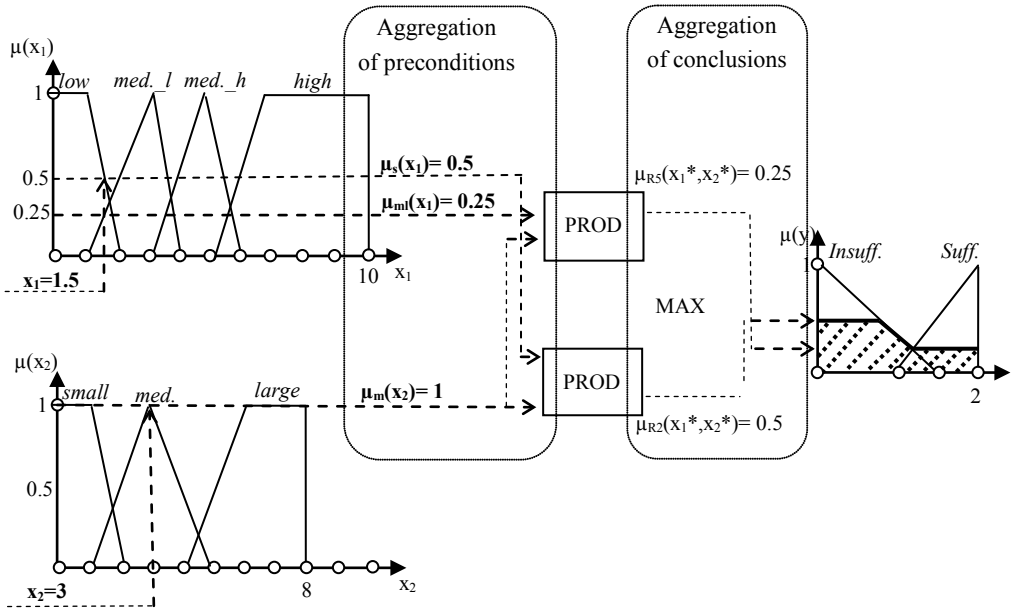

Diagram 6. Example of inference process

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

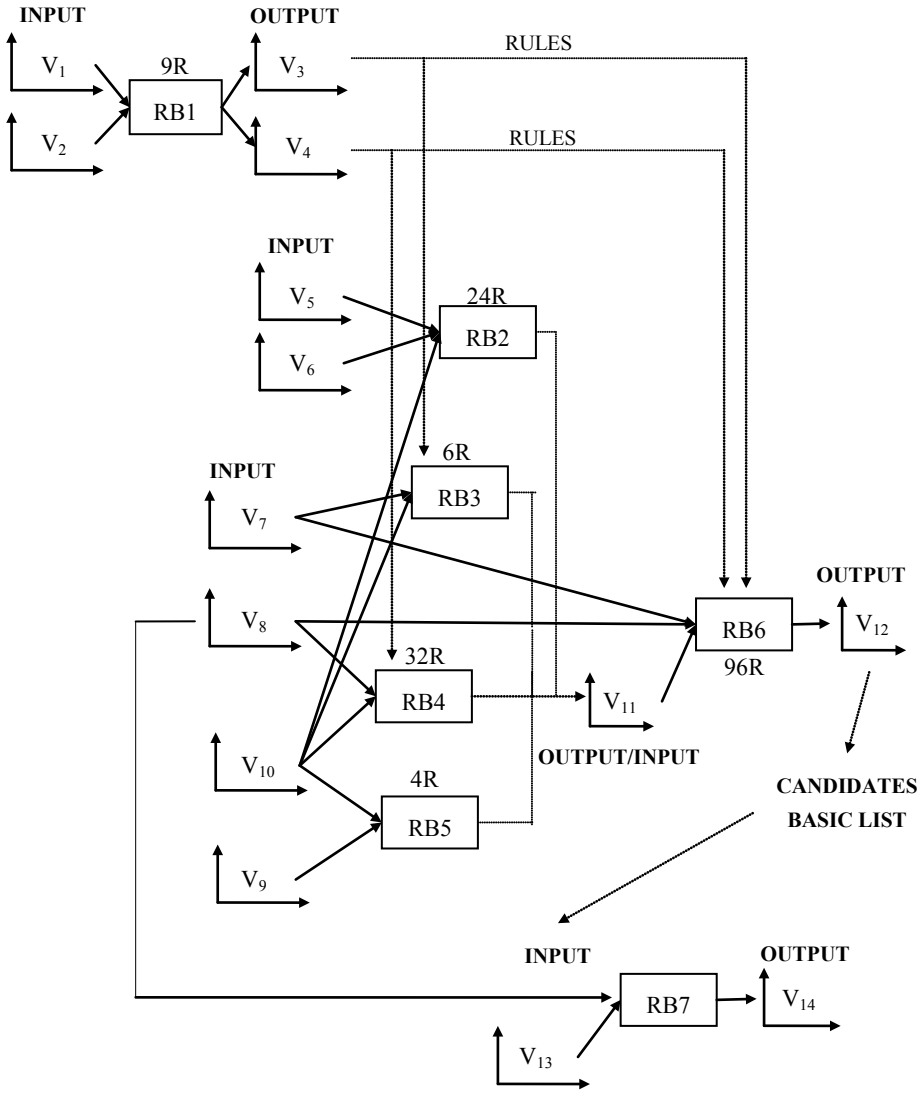

Diagram 7. Design fuzzy system structure

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_2 \ V_1	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:

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

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

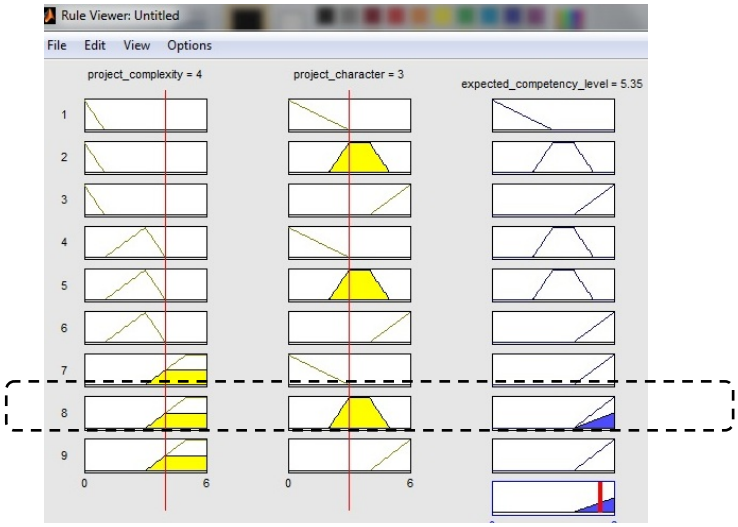

Diagram 8. Inference process in rule viewer

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?

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Key words: standard revenue, cost, controlling, budget

Małgorzata JUCHA [*], Józef MATUSZEK[**]

MODEL OF THE MANAGEMENT OF THE BUDGETING AND CONTROLLING PROCESS IN THE ORGANIZATIONAL ENTITIES OF ACADEMIC INSTITUTIONS

Abstract

In this article, the tendencies of the development of financing and functioning of academic institutions on the present-day educational market are presented. The required changes are characterized in the way finances are managed with a particular consideration of public academic institutions. Proposals are provided in relation to the determination of standard revenues of the organizational entities of academic institutions, analysis methods of the costs of the functioning of these entities and the budgeting of their operation. Prospects are presented of the development of the controlling of the realization of the budgets of the organizational entities of academic institutions.

1. INTRODUCTION

The national higher education system is entering a new stage of its functioning. A growing competition between academic institutions, progressing changes in the rules of financing of academic institutions, the numbers of students recruited which are to decrease in the coming future, increasing investment demands, growing numbers of unemployed graduates, increasing demands on the part of the economy concerning the quality of teaching and related to the skills possessed by graduates: all of these force changes in the management of academic institutions. Running of academic institutions, regardless of the social functions they perform, is becoming increasingly more similar to managing of an enterprise. The financing systems of academic institutions are changing: their community functions, in line with the tendency which is occurring at present, is being taken over by grants and other financing sources obtained; cf. Figs. 1, 2 and 3.

[*] mgr, Politechnika Koszalińska, ul. Śniadeckich 2, 75-453 Koszalin, matiz62@wp.pl
[**] prof. dr hab. inż., Akademia Techniczno-Humanistyczna, ul. Willowa 2, 43-309 Bielsko-Biała, jmatuszek@ath.bielsko.pl

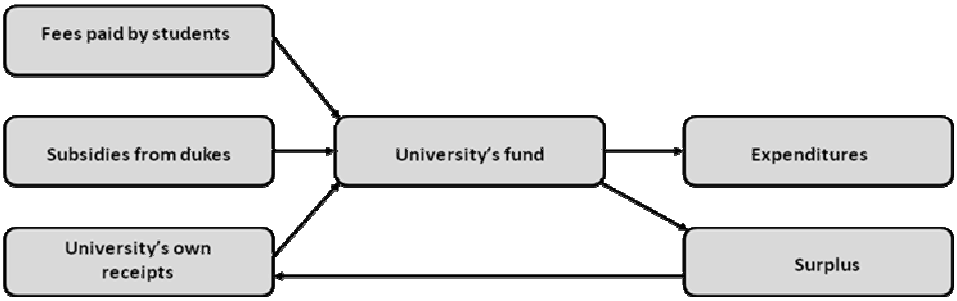

Fig. 1. Diagram of the flow of finances at a medieval university
Source: Author's own studies

2. PURPOSE AND SCOPE OF THE STUDY

The basis for decision making in management processes is formed by the knowledge of standard revenues, the real functioning costs, the ability to determine the budgets of individual organizational units, pursuing an adequate staff policy as well as the accuracy of the forecasting of future events in the manner of the university financing, on the labor market, the development of the competition.

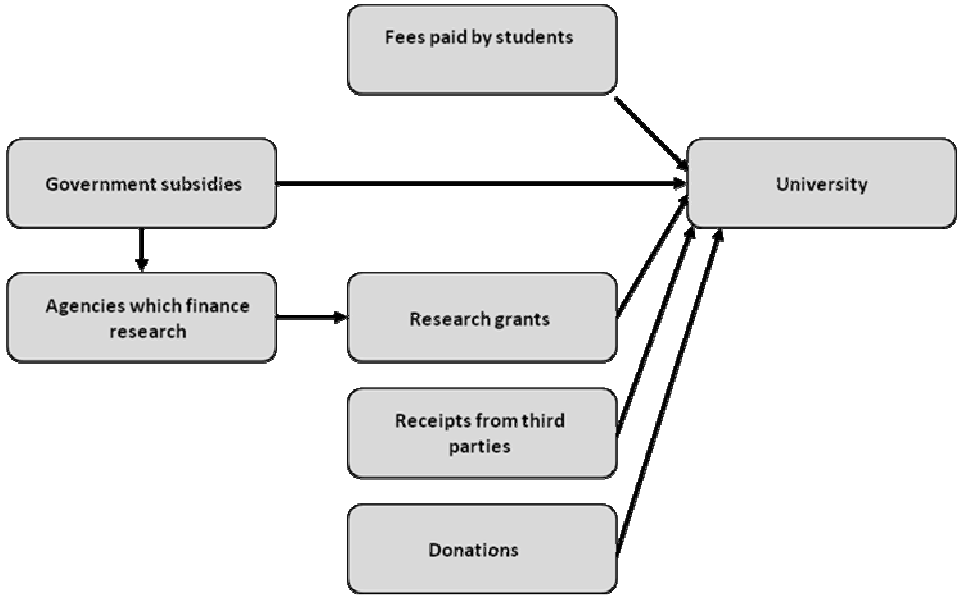

Fig. 2. Diagram of the flow of funds at present-day universities
Source: Author's own studies

Management of the university's finances is reflected in the efficiency of the use of financial streams, also in the structure of capitals. It has a huge influence on the possibility of the

development and investing in the university's assets, which constitute the basis for scientific and didactic activities. Decisions concerning the direction of the flow of financial streams are taken under a current internal analysis; they make it possible to determine the strengths and weaknesses of the organization. Tools in the form of analysis indices which correspond to the specificity of the functioning of an academic institution allow one to measure efficiency.

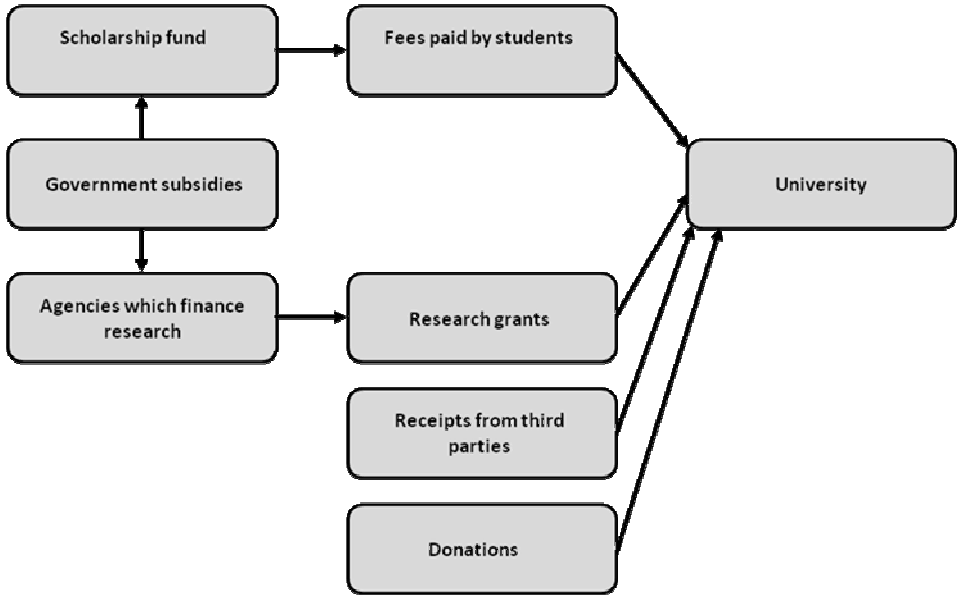

Fig. 3. Diagram of the flow of funds at third generation universities
Source: Author's own studies

Current monitoring serves the purpose of an assessment of the financial situation and makes it possible to address unfavorable internal economic phenomena, i.e. the efficiency of the use of financial streams. Monitoring of changes on the market of didactic services makes it possible to compete with competitors and to meet the requirements and preferences of customers.

The purpose of the present study is:

- to develop the data required to determine the management model at a university; this model will guarantee the achievement of the objective and the realization of the university's strategy with specific conditions being met;
- to develop a budgeting model which determines the distribution of funds and the way in which these are disbursed;
- to develop a control method of the realization of financial values and its cohesion with strategic objectives.

The chief effect of the model developed is such an academic institution management system which permits an effective use of the property resources and the financial resources of an academic institution. It also allows a coordination of the activities of all units and enables an achievement of the strategic objective.

Theses of the study:

The budgeting and controlling model of the organizational entities of an academic institution based on the determination of the standard functioning cost of the organizational entities of an academic institution in combination with the motivating system of the effectiveness of their functioning and the development strategy of an academic institution form the basis for the management of the present-day academic institution:

- financing through revenues,
- a smaller contribution of permanent co-financing,
- a greater staff level factor,
- knowledge of the effects of the operation of teams that are smaller than a faculty.

3. STANDARD REVENUES OF THE ORGANIZATIONAL ENTITIES OF AN ACADEMIC INSTITUTION

3.1. Notion of standard revenues of organizational entities

The algorithms of the allocation of funds, which are at the disposal of an academic institution to its organizational entities, form the basis for the determination of the standard revenues of the organizational entities of an academic institution. The problem is to determine the real revenues of these entities; these revenues constitute their contribution to the total budget of an academic institution. Standard revenues are understood to be revenues related to didactics, subsidies from the government budget, fees paid by students, receipts from research work and other services to production and service enterprises, local government institutions etc. This is also funds obtained by organizational entities e.g. from cooperation with the economy, through an execution of scientific and research projects by them etc.

3.2. Algorithm of the determination of standard revenues

A complex organizational structure of an academic institution, the development prospects of an academic institution, the staff development, establishing new fields of study, functioning within the framework of an academic institution of various didactic teams and research teams with various operating costs: all of these result in a requirement to introduce algorithms of a division of funds for the construction of budget and financial controlling of the operation of the individual organizational units of an academic institution[2]. These algorithms, with a growing pressure on an economization of the operation of an academic institution, are constantly being improved and their development has not been completed as of this day. These algorithms are characterized by an increasing accuracy of calculations, determination of funds found and budgeting of increasingly smaller organizational entities of an academic institution: chairs, independent departments etc.

The model proposed to cover the needs of decision making at an academic institution permits a determination of the real costs of the functioning of an organizational entity (1).

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$$Fj = Fk_j + Fs_j = Fk_j + \sum_K ((F_{SBKj} + F_{SCKj}) * \frac{IG_{Kj}}{IG_K}) \quad (1)$$

where:

F_{SBkj} – funds allocated to "j" unit from government budget for students attending classes organized by it and who study on "k^{th}" field of studies,

F_{SCkj} – funds allocated to "j" unit from fees paid by those students who attend the classes organized by it and who study on "k^{th}" field of studies

KS – field of studies,

IG_{kjp} – number of hours related to given classes taking into consideration cost consumption index "p" of classes run by "j^{th}" organizational entity on "k^{th}" field of studies,

IGk – number of hours of classes on the field conducted by an academic institution on "k^{th}" field of studies, whereas:

Fj – funds allocated to "j" entity, for j = 1, …J,

Fkj – funds allocated to "j" entity for the staff of this entity,

Fsj – funds allocated to "j" entity for those students who attend the classes conducted by it.

With this settlement of finances in relation to chairs, the funds allocated correspond to the real functioning costs of chairs. The abovementioned costs need to constitute the basis for making strategic decisions of an academic institution and a department; they should form the grounds for the budgeting of the organizational entities of a department. The heads of the entities are forced to economize (the more there are hours conducted on a field of studies in those units that conduct this field, the smaller amounts of funds are allocated to them).

4. CALCULATION OF TEACHING COSTS

4.1. Modeling of teaching costs

In order to introduce actions concerning the functioning of an academic institution both in the area of costs and incomes, the university authorities need to possess fast and properly computed initial calculation so that the effects of the decisions taken could be determined.

An academic institution, while preparing to open a new field of studies, before it takes a decision, needs to collect information concerning the following:

- any additional costs to be borne by an academic institution,
- the values to be reached by the costs during the first year,
- what costs will burden the budget of the academic institution in the years to come.

Obtaining of this information with the currently used account of costs based on historic data does not permit a calculation of future costs. This requires a lot of work and time, which is also a cost value: "time is money".

A solution was proposed based on the results of an analysis of the structure of costs by type which was conducted on the basis of reporting data from several academic institutions[3]. The results of this analysis demonstrate that the most important cost which is borne by academic institutions is personnel costs as they constitute over 70 per cent of the total costs. If we accurately assess the personnel costs, the remaining value can be added on the basis of a cost margin.

For the purpose of a calculation of personnel costs, the data is required concerning those parameters which have an impact on them. When analyzing personnel costs, it was established that the head of an entity, prior to making a decision concerning opening of a new field of studies, needs to be familiar with those analytical values which have an influence on the calculation of the final cost; these are the following:

- number of lecture groups,
- number of class groups,
- number of laboratory groups,
- staffing,
- rates of remuneration for those who are employed to operate the field of studies.

The authorities of an academic institution need to know the value of the costs; they also need to know what profits can be expected in relation to the subsidy obtained and fees for studies in connection with the opening of a specific field of studies. Owing to this information, it can be established what the consequences of the decisions will be. If a loss is the result of specific activities, it needs to be assessed over what period it will maintain; if the result is a profit, then its value needs to be determined.

In order to obtain complete information in this scope, the account of teaching costs makes it possible to capture the full teaching cost over the financial year.

In order to find a cost structure which will provide an answer to the question: how much does one student cost over a year?, it is necessary to establish and to analyze several managerial factors which are required to take a decision, such as the following:

- what product (e.g. a new field of studies),
- data concerning the demand in the scope of dynamics,
- qualitative limitations (fashion, demand on the labor market for concrete specialists, easy and comfortable studying),
- the picture of the situation on the market.

One needs to pay attention to the fact that in the case of determining fees for educational services, costs are not the only value that limit their amount. An example is fees for legal, medical and psychology studies. The price for the abovementioned field of studies depends from the demand, while the price for extramural studies is not a factor which discourages future students. An example where the price for the studies constitutes the main condition concerning undertaking of studies is technical studies, which require a huge amount of work on the part of future students during the studies; technical studies are much more difficult concerning the subjects; yet another factor is skills which are tested during laboratory classes on technical studies.

A decision taken by the university authorities concerning the possibility to undertake actions aimed at starting such a field of studies needs to depend above all from the scientific

[3] KOPCZEWSKI M., JUCHA M.: *Analiza kosztów kształcenia w procesie podejmowania decyzji w szkołach wyższych, Uwarunkowania zastosowań e-biznesu w gospodarce*, Wyższa Szkoła Ekonomiczno-Informatyczna, Warszawa, 2008

personnel, secondly from the laboratories and their equipment, and thirdly from the costs that need to be borne in order to obtain a good quality of teaching.

Taking into account the abovementioned quantitative parameters (e.g. the number of hours, the hourly rate) and qualitative parameters (the level of teaching), it is to be stated that the teaching costs are not the only factor on which decisions taken at an academic institution are based. The cost values that need to be calculated and the qualitative factors give a complete value of didactic services.

A numerical example will be presented below, which demonstrates the significance of the calculation of the basic decision factor, i.e. the cost of remuneration.

4.2. Estimation of teaching costs

The purpose of an estimation of teaching costs is to determine which costs need to be taken into account when planning to open a new field of studies. In item 4.1, those costs were described which have a substantial impact on decisions related to planning a new field of studies. The components of personnel costs related to conducting didactic classes on a field of studies are comprised of data concerning the following:

- number of didactic hours,
- types of didactic classes,
- the hourly rates of those persons who conduct didactic classes.

The abovementioned data constitutes the elements of the dependence[4] which calculates the costs of conducting a subject. The component of the cost of conducting a subject includes the personal cost, which can be calculated on the basis of (2):

$$Ko = \left[(Lh_w \cdot Gr_w \cdot A_w) + (Lh_c \cdot Gr_c \cdot A_c) + (Lh_p \cdot Gr_p \cdot A_p) + (Lh_l \cdot Gr_l \cdot A_l)\right] \cdot N \quad (2)$$

where:

Ko – the personal cost of the subject,
Lh_w – the number of lecture hours for the subject,
Lh_c – the number of class hours for the subject,
Lh_l – the number of laboratory hours for the subject,
Lh_p – the number of project hours for the subject,
Gr_w – the number of lecture groups,
Gr_c – the number of class groups,
Gr_l – the number of laboratory groups,
Gr_p – the number of project groups,
A_w, A_c, A_l, A_p – an hourly rate for the teacher who conducts: lectures, classes, laboratories, projects,
N – the value which increases the costs of remuneration (benefits to employees 30%), a constant of 1.3.

[4] KOPCZEWSKI M., JUCHA M.: *Analiza kosztów kształcenia w procesie podejmowania decyzji w szkołach wyższych, Uwarunkowania zastosowań e-biznesu w gospodarce*, Wyższa Szkoła Ekonomiczno-Informatyczna, Warszawa, 2008, str. 118

The personal costs obtained from Dependence (2) is a component of the cost of conducting a subject (3):

$$Kpp = Ko + (Ko \cdot C), \tag{3}$$

where:

Kpp – the cost of conducting a subject,

Ko – personal cost (gross remuneration + margins),

C – proportion of personal costs to total costs 2/8 (costs of maintaining rooms, laboratories: energy, materials, external services, depreciation, equipment).

On the basis of Dependence (3), the cost of conducting a subject is calculated by accepting an estimate number of didactic hours. At the same time, the data concerning remuneration rates is calculated on the basis of remuneration tables of those employees who are academic teachers, as specified in the Regulation issued by the Minister of Science and Higher Education concerning the conditions of remuneration for work and granting of other benefits in relation to work to employees hired by public academic institutions, dated 22 Dec. 2006, Journal of Laws No. 251, Item 1852 from the year 2006. The results obtained from Dependence (3) are presented in Table 1 on the example of a subject which is conducted in the "Information Science" field of studies by the Faculty of Electronics and Information Science at the Koszalin University of Technology. This subject is conducted for 44 hours. The following persons are involved in conducting the subject: one professor who delivers lectures and an assistant who conducts classes. The didactic hours are divided into two types of didactic classes in the form of 22 hours of lectures and 22 hours of classes. It was accepted for the purpose of calculations that the cost of the monthly gross remuneration of the professor is approximately PLN 5,000 and PLN 2,800 of the assistant. The remuneration multiplied by 12 months and divided by the teaching load gives the hourly rate of conducting the didactic classes. The teaching load is the number of didactic hours conducted by an academic teacher during an academic year, which corresponds to the position in the university. For example, 240 hours of the teaching load are accepted for the professor to calculate the rate, and 240 hours of the teaching load for the assistant to calculate the rate; the result was multiplied by the number of the didactic hours and further increased by 30 per cent. This increase is related to margins for remuneration which constitute those costs which must be borne by an employer to hire employees. These are social insurance premiums, the employee benefit fund and the reward fund.

The example given above demonstrates dependences between the remuneration cost and the data required for its calculation; it demonstrates the possibility to calculate the total costs of conducting a subject. In order to calculate the cost of conducting a field of studies, the subjects included in the curriculum need to be put together; further, the number of hours, the forms of conducting of classes and the number of student groups need to be established. When possessing these values, the employees need to be assigned to each subject; then, on the basis of the contract concluded with each of them, we can determine the rate for one hour of classes conducted.

Tab. 1. Components of the calculation of the costs of conducting a subject related to opening a new field of studies

Subject	Number of hours	Form of conducting of classes	Number of groups **Grw/ Grc**	Lecturer's position	Rate for didactic hour **Aw/Ac**	Costs of remuneration	Personal costs **Kow/Koc**	Cost of conducting of subject **Kpp**
Analog technique–signals and systems	44	22 lectures	1	professor	PLN 250	5 500	7 150	**28 958**
		22 classes	4	assistant	PLN 140	12 320	16 016	

Source: Author's own study

The cost of conducting a field of studies is the sum of the costs of the realization of the subjects which are foreseen to be conducted in the teaching standards, which are obtained from the following dependence:

$$Kpk = (Kpp_1 + Kpp_2 + Kpp_3 + \cdots + Kpp_i), \quad (4)$$

where:

Kpk – the cost of conducting of a field of studies,

Kpp_i – the cost of conducting of i^{th} subject.

What cost will be borne by an academic institution when introducing an exemplary subject?

The calculation results obtained with the use of the model provide answers to this and other questions above. They enable those who manage an academic institution to take a decision concerning those fields of studies which are being opened or closed.

Prior to taking a decision concerning opening of a new field of studies or concerning a continuation of an existing one, it is to be remembered that over 70 per cent of the teaching cost of a student is remuneration and margins.

One also needs to bear it in mind that it is not only numerical data concerning costs which is required to make managerial decisions. Several non-measurable factors need to be considered. First of all, one needs to determine what product is of an interest to them: e.g. a new field of studies; data concerning the demand needs to be collected; a long-term forecast of the demand for a given field of studies needs to be provided, it is to be determined how this demand will be changing in time.

The authorities of an academic institution need to remember that the cost is a certain consequence of taking decisions concerning the fields of studies. For this reason, fast information concerning its amount will offer a possibility to secure a source to cover this expense.

The precise data used in the example do not allow one to determine the teaching costs in a situation when we deal with a plan. This plan does not include answers to those questions which are asked at universities:

- What will be the intake of students? – this is the basis for the planning of finances in didactic activities in compliance with the dependence as accepted in the example.

- How many student groups will there be?
- How many didactic hours will there be?

The lack of information concerning the number of students accepted forces an estimate; hence, it is necessary to develop a model which takes into account the imprecise nature of information. Approximate values need to be accepted in planning as it will never be possible to foresee an exact number of students accepted, which determines answers to the questions as to how many groups and how many hours.
For this reason, the model proposed of the calculation of the teaching costs includes an element of uncertainty in the form of fuzzy numbers.

The cost calculation model based on fuzzy numbers has allowed the gap to be filled concerning the lack of strategic information. For this reason, the proposal for academic institutions in the form of a model of the costs account addresses the needs of managers. This is a model which offers the possibility to provide answers to questions related to the cost of the subject, the field of study, the entity and the entire academic institution concerning the teaching of students and graduates. It facilitates forecasting with the aid of imprecise data and permits an introduction of historic (precise) data, owing to which the plan can be reviewed with respect to its execution. Any aberrations occurring serve as an indication and make it possible to make input data more precise as the imprecision level of input data determines the imprecision of output data.

4.3. Estimation of teaching costs based on fuzzy numbers: an example

The purpose of this example is an illustration of the determination of the total cost of conducting of a subject on the basis of the model proposed. The determination of the cost is related to the subject of Economic Sciences.

Table 2 contains those components which are used to determine costs. The manner of the determination of the cost of conducting a subject Kpp is specified in the internal regulations of the academic institution. The following factors: the number of groups, the hourly rate of work, the number of hours etc. have an influence on the value of the cost. Value Kpp in Table 2 was determined on the basis of precise data. It was assumed that the number of groups formed in the new academic year is 1 for lecture groups and 4 for class groups.

Tab. 2. Components of the calculation of the costs of conducting of a subject in relation to opening of a new field of studies

Subject	Number of hours	Form of conducting of classes **Lhw/Lhć**	Number of groups $\frac{Gr_w}{Gr_c}$	Lecturer's position	Rate for didactic hour **Aw/Ać**	Costs of remuneration	Personal costs Ko	Costs of conducting of subject Kpp
Economic Sciences	70	45 lectures	1	Professor	300 zł	13500	17 550	**47 357**
		25 classes	4	Assistant	120 zł	12000	15 600	

Source: Author's own study

Concerning this approach, there arises the following question: *what costs are related with conducting of the subject in the case when part of the data is of an imprecise nature?* For example, the number of lecture and class groups is determined with fuzzy numbers. To provide an answer to this question, the model MK (1) proposed was used.

In the model, the following set was accepted of fuzzy decision variables $\hat{V}$:

$$\hat{V} = \{\widehat{Ko}_w, \widehat{Ko}_c, \widehat{Ko}, \widehat{Kpp}, \widehat{Lh}_w, \widehat{Lh}_c, \widehat{Gr}_w, \widehat{Gr}_c, \hat{A}_w, \hat{A}_c, \hat{C}_1, \hat{C}_2, \hat{N}_{w1}, \hat{N}_{w2}\}, \tag{5}$$

where:

$\widehat{Ko}_w$ – the personal cost of lectures,

$\widehat{Ko}_c$ – the personal cost of classes,

$\widehat{Ko}$ – the personal cost of conducting of the subject,

$\widehat{Kpp}$ – the cost of conducting of the subject,,

$\widehat{Lh}_w$ – the number of lecture hours for the subject,

$\widehat{Lh}_c$ – the number of class hours for the subject,

$\widehat{Gr}_c$ – foreseen number of class groups,

$\widehat{Gr}_w$ – foreseen number of lecture groups of the representation of fuzzy numbers,

$\hat{A}_w$ – the hourly rate of the teacher in charge of the lectures,

$\hat{A}_c$ – the hourly rate of the teacher in charge of the classes,

$\hat{C}_1, \hat{C}_2$ – constant proportionalities of personal costs to total costs,

$\hat{N}_{w1}, \hat{N}_{w2}$ – the value which increases the costs of remuneration.

Variables $\hat{V}$ represent costs and the components required for their calculations. The relations which describe how the values of costs depend from specific parameters are formulated in the form of relationship $\hat{R}_{LR}$:

$$\hat{R}_{LR} = \{\hat{R}_{LR,1}, \hat{R}_{LR,2}, \hat{R}_{LR,3}, \hat{R}_{LR,4}\}, \tag{6}$$

where the individual relations in compliance with [4] take the following form:

$$\hat{R}_{LR,1}: \ \widehat{Kpp} \cdot \hat{C}_2 = \widehat{Ko} \cdot \hat{C}_1 \tag{7}$$

$$\hat{R}_{LR,2}: \ \widehat{Ko} = \widehat{Ko}_w + \widehat{Ko}_c \tag{8}$$

$$\hat{R}_{LR,3}: \ \widehat{Ko}_c \cdot \hat{N}_{w1} = \widehat{Lh}_c \cdot \widehat{Gr}_c \cdot \hat{A}_c \cdot \hat{N}_{w2} \tag{9}$$

$$\hat{R}_{LR,4}: \ \widehat{Ko}_w \cdot \hat{N}_{w1} = \widehat{Lh}_w \cdot \widehat{Gr}_w \cdot \hat{A}_w \cdot \hat{N}_{w2} \tag{10}$$

The variables of costs, i.e. $\widehat{Ko}_w, \widehat{Ko}_c, \widehat{Ko}$ form a set of input variables $\hat{U}$ whereas the remaining variables $\widehat{Lh}_w, \widehat{Lh}_c, \widehat{Gr}_w, \widehat{Gr}_c, \hat{A}_w, \hat{A}_c, \hat{C}_1, \hat{C}_2, \hat{N}_{w1}, \hat{N}_{w2}$ form output variables $\hat{Y}$.

For output variables, relations $\hat{R}_{LR\hat{Y}}$ are known which assign their values to the variables:

$$\hat{R}_{LR\hat{Y}1}: \widehat{Gr}_w = (2,2,2,0)_{LR} \quad (11)$$

$$\hat{R}_{LR\hat{Y}2}: \widehat{Gr}_c = (8,8,2,3)_{LR} \quad (12)$$

$$\hat{R}_{LR\hat{Y}3}: \widehat{Lh}_c = (25,25,0,0)_{LR} \quad (13)$$

$$\hat{R}_{LR\hat{Y}4}: \widehat{Lh}_w = (45,45,0,0)_{LR} \quad (14)$$

$$\hat{R}_{LR\hat{Y}5}: \hat{A}_w = (300,300,0,0)_{LR} \quad (15)$$

$$\hat{R}_{LR\hat{Y}6}: \hat{A}_c = (120,120,0,0)_{LR} \quad (16)$$

$$\hat{R}_{LR\hat{Y}7}: \widehat{N}_{w1} = (13,13,0,0)_{LR} \quad (17)$$

$$\hat{R}_{LR\hat{Y}8}: \widehat{N}_{w2} = (10,10,0,0)_{LR} \quad (18)$$

$$\hat{R}_{LR\hat{Y}9}: \hat{C}_1 = (10,10,0,0)_{LR} \quad (19)$$

$$\hat{R}_{LR\hat{Y}10}: \hat{C}_2 = (7,7,0,0)_{LR} \quad (20)$$

All the variables apart from $\widehat{Gr}_w$ and $\widehat{Gr}_c$, accept precise data represented in the form of singletones.

It is to be noted that those relations which occur both in set $\hat{R}_{LR}$ and in $\hat{R}_{LR\hat{Y}}$ accept the form of "equivalent" relations, whose degree of fulfillment $\hat{\mu}_i$ is defined (19). It was accepted that the degree for each relation $\hat{R}_{LR}$ and $\hat{R}_{LR\hat{Y}}$ is 1 (S ,$\hat{S}_{\hat{Y}} = \mathbf{1}$).

In the context of the model defined in this manner, the question concerning the cost of conducting of the subject of Economic Sciences is as follows:

Are there such values of variables $\hat{U}$ *(the values of costs), for which relations included in set* $\hat{R}_{LR}$ *and relations from set* $\hat{R}_{LR\hat{Y}}$ *will certainly be fulfilled (degree* S , $\hat{S}_{\hat{Y}} = \mathbf{1}$ *)?*

The problem under consideration was brought down to the problems of the fulfillment of limitations PS , and it was solved with the use of techniques of programming with limitations. The set of solutions obtained contained only one permissible solutions. The costs of conducting of the subject are as follows:

$$\widehat{Ko}_c = (31200,31200,7800,11700)_{LR} \quad (21)$$

$$\widehat{Ko}_w = (35100,35100,17550,0)_{LR} \quad (22)$$

$$\widehat{Ko} = (66300,66300,23350,29350)_{LR} \quad (23)$$

$$\widehat{Kpp} = (95285,95285,33357,41928)_{LR} \quad (24)$$

The values of the costs obtained are presented in Fig. 4.

With the size of the number of lecture groups $\widehat{Gr}_w$ "*being not greater than 2*" and of class groups $\widehat{Gr}_c$ "*being ca. 8*", the cost of conducting the subject ($\widehat{Kpp}$) is between 61928 and 137213. The middle value of number $\widehat{Kpp}$ is 95285. This means that we are certain that on level 1 we will obtain the cost on this level. We have a zero level of certainty that the cost will

reach the value of 61928 or 137213. For this reason, the level of the costs of conducting the subject is "*ca. 95285*".

The determination of the costs of conducting the subject on the basis of fuzzy numbers makes it possible to determine the range of those costs which are possible to be obtained with those data whose value is not certain and is difficult to assess with hundred percent certainty. In general, each component of cost $\widetilde{K_{pp}}$ may be a fuzzy number in a specific space of consideration with the level of certainty being assigned. In this manner, based on the older years, one can determine the number of students on the basis of the teaching efficiency on the individual years of studies.

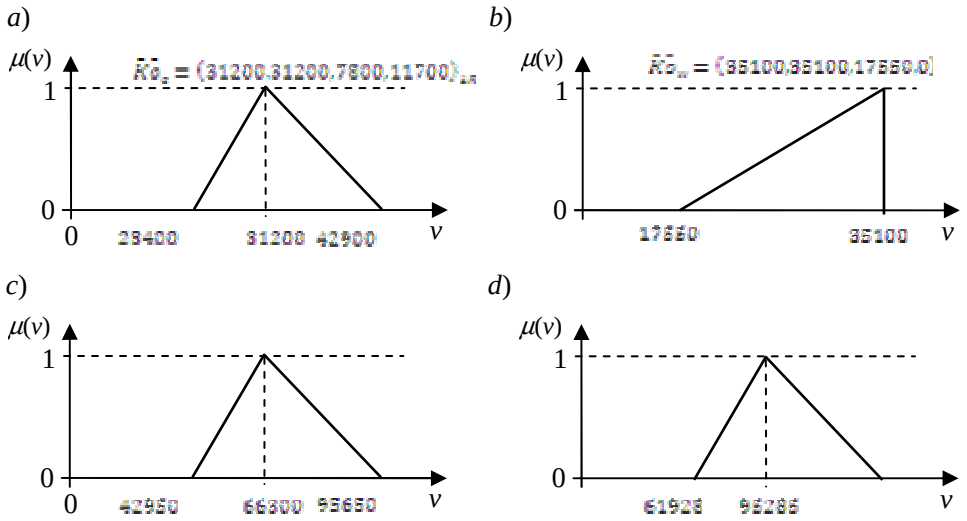

Fig. 4. Costs of conducting a subject: a) personal costs of classes, b) personal costs of lectures, c) personal costs of conducting a subject, d) total costs of conducting a subject
Source: Author's own studies

5. BUDGETING OF ORGANIZATIONAL ENTITIES OF AN ACADEMIC INSTITUTION

The real revenue of the organizational entities of an academic institution forms the basis for the determination of standard revenues of these entities. The basis for the budgeting of these entities is formed by the determination of the real costs of their functioning, conducting an analysis of these costs, a formulation of actions aimed at their reduction and further the determination of their budgets. The field marked on UAR may have for example three values, where:

U – standard revenue,
V – budget assigned,
R – real costs borne.

Having the revenues estimated in accordance with the model accepted and having the costs assessed, we build the budget of the organizational entity and of the entire academic institution.

However, we face the problem which concerns not only the lack of balancing of the budget but also the question as to whether those entities which are balanced are to cover the costs of other entities with worse financial results. Perhaps a good solution is to liquidate such entities regardless of the effect? What decision is to be taken? An answer to this question will be provided in the further chapter concerning provision of variants related to decision making.

6. SELECTED PROBLEMS OF MANAGING AN ACADEMIC INSTITUTION

Management of an academic institution involves a selection of an optimal variant which yields the best effects possible in the form of an economic account, yet this is not all. Those who manage an academic institution are also directed by the strategy of operation. The number of candidates in a given field of studies has the greatest impact on the effects of operations in the didactic area. The number of students in a given field of studies and the teaching efficiency constitute important elements, as well; cf. Fig. 8.

We need to verify what conditions have an influence on the selection of specific fields of studies. The first factor which has an influence of the candidate choosing a given field of studies is an academic institution. Those academic institutions are selected which enjoy a high renown in the state, i.e. large academic centers with many years of tradition and a high scientific and didactic position. The second criterion is the competiveness of an academic institution, which is manifested in its scientific potential and the didactic offer. The labor market is yet another factor. This means that there is a possibility for graduates to get good jobs concerning earnings and professional satisfaction. Future candidates look at how well the graduates of a given academic institution are doing, as this provides an image of the teaching quality and an estimation of the usefulness of the knowledge and skills on the labor market.
The environment is yet another important factor, which on many occasions has an influence on undertaking studies on a given field. This decision is influenced by parents, fashion, and very frequently the fact that a friend has chosen the same field of studies, cf. Fig. 9.

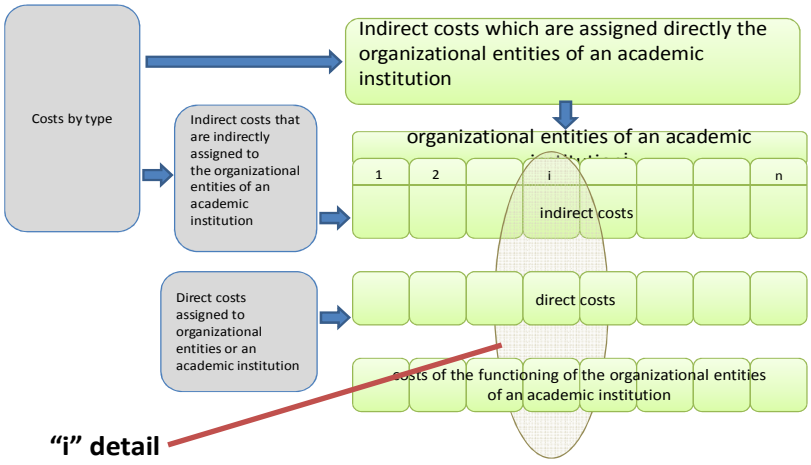

Fig. 5. Accounting sheet of an academic institution

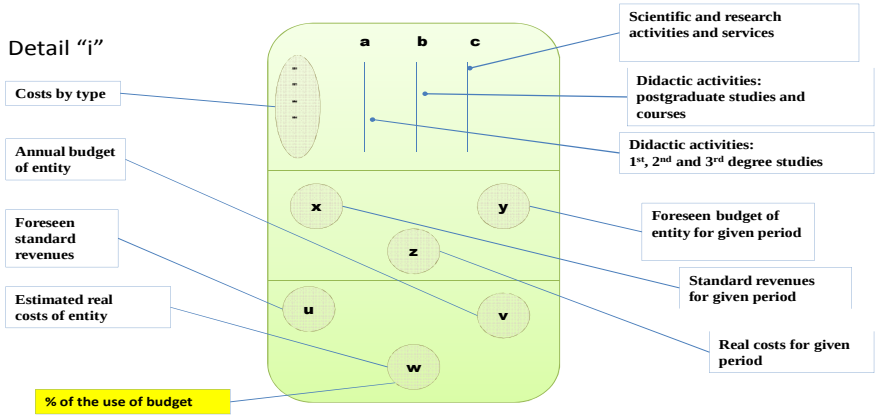

Fig. 6. "i" detail from the accounting sheet of an academic institution, those parameters that determine the financial conditions of an organizational entity of an academic institution (places of the generation of costs)
Source: Author's own studies

Two basic factors: the number of candidates to studies and the teaching efficiency have an influence on the number of those studying in a given academic institution. If the number of candidates to studies in relation to a given field of studies is decreasing and the number of students is also dropping, this means that such a field of studies will have to be eventually closed.

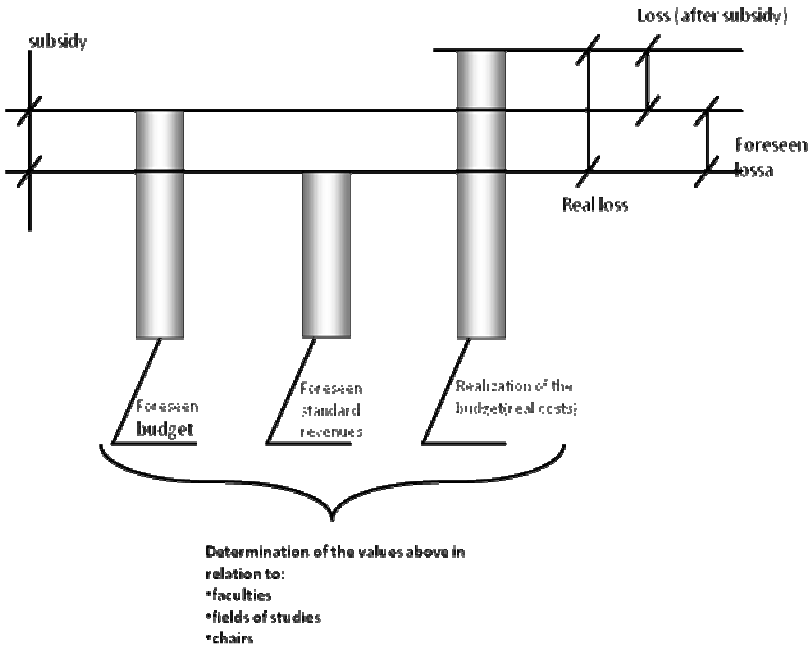

Fig. 7. Principle of budgeting of organizational entities of faculty
Source: Author's own studies

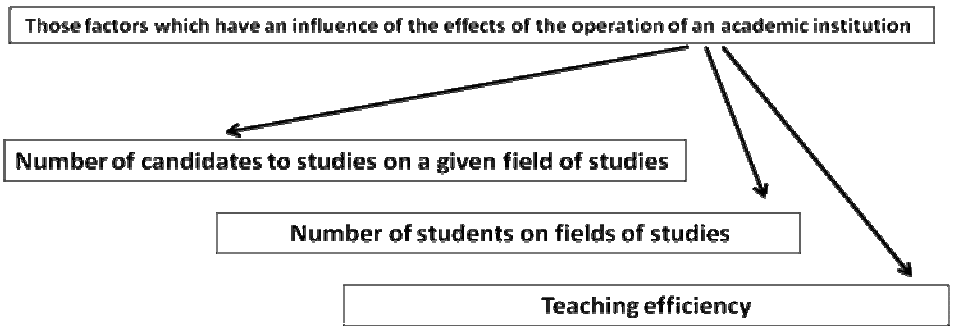

Fig. 8. Those factors which have an influence on the effect of the operation of an academic institution
Source: Author's own studies

If, however, admittance of students to the first year of studies compensates for the decreasing number of students on higher years, this means a stability of a given field of studies. In those conditions when as a result of high numbers of those recruited and a high teaching efficiency a given field of studies has a growing number of students, this demonstrates a development and constitutes a certain source of revenues for the academic institution; cf. Fig. 10.

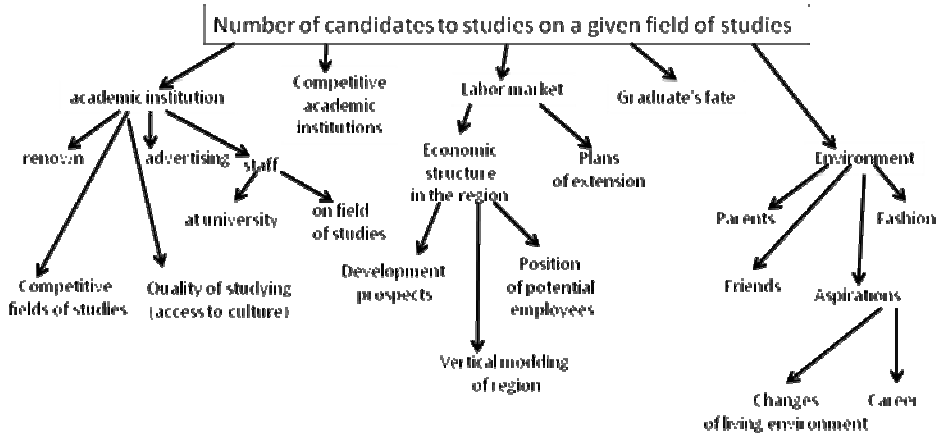

Fig. 9. Those factors which have an influence on the number of candidates to a given field of studies

Source: Author's own studies

The teaching efficiency as an element which has an influence on the number of students depends from students, i.e. if they want to study and to complete studies, or whether they change their university or the field of studies; or, perhaps as a consequence of various events, they decide to resign from studies.

The effects of the operation of an academic institution depend from the factors discussed above, which have different consequences; some of these deteriorate these effects and others make these effects stronger. This may for example mean a large number of students and a high teaching quality. Management of an academic institution consists in choosing such a decision which will eventually result in its development in safe conditions of financing.

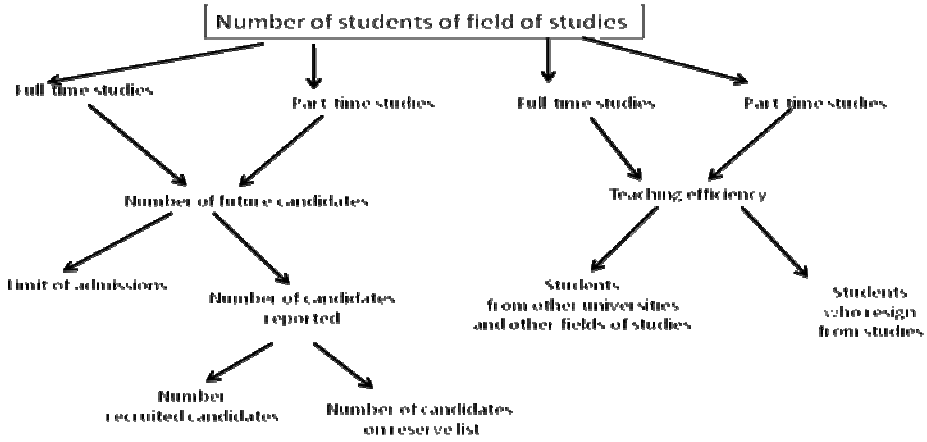

Fig. 10. Those factors which have an influence on the number of students on a given field of studies

Source: Author's own studies

In the model proposed of the management of an academic institution, various variants of solutions are taken into account, cf. Fig. 11. The results obtained of the analyses conducted facilitate the choice of those which the manager recognizes as the most favorable ones. The choice is made with the use of a multi-criteria method on two stages:

- determination of a set of compromises (a set of Pareto-optimal solutions)
- selection of the best solution from the set of compromises

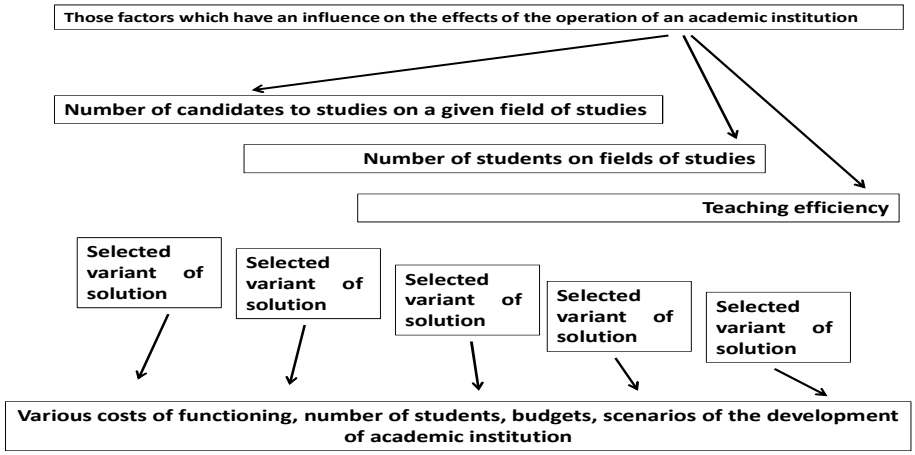

Fig. 11. Variation of decision making
Source: Author's own studies

Optimum in Pareto sense, Fig. 12:

- determination of the area of solutions
- determination of the area of possible solutions
- determination of the area of possible solutions in Pareto sense
  determination of optimal solution

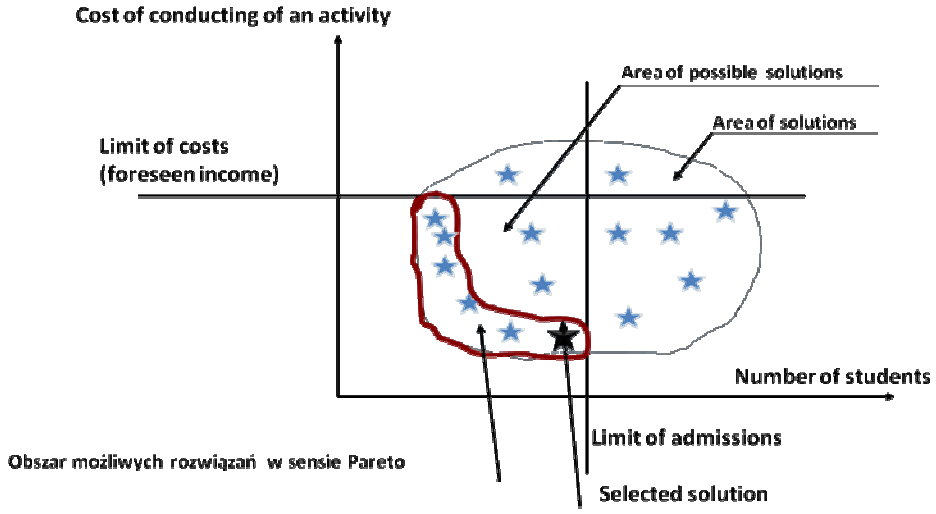

Fig. 12. Estimation of costs of the number of students by experts according to the estimation of the influence of factors on the functioning of an academic institution
Source: Author's own studies

If we select as an optimal solution, i.e. the use of the minimum cost criterion, our decision concerning a limit of admissions denotes value in Fig. 12, which is specified as the selected solution.

7. SUMMARY AND CONCLUSIONS

The model proposed of the management of an academic institution through the determination of costs and budgeting makes the following possible:

- an analysis of the costs of the subject conducted, of the field of studies, the organizational entity, the faculty, the academic institution,
- provision of data for the management of an academic institution concerning estimation of costs on the basis of the variables possessed, and also with the level of the university's budget being specified,
- an estimation of the impact of the creation of new fields of studies on the costs of conducting of the existing fields of studies.

Directions of further research:

- an extension of the model to include issues of the comparison of data foreseen with the realization,
- determination of the costs of the specific operations in an academic institution,
- implementation of a system to support decision making in the management of an academic institution.

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Silvia PALAJOVÁ[*], Štefan FIGA[**], Milan GREGOR[***]

SIMULATION OF MANUFACTURING AND LOGISTICS SYSTEMS FOR THE 21TH CENTURY

Abstract

This paper deals with computer simulation of manufacturing systems. It contains the basic simulation theory and principles of a simulation project management. Furthermore the authors introduced the idea of parametric simulation model, followed by special application areas of simulation, e.g. scheduling, emulation, metamodelling. The paper discusses the possibility to utilize a cloud computing technology in simulation. The case example of the application of simulation by the optimization of real production system concludes the working part of paper. The final part summarizes benefits and recommendations.

1. INTRODUCTION

If today's enterprises want to stay on the market and be winners in competition they have to respond flexibly to the requirements of market environment, whether requirements for changes of production program, outputs, or loading and managing changes of the system. This relates to the detailed production planning and taking quick and correct decisions.

Currently, it is axiomatic to solve complex problems by an appropriate computer model that reflects characteristics of a real system or helps to find a solution close to optimal, or directly optimal, for existing or conceptual systems. Therefore, a computer simulation is still gaining major importance. It allows quick testing of various variants of solutions and it minimizes the risk of wrong decisions. This is reflected to considerable economic benefits.

2. SIMULATION OF MANUFACTURING SYSTEMS

Simulation is a method involving the replacement of the dynamic system by its simulation model in order to:

- obtain information how modeled system works in given circumstances,

* Ing. Silvia Palajová, **Ing. Štefan Figa, ***prof. Ing. Milan Gregor, PhD.: University of Zilina, Faculty of Mechanical Engineering, Department of Industrial Engineering; Univezitná 1, 010 26 Žilina, Slovak Republic; e-mail: {silvia.palajova, stefan.figa, milan.gregor}@fstroj.uniza.sk

- conduct experiments with it by the change of input parameters in order to detect how does the model behave, so how would the real system behave.

Such model includes only those characteristics of a real system which the analyst is interested in. After evaluation of results the analyst makes conclusions about the whole real system, based on experiments with the model.

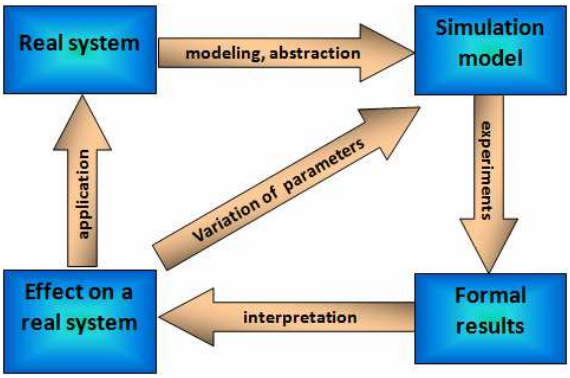

Fig. 1. The Principle of Simulation

Simulation overcomes many boundary conditions and limitations of analytical modeling procedures, and its use is justifiable especially in those cases where other solution options have failed.

2.1. Simulation Project

Simulation is not just to build a simulation model and the random "playing" with it on computer. It is needed to access the simulation as a project. Each project has to start with a thorough analysis of the problem and selecting appropriate methods and procedures for their solving. It means to determine whether and in what phase it is necessary to use simulation, or if simpler method is sufficient. This decision greatly affects the time and financial costs to fix the problem.

The simulation project includes the following general phases:

1. System analysis and problem definition, formulation of simulation's objectives. This phase includes preparation of requirements used to verify selected problems in designing and operation of manufacturing systems (e.g. dynamic permeability changes depending on range of goods changes and output changes, determination of shift influence on its flexibility and productivity, an alternative material flow in production system, tools flow and organization of tools assigning to technological workplace, identification of a narrow activities or elements of the production system, number and types of machines determination, etc.).
2. Collection and processing of process information, preparation of input data for model creating - estimates of the parameters and types of random variables distribution (Chi-square test).
3. An abstract logical model creating.
4. Construction of the model on a computer that is based on requirements formulation and on functional relationships of elements and activities of the real system.

5. Model verification and testing - verification and validation. It means to determine validity area of functional relationships (check the model from a logic view, extant of its validity, sensitivity for changes of its elements, etc.).
6. Planning and preparation of simulation experiments (pilot runs or short simulations, warm up period estimation, initial conditions determination, length of simulation run determination). Experiments should respect requirements of questions and issues set couched in the task.
7. Execution of simulation experiments with a change of factors in the model, perhaps even adjusting the model.
8. Evaluation and processing of experiments results, the final report.

2.2. Parametric Simulation Model

External information system (e.g. MS Excel) is often source of data for simulation model. It allows easy transfer and data processing, and it facilitates manipulation with data in database of the model. Parametric simulation model is a practical tool for finding problems' causes of the selected type of manufacturing systems, created for selected input variables. After modeling and entering the specific characteristics of production system (such a service time for each workstation, the way of parts arrival to the workstation, the transportation size, the way of manufacturing system control, etc.) can the process be simulated with sufficient precision. The analyst can also directly see critical points of production process and simulate various possibilities for their removal.

The obtained results, in the form of tables or graphs, are after execution of simulation experiments automatically transferred to external information system and on their base optimization of real system can be done. All this can be carried out without detailed knowledge of modeling and simulation methods and without deep knowledge about simulation software.

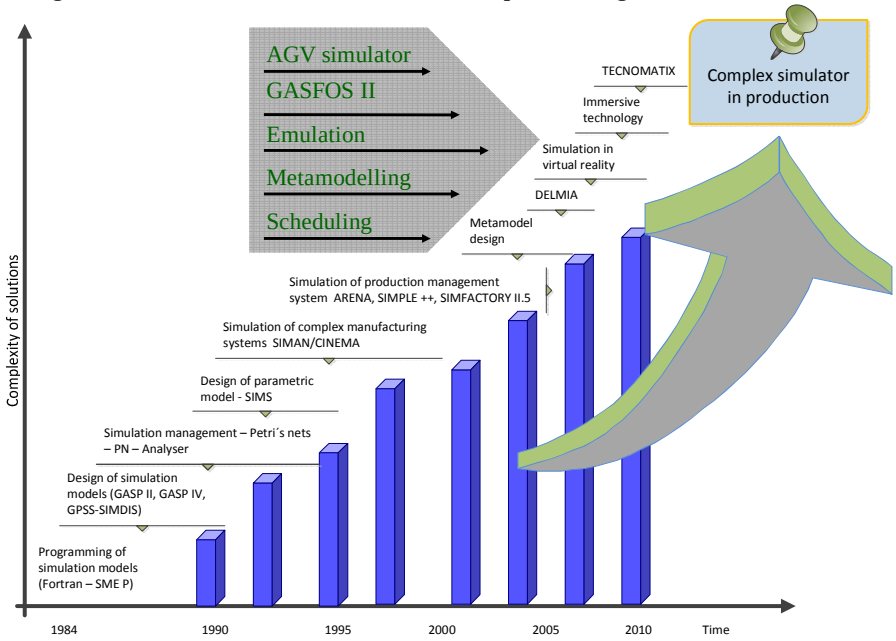

Fig. 2. Complex Simulator in Production

The current research intention of The University of Zilina in cooperation with the Central European Institute of Technology (CEIT) is to develop a complex simulator of production system, which will include progressive tools described below. The development of simulation tools at the University of Zilina dates back to 1984, when simulation models were programmed. Later it was a design of simulation model with the use of Petri´s nets, simulation of complex manufacturing and production management. Nowadays top commercially available simulation software systems are in use and the main effort is focused in development of supportive modules like: AGV simulator, optimization module GASFOS II, emulation, metamodelling and scheduling. The result is a complex simulator that is easily useable and implementable in a wide range of applications.

3. PROGRESSIVE APPROACHES IN SIMULATION OF MANUFACTURING SYSTEMS

3.1. Scheduling and Simulation

The production process of manufacturing enterprises has always been a key factor for overall business success. Production scheduling problems are facing thousands of companies all over the world that are engaged in the production of material goods. Therefore, the solution of production scheduling problems effectively and efficiently has attracted the interest of many experts and researchers from both fields of production control and combinatorial optimization.

The scheduling can be described as the allocation of available resources over time to meet the performance criteria defined in a domain. Typically, a scheduling handles a set of jobs to be completed, whereas each job consists of a set of operations. Each operation is performed by specific resources such as machines and operators. In terms of scheduling theory, most of scheduling problems are in the class of NP (non-deterministic polynomial-time) hard (Pinedo, 2002).

Scheduling using Simulation and Evolutionary Methods (SSEM) consists of three modules, which are necessary for generating, evaluating and optimizing production schedule. The first module was developed for generating a schedule respectively scheduling using priority rules. The second module was designed to evaluate production schedule with support of a parametric simulation model and the third module executes the implementation of evolutionary optimization methods to get better solutions.

The conceptual system architecture of the SSEM is represented in Figure 3, which shows its three main modules. The flow of information among given modules is represented by the directed arrows. The input data can be provided from the production database systems such as Enterprise Resource Planning (ERP) system or Manufacturing Enterprise System (MES). The obtained output is the schedule optimized according to the selected criterion value (for example minimization of makespan).

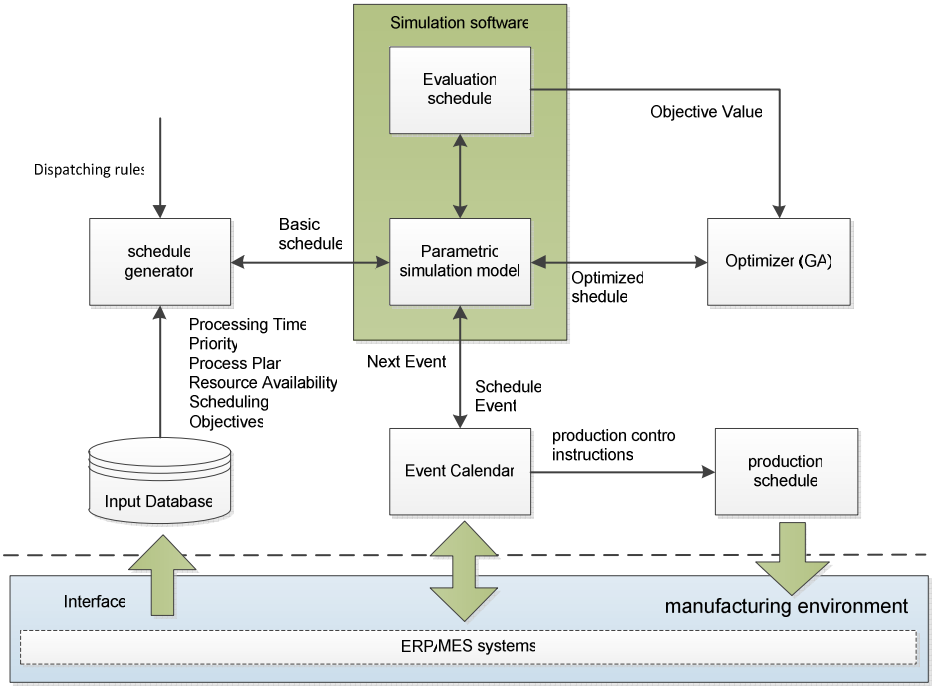

Fig. 3. Conceptual SSEM Architecture

A more detailed description of individual modules can be found in (Figa, 2011), which describes the various modules necessary to generate, to evaluate and to optimize the production schedule. Proposed methodology can be used as the practical tool for manager in a practice for a quick identification of bottlenecks in the generated schedule to minimize production costs.

3.2. Emulation

Apart from production planning management, production management requires current information about real manufacturing process (feedback from the manufacturing process) in a real time. The systems collecting data from a manufacturing process inform about the current states of production facilities. They also provide an opportunity to intervene in production process and affect it, to change real system's settings on computer.

The emulation means connecting a real system with its parametric simulation model and loading the data directly from a real system into a model database (possible by using sensors connected via a control unit in computer). In addition to simplify data handling this system allows to change settings of a real system (a vector of input factors) on computer using excel interface which eliminates need for knowledge of simulation program. Fundamental of emulation is that the simulation model is a substitute of real, missing module, respectively elements of comprehensive simulation model are gradually replaced by real devices.

The main advantage of this purpose is rapid determination of the effect of changes in guiding principles of production on a virtual model, which is in direct connection to the real production system. Emulation environment can monitor production respectively logistic

system, evaluate collected data in a real time, update the model on the base of data from a real system, and execute experiments on accurate, updated and verified simulation model.

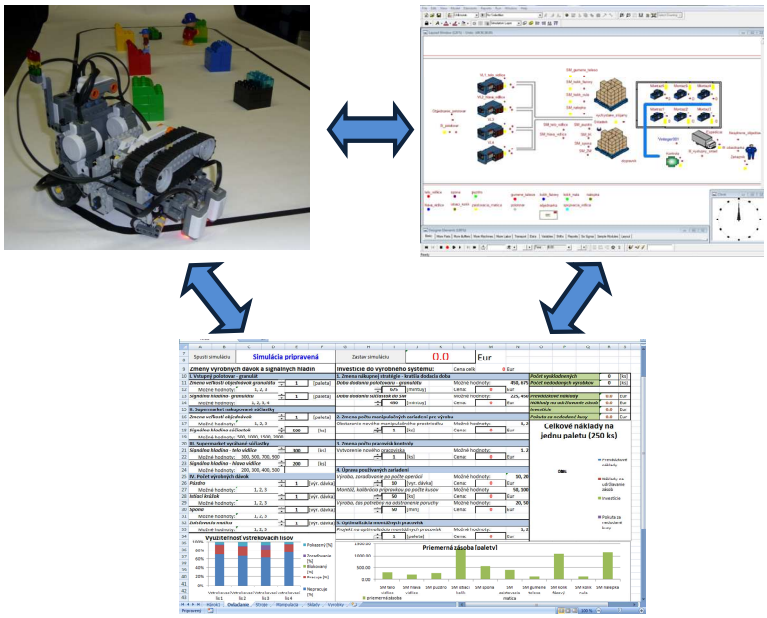

Fig. 4. Real System - Simulation Model - MS Excel Interface (Palajová, 2011)

3.3. Simulation Metamodelling

Simulation runs are usually computationally difficult and it is not unusual for complex simulation models that they last for hours. For practical applications of simulation optimization it is important that the optimization process is constrained within reasonable time limits and the efficiency of the optimization process is crucial. One of the possible ways how to enhance effectiveness of simulation optimization and reduce the requirements of time-consuming simulation is to use computationally cheap metamodels (Persson, 2010).

Simulation metamodel (Barton, 1992) is a model of simulation model and it explains the fundamental nature of the system's input-output relationships through simple mathematical functions:

$$Y = \underbrace{f(X,\beta)}_{\eta} + \varepsilon \tag{1}$$

$Y = f(X,\beta)$ - regression function,
Y – dependent variable,
X – vector of values of input factors,
ε - vector of random numbers.

This relationship is the regression model that expresses free (stochastic) dependence between explanatory variables X and explaining variable Y. It means that for one particular combination of values of independent variables X may depend variable Y acquire different values. It is caused by an influence of random events ε.

The metamodel creation (see Figure 5) begins with a simulation model which is preceded by defining the problem, defining the scope of input variables, the draft of the plan of experiments. After construction of a computer simulation model, his validation and verification is made, so logical structure of the model with respect to real system is proved. Then predefined number of replications for different input values is executed with the simulation model. In order to continue in metamodel development process the analyst has to be sure that data are sufficiently independent.

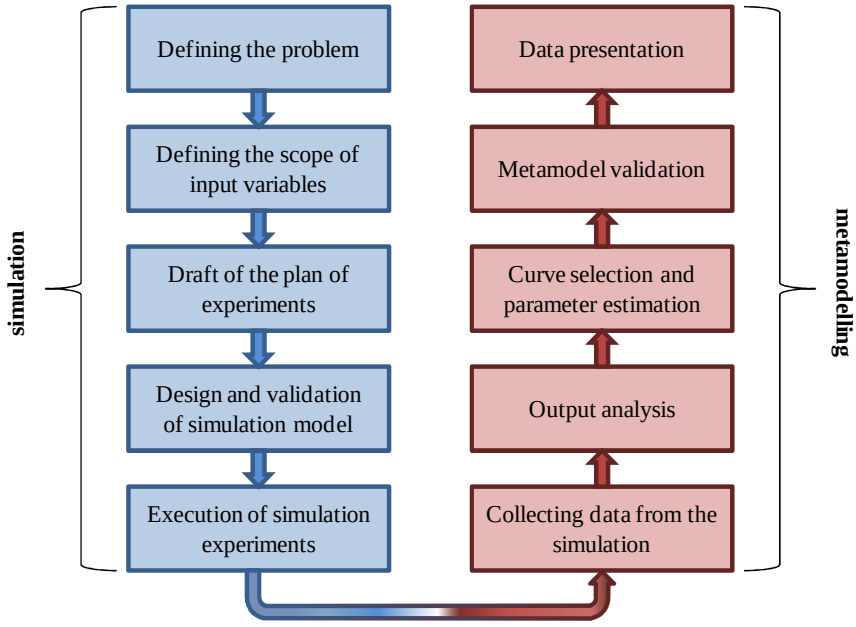

Fig. 5. Metamodel Development Process

In the next step, output data from the simulation are collected. In order to simplify the metamodel it is possible to combine some of the entries and remove those which have proved to be needless. These results are used for deriving a statistical model in the form of regression.

The heart of metamodelling is to determine a vector $\beta = (\beta_1, \beta_2, ..., \beta_p)^T$ which is a set of coefficients that determine regression function. Method of least squares is the most common method for estimation of regression functions. It is used for calculation of functions, providing its estimation is linear in parameters or it can be achieved by simple transformation. The values of the vector β are used for creating of curves that describe the metamodel. In order to check a suitability of the metamodel for intended purposes, validation of the metamodel (by comparison of metamodel with simulation output data using mathematical statistics) is done. The graphical representation of metamodel's inputs – outputs relationships provides a simple presentation of expected system behavior, often known as the approximate control.

Simulation metamodelling is an appropriate managing and optimizing tool for complex manufacturing systems. The research work (Hromada, 2004) was done at the Department of Industrial Engineering of the University of Žilina and it deals with the system analysis of input factors influence on the performance of manufacturing system. This approach uses computer simulation and metamodelling principles, and proposed methods were verified

in practical conditions. Other publications focus on metamodelling as a support tool in the frame of Digital Factory (Gregor, 2008a), as a practical approach for a statistical summary of simulation results (Gregor, 2005), (Gregor, 2008b), or as a support tool for designing and testing the control principles in production (Škorík, 2010). Theoretical assumptions and developments were validated on the chosen production system. Principles of experimental concept of production management with simulation metamodelling application are shown in Figure 6.

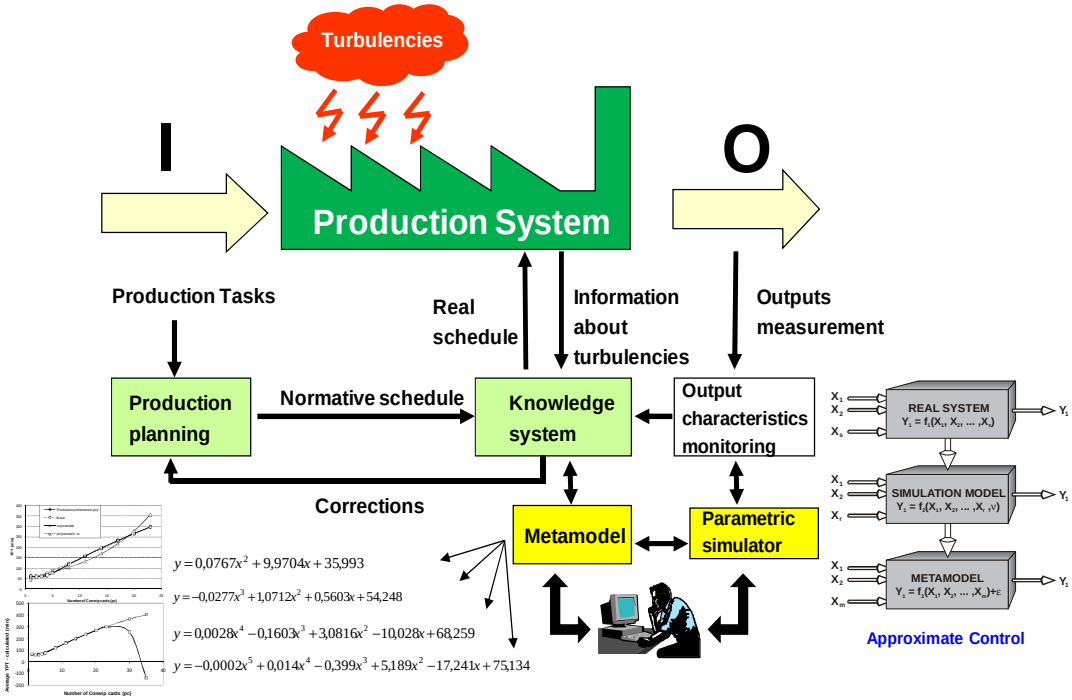

Fig. 6. Possible Configuration for Decision Support (Gregor, 2010)

3.4. Cloud Computing

One of the main problems why companies do not use simulation approaches is their high cost. One of the possible ways how to resolve this problem is to use cloud computing, a particular type of service providing called „Sofware as a Service - SaaS“. It means that software (in our case simulation software and its modules) is provided as a service. Hence the company avoids any need to own such software, whereby costs connected with the special software purchase and employees training are significantly reduced. The difference between traditional approach of software delivery and SaaS model is shown in Figures 7 and 8, respectively.

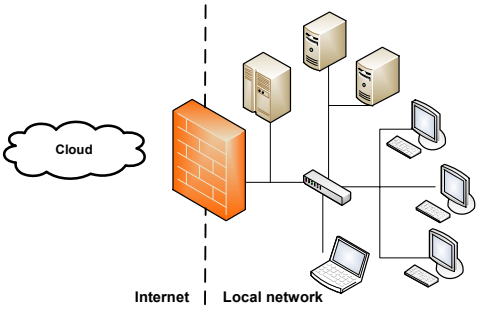

Fig. 7. Traditional Computing Model

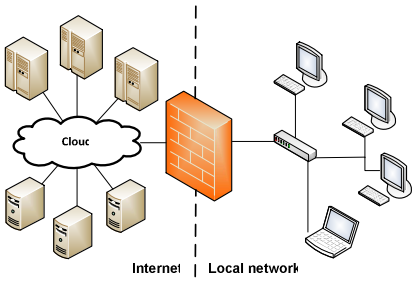

Fig. 8. SaaS Model

The traditional software requires local storage of data, whether on local disks or network resources. Servers, databases and other key elements of IT infrastructure are situated on the right side from the firewall "local network". In contrast, in the SaaS applications can be many of these resources outsourced and safely accessible via the Internet. They store clients' data into "cloud", what is a general term used for outsourced storage and computer equipment used for support of most of the web sites and applications.

The principle of such approach functioning in terms of simulation exploitation shows Figure 9.

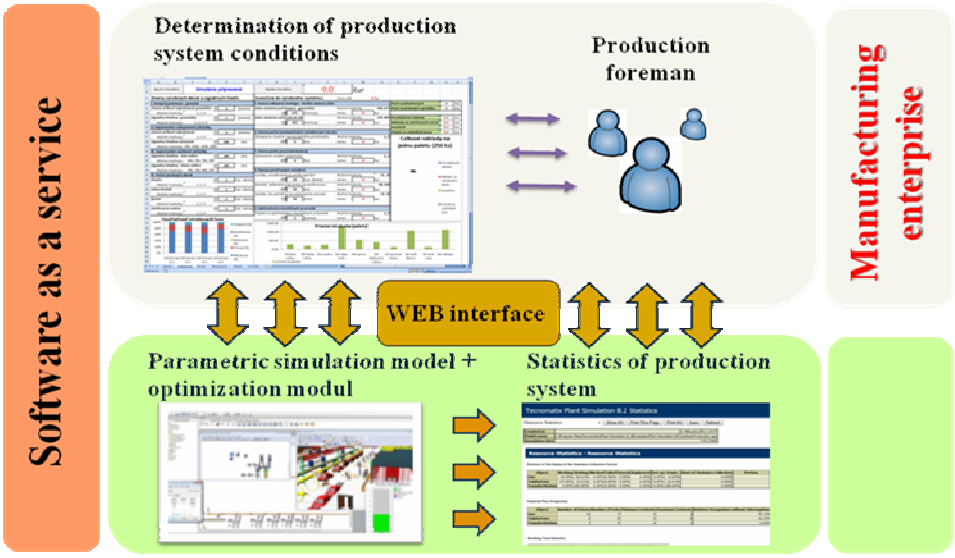

Fig. 9. The Principle of SaaS Functioning in Terms of Simulation Exploitation

Customers simply open excel interface where they set required parameters (such as production orders, availability of machines, workers, etc.) and initialized input parameters are loaded to the simulation model (located on a server in an external company) by using the Web interface. Simulation runs on this external server. After simulation the customer has available production system's statistics which he either accept or select another evaluative criterion to obtain better solution. So customer can flexibly respond to changes in the production environment and quickly incorporate them into the production.

Another advantage of this approach for users is that the responsibility for the system and potential problems are fully at the SaaS provider site.

4. CASE STUDY

Presented case study demonstrates one of the progressive approaches named “emulation” which was used in implementation of the FTS-CEIT AGV systems, developed in CEIT.

Simulation model was created on the basis of technological design of logistics system, using the autonomous conveyor system. The base of autonomous conveyor system consists of three main elements (Figure 10): FTS-CEIT AGV, dynamic conveyor and static conveyor. FTS-CEIT AGV is coupled with dynamic conveyors. Material is automatically imported from warehouse to the assembly line using dynamic conveyor. Transfer of material between dynamic conveyors and lines respectively warehouse is ensured through static conveyors, which are located in unloading and loading positions. The assembly line operator calls loaded AGV remotely as needed from waiting position.

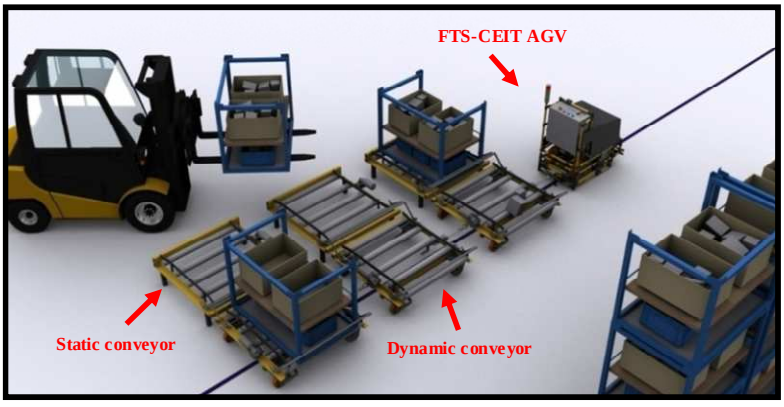

Fig. 10. Autonomous Conveyor System

The basic prerequisite for proper functionality of logistics system is the cycle of assembly line with value of 1.1 minutes. One FTS-CEIT AGV can trail 5 or 3 dynamic conveyor (depending on variant of simulation model). Each palette has 20 pieces of specific door panels. Automatic unloading/loading of dynamic conveyor takes 20 seconds and transport speed of FTS-CEIT AGV is 1 m/s for straight track, 0,2 m/s for smaller curves ,0,3 m/s for larger curves, 0,1 m/s for loading/unloading zone, traction ratio (charging time/driving time) = 1/5. The behavior of system is shown in Figure 11.

Three variants of logistic system have been designed within experiments, which can abide requirements of cycle time of assembly line. Particular variants vary by number of trucks serving logistics system and number of dynamic conveyor systems:

- *Variant 1* – one FTS-CEIT AGV and five trailed dynamic conveyors,
- *Variant 2* – two FTS-CEIT AGVs and each AGV trails five dynamic conveyors,
- *Variant 3* - two FTS-CEIT AGVs and each AGV trails three dynamic conveyors.

The FTS-CEIT AGVs supply all assembly workplaces in variants 1 and 2. The first FTS CEIT AGV supplies assembly workplace with right door panels in variant 3 and the second FTS-CEIT AGV supplies assembly workplace with left door panels.

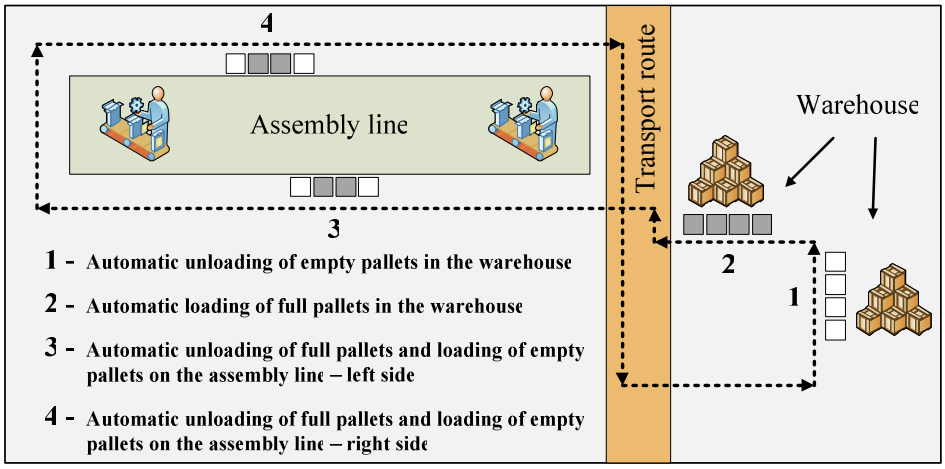

Fig. 11. Basic Principle of the Simulation Model

The following parameters have been monitored to compare usage of AGVs:

- *Idle* - the percentage time that the vehicle was idle,
- *Transfer* - the percentage time that the vehicle spent loading and unloading, including the time that the vehicle spent attempting to load or unload,
- *Loaded* - the percentage time that the vehicle was loaded with parts,
- *Stop* - the percentage time that the vehicle was stopped impact of random collision situations or was recharged,
- Waiting - the percentage time that the vehicle was waiting for call.

The following table shows statistics on the effectiveness of FTS-CEIT AGVs in different variants.

Tab.1 The efficiency of FTS-CEIT AGVs

Name of parameter/ Variant	Variant 1	Variant 2		Variant 3	
	AGV	AGV 1	AGV 2	AGV 1	AGV 2
Idle [%]	15.38	53.40	53.34	39.09	34.21
Transfer [%]	22.29	12.27	12.29	12.37	12.18
Loaded [%]	44.45	24.47	24.49	28.86	33.96
Stop [%]	17.88	9.87	9.87	19.68	19.65
Waiting [%]	0.00	44.87	44.83	12.17	12.29

The overall efficiency of AGVs is shown in the chart below (Figure 12) and was defined as a sum of times of all activities that were directly involved in a transport of pallets of door panels (%Idle + % Transfer + % Loaded + % Stop). Also the compliance requirement for cycle time of the assembly line can be seen in the Figure 12. Based on comparison of compliance of requirement for cycle of the assembly line variant 1 is not suitable, because the time, which

AGV needs to transport single circuit, is about 24 minutes and line required 22 minutes cycle time. This problem was corrected by increasing the number of FTS-CEIT AGVs (variants 2 and 3). Other variants comply with requirements of the production cycle of the system. By comparing of statistics and overall effectiveness of trucks, the best solution was variant 2. Variant 3 is suitable in terms of compliance requirement for cycle of the assembly line.

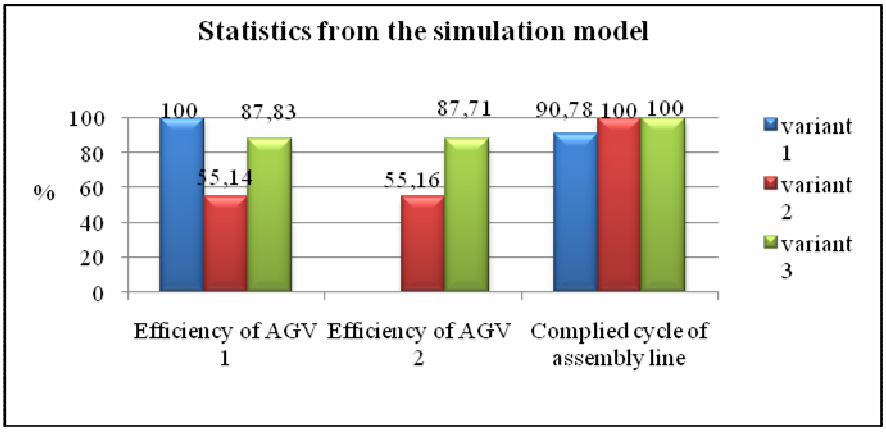

Fig. 12. Simulation Statistics

The three variants have been designed within experiments that were tested also in terms of action random collision situations:

- *Variant 1* - one FTS-CEIT AGV with efficiency of 100%, 5 dynamic conveyors needed, unrealized requirement of production cycle,
- *Variant 2* – two FTS-CEIT AGVs with average efficiency of 55,15%, 10 dynamic conveyors needed, realized requirement of production cycle,
- *Variant 3* - two FTS-CEIT AGVs with average efficiency of 87,77%, 6 dynamic conveyors need, realized requirement of production cycle.

Each designed variants needed 16 static conveyors.

The simulation and emulation offered as a part of product in implementation of logistics systems FTS-CEIT has been shown as an excellent tool. The simulation helped to find not only required number of FTS-CEIT AGVs, but also it supported the identification of system bottlenecks and thanks to that the logistical system was developed which could fit all requirements for this system in pre-implementation phase.

5. CONCLUSION

Using an appropriate combination of particular approaches designer of manufacturing systems can flexibly respond to customer's requirements and provide them a tailored service. These progressive approaches are not groundbreaking ways in the use of simulation in terms of practice; they just make availability of such solution easier. In order to make simulation part of business systems, it is necessary to develop simplified application methods (interface between user and simulation) that enable rapid use of simulation in the commercial sector, not only in terms of research. The authors vision is to afford a simulation for simple problems

when they get rapidly a solution and so flexibly respond to turbulent changes. The simpler simulation for commercial sector is, the more it is in use.

The above mentioned progressive simulation approaches allow:

- to easily enter own values of elective variables (loading input data from an external source),
- to operate parametric simulation model by managers and operators in production shop,
- to test various managing and optimizing methods without deeper knowledge of modeling and simulation methods, and simulation software,
- to execute simulation runs and process optimization without possession of simulation software,
- to find the best solution of company problems in a very short time,
- to save financial resources.

The approaches described in this paper aim to the improvement of companies' interest in simulation of manufacturing and logistics systems.

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Monika TOMČÍKOVÁ*, Peter ŽIVČÁK**

THE PROCEEDINGS OF ADAPTATION PROCESS IN THE COMPANY

Abstract

Human labor is one of the main factors influencing the nature, level and results of business process. Development of the company depends on the diligence and productivity of employees. Staffing processes preceding the acquisition, selection and recruitment. The onset of the employee's work is a process of adaptation. The employee, however, a new job must first be familiar with the work tasks and environments. Výsledkomeffective adaptation is an understanding of business goals, identify new employee with the company, quickly achieving the objectives of the individual and group, improving workingrelationships. Meeting the expectations of workers taken in the process of adaptation is evidence of appropriate processing andsubsequent implementation of the different steps of the adaptation process in the enterprise

1. DEFINING CONCEPT OF WORD ADAPTATION

According to Vajner (2007) "worker implementation and his/her integration (or orientation as well, adaptation) is conclusion of selection process and beginning of working process. It is a process of worker adaptation to working and social environment."
Koubek (2004) describes adapting process using word orientation and explains it as perfectly refined program, which is making the process of knowing each other, new work conditions, social environment and its work duties faster and easier.

2. ADAPTING PROCESS

Most of new employees are trying to fit in new environment as soon as they start to work. Their first impression from new collective is usually the most important. It is well known that if person will not get interested at the beginning it is not going to change later either and he

* PhDr. Monika Tomčíková, Prešovská univerzita v Prešove, Fakulta manažmentu, Katedra manažmentu, mob.: +421 949 156 777, email: monika.tomcikova@gmail.com

** PhDr. Peter Živčák, Prešovská univerzita v Prešove, Fakulta manažmentu, Katedra manažmentu, mob.: +421 917 683 780, email: dr.pzivcak@gmail.com

or she will not continue doing it. If an employee is motivated during adapting process already, he/she has better chance to be successful in new job.

Process of adaptation is going through these phases:

1. Preoperational phase, which includes time period before change of life conditions. Person is creating an idea of what is awaiting for him/her and how he/she should gt ready for it.
2. Phase of global orientation, which is coming after moment when new conditions start to have its influence on person.
3. Phase of conscious changing of relationships starts when person starts to change his/her relationship towards new, changed life conditions and is able to use his/her potential for dealing with those changes.
4. Phase of adaptation, comes as a result of getting through the new life situation and conditions, or in case phase of resignation when the previous phase was not managed well. (Provazník, 1997)

3. ADAPTATION PROGRAM

Majority of companies has a system of adaptation for newly hired employees. This system is composed of individual adaptation programs. Specific programs depend on size of the company and its content.

Accoding to Sojka and kol., 2008, this package should be combined of:

- organizational scheme of company,
- handbook of firm culture and politics,
- copy of collective agreement,
- description of job position,
- description of befits for employee,
- list of educational opportunities,
- information regarding dates and procedures of evaluation,
- company regulations,
- list of phone numbers and addresses,
- company paper and magazine etc.

4. TYPES OF ADAPTATION

Generally we distinguish three levels of adaptation. These separate types are interfacing and influencing among theme selves, nevertheless they are still quite independent and they can develop each in different direction with different level of success, those are:

1. Social adaptation – is process, which result is adequate inclusion of a new employee into private relationships connected to specific job group and into social atmosphere of organizational collective as well as assimilation to the new social roll. It is so called orientation component
2. Occupation adaptation – is process, which result is adequate handling of work tasks and achievement of required performance standard as well as training and education of employee. This component is marked as so called training.

3. Adaptation to the corporate culture – meaning, "forming of fellowship feeling of employee with company by showing him/her how does her/his job settle into the overall company frame". (Sojka a kol., 2008)

4.1.Social adaptation

Social adaptation concerns mainly employee positioning into a team, into work group. Employee should therefore be able to fit in collective, adjust to current conditions and interpersonal relationships. He/she has to be able to co-operate, accept group, into which h/she was put. To assure the adaptation process to be successful, other employees need to accept and welcome new colleague. It is complicated process of relationships, two-way adjusting and learning to compromise, which is not always running without problems. Crucial is the willingness to accept and adjust to new conditions for both sides, for "old collective" as well as for new member. The aim of social adaptation is to achieve employee inclusion into existing system of interpersonal relationships on workplace and in company (Kachňáková, 2003).

Chart 1: Factors affecting the process of social adaptation

External factors	Internal factors
• work group • relationships – formal, informal • existing habits and traditions • personality of supervisor • social climate at workplace	• level of employee socialization • level of person social maturity • social capacity of an individual etc.

Source: SOJKA, 2008

4.2.Work adaptation

Content of work adaptation is tightly connected to specific conditions of employment, for which employee was hired with his/her abilities, characteristics, knowledge, meaning with his/her readiness to do the given work.

Processes of adaptation are included here:

- physical and work conditions (noise, lightning at work, coloring, regime of work and rest, number of people in office etc.)
- character and content of work activity (requirements of position regarding the knowledge, skills, experience etc.)
- managing system and work organization in organization (Kachaňáková, 2003).

Chart 2 : Factors influencing process of work adaptation

Objective factors	Subjective factors
• content an characteristics of work • work organization • work conditions • method and style of managing • evaluation of working performance • rewarding system • opportunities of education and development	• professional competence (professional capacity) • work ability (performance capacity) • personal profile (personal capacity) • social profile (social capacity) • personal and work focus (motivational capacity) • situational state of person

Source: Sojka, 2008

4.3.Adaptation to corporate culture

The goal of adaptation process in area of corporate culture is to help new employees to better orient in existing social norms and standards of procedures, adjust to it and achieve self-identification of company dealings and employee, which is leading toward his/her prosperity and god name spreading. Factors, which either positively or negatively influence course of this kind of adaptation, are for instance power of corporate culture, relationship between dominant culture and subcultures in organization, stability or variability of the culture etc. Positive result of this adaptation form is specific degree of employee identification with organization, loyalty of employee toward organization (Sojka, 2008)

5. INFORMATION GIVEN DURING PROCESS OF ADAPTATION

Adaptation concerns mostly newly hired employees. Entry to new position is generally accompanied by introductory courses. Its number and level of difficulty depend on type of organization, as well as on work character, for which the employee was hired. Amount of materials which will familiarize new worker with requirements of his/her employment, methodologies, rules, and regulations, are coming one by one in time, not only throughout adaptation process but according to character of work and according to what situation needs. (Koubek 2004).

In so called orientation informational package, which is given to employee in written form, so he/she can study should according to Koubek (1997) composed of:

- Organizational scheme,
- Handbook about corporate politics and culture,
- copy of collective agreement,
- description of job position,
- description of befits for employee,
- list of educational opportunities,
- copies of forms for employee work performance evaluation information regarding dates and procedures of evaluation,
- copies of other forms used by employees,
- informational sources (informational overviews),
- list of phone numbers and addresses,
- Company paper and magazine etc.

- information regarding employee insurance,
- company regulations and rules of rewarding.

6. ADAPTATION EVALUATION

Olex argues (2008) that employees get feedback base on continuous evaluations and final adaptation evaluation

- test is used for evaluation of whole-company adaptation of employees after first week of adaptation. It is used to find out how the person coped with work duties and rules or company functioning and possible problems if occurred any during this phase,
- continues evaluation of work routine by department supervisor is accomplished after third, sixth and ninth week of work,
- final evaluation of entire adaptation takes place after finalizing three-months adaptation process. Concluding evaluation is completed by head manager of the department and team of people from human resources, as well as by employee himself/herself b form of self-evaluation.

7. TIME SCHEDULE OF ADAPTATION

According to Stýbl (1998) it is imperative, so that efficient adaptation process was not hurried. It needs time, which is different and depends on characteristics of work, experience and practice of person who is adapting, from level and quality of adapting process etc. In any case adaptation plan should be worked out efficiently so specific adaptation tasks can be managed according to it.

Chart 3: Time agenda of integration and adaptation process

Time of employment	Adaption process
Before start	So called home preparation – during this phase future employee is given materials for study, he/she has opportunity to visit future workplace, meet future co-workers
week	Employee is getting information associated with work entry – contract signing, courses (work safety, basic introductory etc.) meeting with colleagues, supervisors, subordinates, is getting a lot of new information regarding the organization.
2. - 4. weeks	Different courses and work seminars Collecting of experiences on different departments Employee is in contact with his/her couch, tutor, mentor and is continuously evaluating integration and adaptation process.
2. - 5. month	Goals had been defined, employee is performing tasks and activities – consulting and evaluating missions
6. month	End of adaptation process – evaluation of fulfillment of given objectives, defining of ne tasks.

Source : VAJNER, 2007

8. CONCLUSION

Employee adaptation which stands on the edge of selection of human resources and personal development is in theory ad in practice given much less, as to other activities of human resources managing. Directed workers adaptation is a beneficial as it comes to shortening the time period when the worker is not giving a standard performance and his/her orientation in new environment is not sufficient yet. It helps people to create positive relationship toward their job and toward organization as well as it motivate him/her to do the job better.

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Keywords: *Service-Oriented Architecture (SOA), platform one4all, ERP*

Daniel GĄSKA[*], Antoni ŚWIĆ [**]

PLATFORM ONE4ALL AS SERVICE ORIENTED ARCHITECTURE (SOA) IN IMPLEMENTING COMPUTER SOLUTIONS

Abstract:

The paper presents platform one4all uses several computer products implementing as services for realization of the basic/fundamental business processes, communication and workflow management, project management, or the analysis of business activities. The newly presented the foundations of building the systems of Service Oriented Architecture, SOA, their conception and influence on functioning of the whole enterprise.

1. INTRODUCTION - SOA

Service-oriented architecture (SOA) is an emerging architectural style that helps meet several demands. SOA projects designed to quickly and iteratively deliver on business goals are referred to as a "real-world" approach to service orientation [5].

Creating systems based on the model of service oriented architecture has become a widely applied practice thanks to which it is possible to create computer solutions for enterprises which are characterized by the higher elasticity and expandable architecture.

Companies implementing computer solutions strongly emphasize close cooperation with business partners which leads to creating complex structures with many applications communicating in order to exchange information between them.

To prevent the negative outcomes of the integration of many applications which should cooperate during the exchange of information, the enterprise should develop and integrate two main areas: business applications and the environment in which they work. Business applications are the services created or bought which can be applied directly to various functions of business organizations. On the other hand, the working environment is a set of services realized by the computer infrastructure which are used by business applications [3].

Thanks to implementing the philosophy of SOA, the enterprise can become fit and the services which we initiate in the enterprise lead to the introduction of the general government.

[*] Mgr inż. Daniel Gąska, Instytut Technologicznych Systemów Informacyjnych, Politechnika Lubelska, 20-618 Lublin Nadbystrzycka 36, (0-81) 538 44 96, e-mail: d.gaska@pollub.pl

[**] Dr hab. inż. Antoni Świć, prof. PL, Instytut Technologicznych Systemów Informacyjnych Politechnika Lubelska, 20-618 Lublin Nadbystrzycka 36, (0-81) 538 44 96, e-mail: a.swic@pollub.pl

2. THE CONCEPT OF SOA - ASSUMPTIONS

Service-oriented architecture (SOA) as shown in Fig. 1 is currently the most popular conceptual architecture for the IT industry addressing the problem of business integration. The concept is brought forward by distinct business motivations. Drivers for SOA in the enterprise domain include the tremendous growth of IT applications, the ever-increasing use of IT tools throughout every aspect of each business, and the resulting need to integrate both in a coherent, scalable, and manageable fashion. The trend toward outsourcing noncore competencies, including the outsourcing of IT as a utility, further fuels this movement. In addition, the plethora of mergers and acquisitions, and the significant increase in business-to-business partnerships and supply chain relationships also point to the pressing need to integrate IT tools and business processes. These are significant drivers that can be summarized as continuous business transformation, and these are the drivers that in large part shape the approach required to address this problem space. These drivers lead to an adoption of service middleware based on loosely coupled granular components and message-based communication; they expose only as much or as little of the underlying network capabilities as needed to ensure successful reuse of the components by multiple services [1].

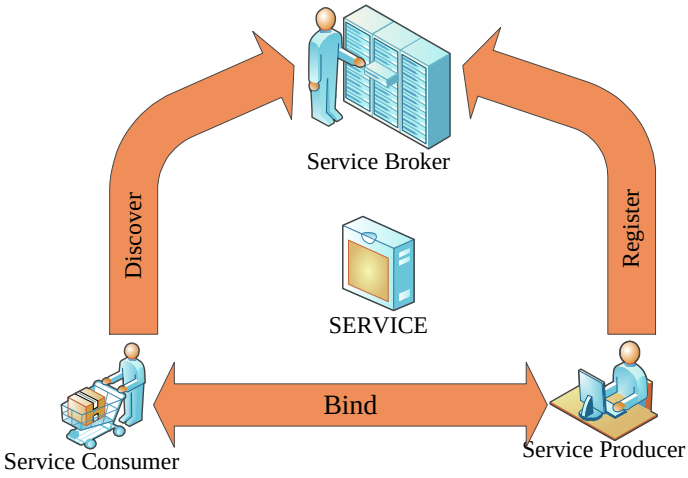

Fig. 1. Basic service-oriented architecture concept

In order to better understand this concept it is necessary to implement of a larger number of components and the relation between the service consumer and service producer, thanks to which SAO becomes easier to understand.

Fig. 2 shows the Service-oriented architecture with more components and more their relations:

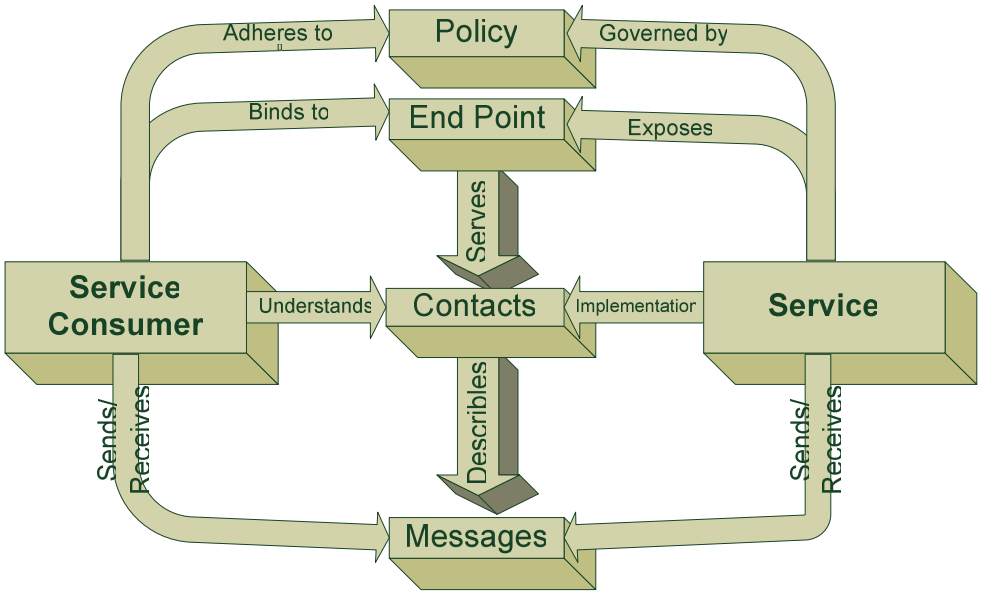

Fig. 2. SOA components and their relations

The components of SOA and the relations among presented in Fig. 2 above define the directions we can take in creating the system.

Services

The central pillar of SOA is the service. We can defines service as "a facility supplying some public demand". A Service should provide a high cohesion and different services. Services should be coarse grained pieces of logic. One of the characteristics of services is service autonomy. Autonomy means the services should be self-sufficient, at least to some extent, healing properties.

Contract

The collection of all the messages supported by the Service is collectively known as the service's contract. The contract can be unilateral, meaning a closed set of messages the service chooses to provide. A contract might also be multilateral or bilateral, that is, between a predefined group of parties. The contract can be considered the interface of the Service akin to interfaces of object in object oriented languages.

End Point

The Endpoint is an address, a URI, a specific place where the service can be found and consumed. A specific contract can be exposed at a specific endpoint.

Message

The unit of communication in SOA is the message. Messages can come in different forms and shapes, for instance, http GET messages (part of the REST style) ,SOAP messages, JMS messages and even SMTP messages are all valid message forms. The differentiator between

a message and other forms of communication such as plain RPC, is that messages have both a header and a body. The header is usually more generic and can be understood by infrastructure and framework components without understanding, and consequently coupling to, every message type. The existence of the header allows for infrastructure components to route reply messages (e.g. correlated messages pattern) or handle security better (see Firewall pattern).

Policy

One important differentiator between Object Orientation or Component Orientation and SOA is the existence of policy. If an interface or contract in SOA lingo, separates specification from implementation. Policy separates dynamic specification from static/semantic specification. Policy represents the conditions for the semantic specification availability for service consumers. The unique aspects of policy are that it can be updated in run-time and that it is externalized from the business logic. The Policy specify dynamic properties like security (encryption, authentication, Id etc.) , auditing, SLA etc.

Service Consumer

A service doesn't mean much if there isn't someone/something in the world that uses it. So to complete the SOA picture we need Service Consumers. A service consumer is any software that interacts with a service by exchanging messages with the service. Consumers can be either client applications or other "neighboring" services their only requirement is that they bind to an SOA contract.

Looking at this SOA definition we can see SOA has a lot of emphasis on interface. Starting from the messages which are the parts of the interface, the contract which is the collection of the messages, the endpoint where the contract is delivered and the policy which governs the behavior of the endpoint. Thus SOA has a total of four different components that deal with the interface vs., for example, OO which only has one. The focus on interfaces is what gives SOA the ability to create loose coupling, composable components, reuse and achieve the various design goals. Another nice attribute of this definition is that we can use as a base for both the technical and the business perspectives of SOA as the common elements of both perspective are used in this definition [6].

3. PLATFORM ONE4ALL

Platform one4all uses Microsoft software to integrate computer solutions in an enterprise. Thanks to using XML language to exchange data between applications it is possible to implement the solution of other manufacturers, such as SAP.

Fig. 3. One4all platform and Microsoft Dynamics business management software in SOA architecture

Decision on choosing the strategy of the informatization requires from the organization (both public institution and private) defining the concrete and measurable goals that will assure them a possibility of their future progress and development, obtaining competitive advantage on the market and also increase effectiveness and rapidness of actions.

one4all is a comprehensive solution that can be easily adopted to the need of the both public and private sector. The solution is built based on the proved technology and environment of the Microsoft systems and know-how and experience of the specialists working on its creation and further development. Operational activity of an organization becomes more effective and forecasting of the desired development directions is possible due to the application of the one4all solution.

one4all in the particularly helps to:

- eliminate the "bottle-necks" and integrate business processes and actions
- manage available funds in the most effective way
- simplify complex processes of human resource and payroll management
- improve project management
- ensure safe and efficient communication and exchange of information among the members of the organization
- organize the work in the most effective way
- assure a proper safety and data protection.

The solution one4all integrates such areas of the organization activity (Fig. 4):

- realization of the basic/fundamental business processes
- communication and workflow management
- project management
- an analysis of the business activity

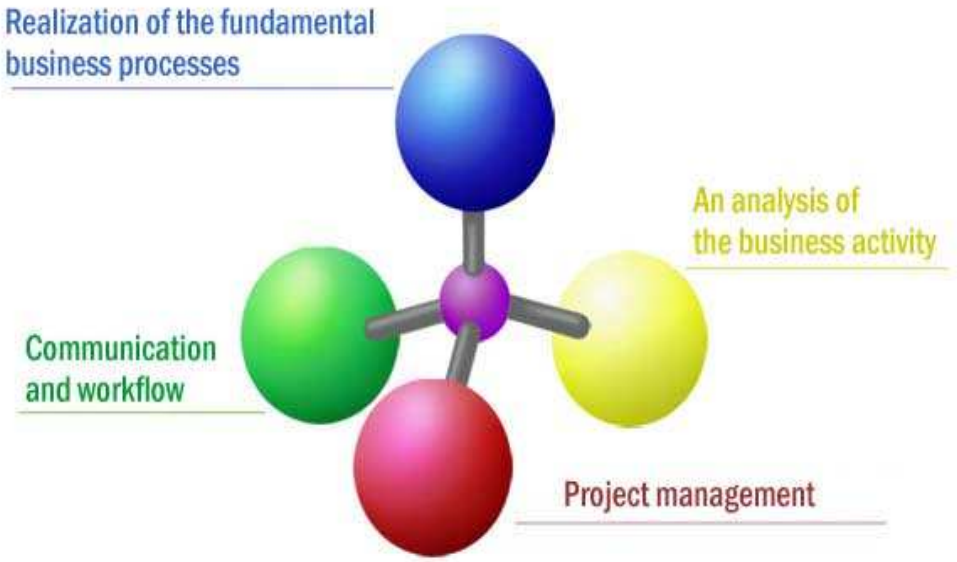

Fig. 4. one4all integrates such areas of the organization activity

Realization of the basic business processes

Area of the realization of the basic business processes is covered by the hand of the ERP class solution to manage organization. This solution makes it possible for the employees and the whole organization to make more optimal business decisions. It contains comprehensive functionalities that automate and improve management of the financial processes, petitioner relations, services for the community, human resources and other. It allows therefore on the integration of processes, technology and employees that can be in the any place in the world. Use of this part of one4all influences then efficiency improvement and overall better functioning the whole organization.

A great example of the processes in this area is a situation in which an institution is assigned with the additional financial means to perform a concrete project. To our institution is sent a letter with such notification. Thanks to the one4all solution within just a few seconds this information is available to all managers who should be informed about this. Also, money is transferred on an account of the institution that on the other hand what has its effect in budget enlargement. Due to the home banking functionality accountant doesn't have manually enter date into the system, only needs to check and book them. So, the work is automated and accelerated and error free.

one4all:

- automates and improves financial processes in each area of functioning the institution
- increases efficiency of the employees
- influences the overall level of the petitioner satisfaction

Communication Management

In today's' times accessibility, exchange and passing through an information is a key aspect of every institution's activity. one4all allows managing knowledge database and sharing the documents through the built-in Documents Center which improves the flow of information in the organization. All data is accessible through the internet and intranet portals created to ensure quick, easy and intuitive access to the required information. Information about events is sent to entitled and interested persons automatically. one4all also gives an opportunity for many engaged persons in concrete task to work on one document at the same time. Another plus is an ability to manage the following versions of the same document with a full insight into changes tracking with an option of reviewing and accepting them. Also, in order to: ensure better communication and understanding of the sent information, create better relations between employees and eliminate barrier of distance one4all uses a communication platform that allows voice and vision transmission for the unique chance to have tele- and video conferences.

The situation when a director of an institution receives a letter with a request to prepare an opinion for the superior institution can be a great example of how to use functionality of this area of one4all solution. The letter is scanned and registered in one4all and from that level is sent to director and then he gives order to the managers and they to their employees. At this time an employee receives an alert which means that he was just assign a task; it also gives them the information about the deadline, other people involved in the task and so on.

Employees of the departments located in a considerable distance from each other use internet cameras to communicate. This way they can effectively exchange ideas and information. During work they create working versions of documents about which other member of the team are notified by e-mail and have access to them. The director receives one and final version of the document already accepted by the managers, but in each second can see how the works were performed.

one4all:

- assures the safe access to information with the use of internet and intranet
- causes simplification of procedures concerning the information and documents exchange
- makes team working in various locations more effective
- eliminates or limits the quantity of paper work
- gives a full insight into the history of the versions of the documents

Project Management

In order to more effectively achieve goals and in optimal way use given resources more and more organizations uses a projectile approach towards their activity. Answering such needs one4all makes it possible to manage and run projects. By just one click managers are able to check use of resources, their accessibility in the concrete moment, work progress and deadlines of each task in the schedule. Resources are booked as a result of full automation in the moment of creating the project and participating employees informed about assigned tasks and deadlines of the particular stages of the project. one4all tracks the whole cycle of the life of the project in a quick and easy way, plans expenditures and controls costs.

We can imagine a situation when a director of an institution is asked to deliver a report concerning the progress of works of the project co-financed by the superior institution. In such situation he asks his employees to indicate the stage of the works for which they are responsible for. Employees who can work in various locations after receiving e-mail with such request actualize the stage of their work. After doing that they send a feedback e-mail that is received by the director what gives him knowledge about the current stage of the particular

works in the project. Such report in a graphic form shows whether works are done on time, tasks are assigned in optimal way to the employees or changes need to be done. Thanks to the functionality of the project management a director not only can easily make a need report but also in any time react to the dynamically changing situation.

one4all:

- supports planning and using of accessible human, material and other resources
- allows controlling the course of the realization of the particular stages of the project
- allows automatically tracking of the cause- effects linkages between individual tasks
- automatically informs participating human resources about allotments and changes in the project and assures obtainment of the back information about the progresses of works (also through internet)

Reporting and Analyses

It is possible to create measurable and effective reports and analyses due to the fact that one4all uses the information from the areas of the realization of business processes, communication and workflow management and project management. Such personalized and answering to specific needs reports are used by the managers and specialists and support them in decision making processes and forecasting future actions. Managers are able to quickly and wisely react to the changing situation due to the fact that analytical data is accessible in the real time. The solution is very functional and friendly use considering the fact that data is presented both in a graphic and tabular form.

Nowadays, many institutions participate in the distribution of the money coming from the external sources (e.g. grants or the financial means of EU) both as final incumbents and intermediary institutions. It isn't uncommon that project managers need to prepare wide and very detailed periodical and final reports. In order to do so they need information from various areas and it is often causing many problems. Using one4all all necessary is already gathered in one solution and creating such multidimensional report is done practically at once. As a result of the use of one4all project managers can concentrate on the realization and the maximization of the obtainment of the positive effects and not on details of reporting.

Additionally, the report which in this moment is merely a fulfillment of the formal requirements can serve to yet better planning next projects in the future thanks to it's

one4all:

- allows making very advanced reports and analyses
- assures access to the information in a real time
- allows making simulations of the various actions, their analysis and predicting results therefore better planning and managing processes in a institution

The utilization of services contained in one4all system is possible thanks to using http protocol and an internet browser (Fig. 6).

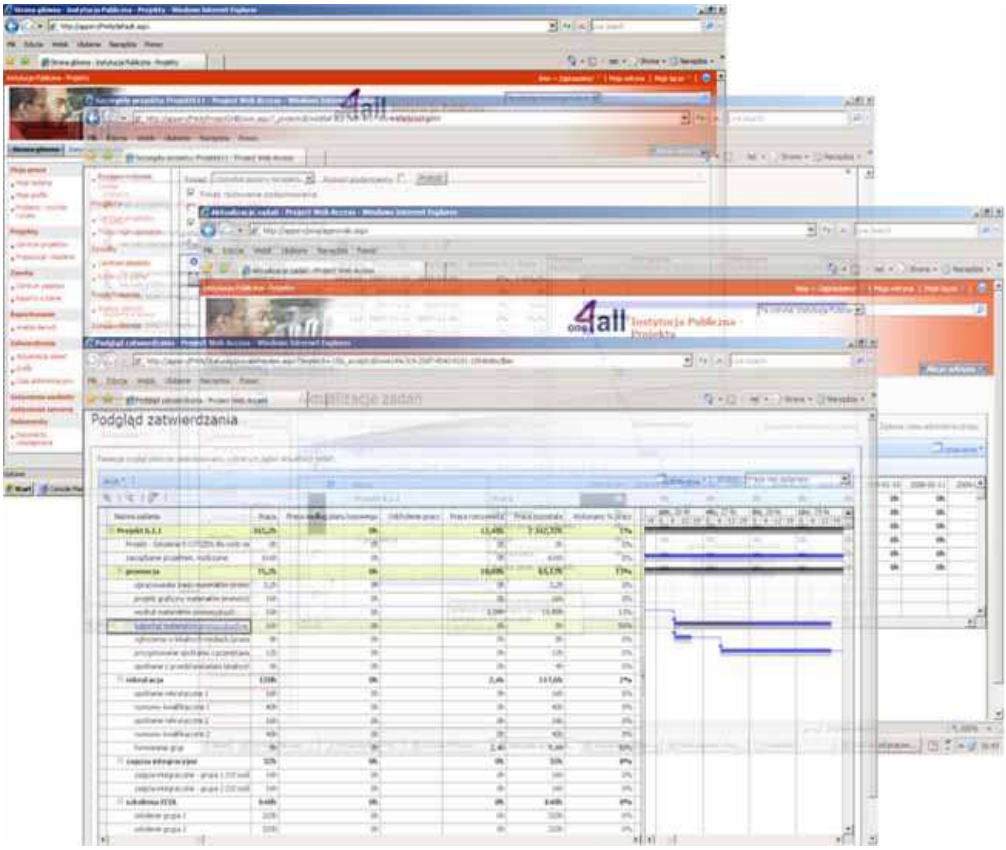

Fig. 6. Platform one4all in internet browser

The area of the realization of basic business processes is done with the help of services realized by the solutions of class ERP (**Enterprise Resource Planning**) which support the management of the organization. This solution enables employees and the whole organization to make optimal business decisions. The complex functionalities which the solution contains automate and improve financial processes, customer relationships management, business services, human resources management and logistic processes (**SCM – Supply Chain Management**), which include the efficiency of transportation (**TMS - Transportation Management System**), the optimization of utilization of the area (**WMS - Warehouse Management System**), selling-buying production processes, and other processes within the organization (Fig. 7,8).

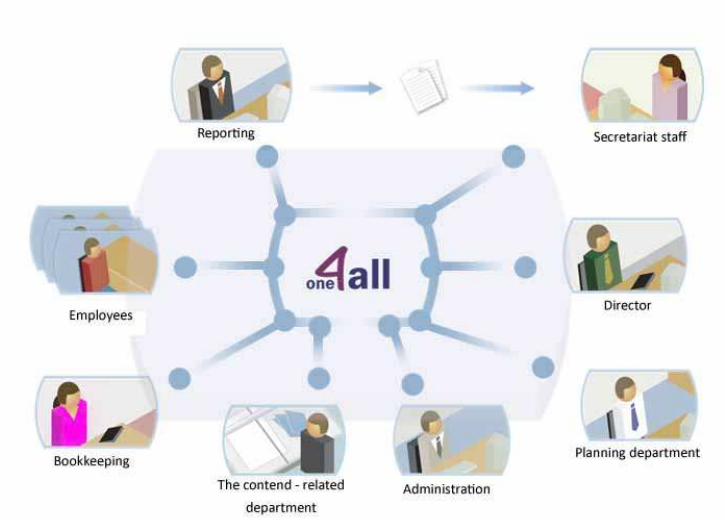

Fig. 7. Description of content-related schedule for the platform one4all

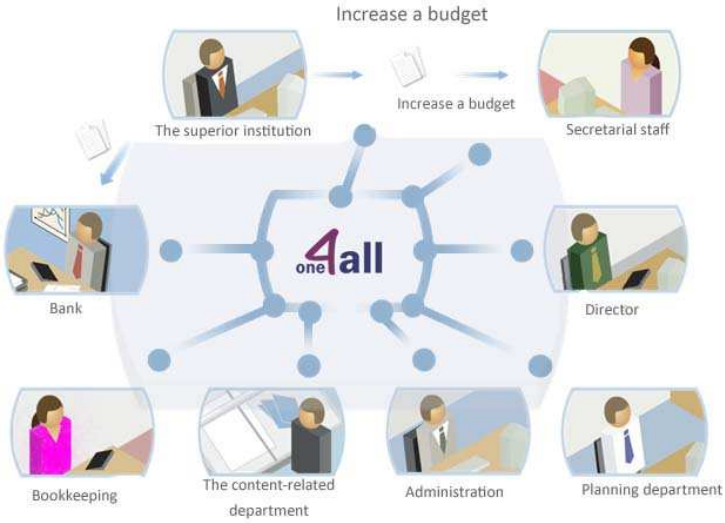

Fig. 8. Description of increase a budget.

4. ENVIRONMENT AND THE COMPONENTS OF SERVICES IN THE PLATFORM ONE4ALL

The solution **one4all** uses the data from the areas of the realization of business processes, the management of transport and workflow and the management of projects. In this system, it is possible to create effective reports and analyses. Such personalized reports and analyses are used by managers and experts, helping them in the process of making future decision and predicting future behaviors. Because that analytic information is accessible in the real time, managers can react immediately to the changing situation.

The platform **one4all** facilitates leadership and management projects. **one4all** allows to follow the whole cycle of the life of the project in the quick and easy way, to plan expenditures and control the costs.

The following Services are included in the solution **one4all**:

- **Microsoft Dynamics AX 4.0** is the elastic solution to the management of the organization which enables employees the organization to make optimal business decisions. The work with the software Microsoft Dynamics AX is similar to working with other application from Microsoft, such as Microsoft Office or Microsoft SQL Server. This means that the new application possesses the same elements as the systems and software which are already used in the organization.

- **Microsoft Dynamics CRM 4.0.** The key processes realized by using the system of CRM are, for example, gaining new customers and building long-lasting relationships with them.

- **SAP Business All-in-One** offers the complex solutions of the world class in the form of pre-configured packets at the affordable price to small and medium-size firms. SAP In the case of firms working in the specific line of business, SAP solutions reflect processes realized in the given environment / sector.

- **ILS.NET**. Sending goods in the chain of deliveries requires the co-ordination of many business processes, including transport, storing and the management of orders. Thanks to the solution Integrated Logistics Solutions ™ one can balance the demand with the supply in the chain of deliveries assuring the delivery of the goods expected by the customers. Exactly compiled orders, the improved process of the realization of deliveries and the total transparency of the goods stored in warehouses will allow to tie all processes in the chain of deliveries.

- **Microsoft Office SharePoint Server 2007** is the integrated packet of easy to use server applications which increase the efficiency of the organization and optimize the co-operation of people, content, processes and business applications.

- **Microsoft Office Communications Server 2007** administers communication in real time (synchronic communication): instant messages, technology VoIP and videoconferencing. Because it co-operates with other existing telecommunication systems, the enterprises can implement advanced technology VoIP without the need to exchange older telephone nets.
- **Microsoft Office Project Server 2007** allows for more effective management of the work of an organization by coordinating it during the entire project, beginning from single and finishing with more complex projects.

- **AX People** is a modern, licensed by Microsoft system which allows managing human resources in the organization. AX People is fully integrated with Microsoft Dynamics AX, but it can also work in the independent way, using only the core of this system.

- **Microsoft® SQL Server™ 2008** is the newest platform for managing and analyzing

data which offers the highest safety of information data along with the comfort and low costs of data management.

5. CONCLUSIONS

The platform one4all is the new concept of the platform which can offer a potential customer a range of services which can be implemented and developed, depending on the specific needs of the organization. The nature of the platform **one4all** makes it possible to implement several services, thanks to which

- Helps to promote the development of the **informative society** since the platform **one4all** allows to work **"at the distance"** and create the new global possibilities of employment; increase the availability of experts services; decrease of costs connected with creating new work places and commuting. The platform one4all makes communication services accessible, enabling the broadcast of sound and picture, employees can contact through tele- and video-conferences which assure more effective communication and better understanding of information, building perfect relationships and overcoming distance barriers.

- The platform **one4all** for higher education institutions – the Modern University, makes it possible to realize advanced functions of e-learning/distance learning which results in raising the quality of teaching and lowering of the costs of education; the access to attractive teaching materials; the better possibilities for self-education.

- The platform **one4all** allows access to services of advanced internet applications which allow implementing the electronic trade and give access to global markets; allowing consumers the choice of the best offers; lowering of the costs of distribution and promotion.

- The utilization of the platform **one4all** is effective in improving the organizational economic activity through: improvement exchanging of information between enterprises and inside enterprises in distant geographical locations; lowering of the costs of the economic activity; facilitation and the acceleration of accounts; the possibility of the remote management of the financial centers at the banks.

- The platform **one4all** for public institutions allows the remote access to legal acts, information about realized undertakings, auctions organized by the administration, legislative plans and the electronic exchange of the correspondence.

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Automotive, experimental car, innovation techniques integration, innovation tools, product design, prototyping.

Michal DÚBRAVČÍK[*], Štefan BABJAK[**], Štefan KENDER[***]

PRODUCT DESIGN TECHNIQUES IN AUTOMOTIVE PRODUCTION

Abstract

In the present and medium term perspective in the future, the mechanical engineering and other industrial branches are facing advanced challenges arising from global changes in the technical, economic and social environment. Submitted article deals with the approach to Product design in automotive sector that is using benefits from the synergic effect of utilizing the innovative methods, techniques and tools, within the integrated model of complex product development. The suggested paradigm is demonstrated on the project of experimental car ICAR 2010 at the Faculty of Mechanical Engineering, Technical University of Kosice, Slovakia.

1. INTRODUCTION

The automotive sector is facing advanced challenges arising from global changes in the technical, economic and social environment. Trend, referred to as the "agile manufacturing" represents the ability to survive and prosper in a competitive environment of continuous and unpredictable changes. It means to respond quickly and effectively to changing markets, produce goods and services according to customer needs via maintain the continuous product innovation, manageable number of product variants, fulfilling the unpredictable requirements of customers, shortening product life cycle and respond to significant fluctuations in sales.

Agile production is different from the lean in the sense that lean production is oriented on the repetitive manufacturing environment with focus on high-volume and low mix, since the agile production is applicable to low-volume and high mix. It is suited to an environment where configurable or specialized products offer a competitive advantage [1].

In the present and medium term perspective in the future, the mechanical engineering and other industrial branches are facing advanced challenges arising from global changes in the technical, economic and social environment. They are influenced by the previous financial

* Ing Michal Dúbravčík, PhD; Technická univerzita w Košicach, Strojnícka fakulta, 040 01 Košice

** Ing Štefan Babjak, PhD; Technická univerzita w Košicach, Strojnícka fakulta, 040 01 Košice

*** Ing Štefan Kender, Technická univerzita w Košicach, Strojnícka fakulta, 040 01 Košice

crisis, followed by the debt crisis (pressure to reduce costs, entering the new markets, innovation and so on).

2. INNOVATION MODEL FOR THE SOLUTION

In important part of the preparatory phase of the project is the analysis of innovation models and selection of the preferred model. Models of innovation inherently respond to changes in the innovation environment, so there are many different models. Basically, there can be distinguished 2 main groups and 5 basic generations of models, as follows [2]:

Traditional linear models of innovation:

- Push model: Science initiates innovation (new knowledge – innovative design – production – customer)
- Pull model: Demands of potential customers – innovation comes from the unmet needs of customers (customers – innovative design – production)

Interactive models: Combination of push of science and pull of customer demands through the feedback loop. Research, development and marketing are in balance.

- Coupling model: interactions between the different elements and feedback between them
- Parallel model: integration between the companies, linking with key suppliers and active customers, emphasis on bindings and alliances, system integration, large networks, flexible and tailored response to continuous innovation.
- Network model: system integration, wide networks, flexible and tailored reactions of radical innovations.

The transformation from traditional, closed innovation to modern, open and performed within the network, is not without problems. Trend is to work also with partners with not clearly and poorly structured problems related to innovation, comprehensive thinking on innovation with a strong focus on future developments and the possible needs of potential users. The challenging tasks of design of innovation processes in the network are:

- Knowledge of integration across the organizations
- Format of partnership for innovation in the network
- Identification of strategic partners
- Balancing the goals and future vision for innovation in the network
- Team structures for innovation in the network
- Skills and practices for innovation networks
- Model for network innovation

3. INNOVATION TECHNIQUES AND TOOLS INTEGRATION APPROACH FOR AN EFFECTIVE PRODUCT DESIGN

Experience from development projects proved that for innovation process in the field of automotive components is the integrated portfolio of innovation methods and techniques an excellent way to gain the benefits of lean approach. The recipe for successful portfolio mixture must consist of four essential ingredients:

3.1. Analytic innovation methods and techniques

They are intended for gathering and evaluation of source data for innovation process and its particular phases launch, including i.a.:

- **Surveys:** marketing surveys for future product users, surveys for branch experts, etc. As a tool of open and user innovation they are helping to refine the product innovation according to user needs and demands. In combination with taking the opinions or suggestions branch specialists into account provide the unique tool to adjust the product bespoke target user groups and assure the competitive success.
- **Benchmarking** of competitive products. Helps development teams become familiar with the bill of materials, part count, features etc. of competitive products in the appropriate segments in order to understand how to improve the engineering and/or design of the product and trends in the area. The more complex, detailed and numerous (in terms of examined competitive products) the benchmarking is, the better. There is also recommended to perform the examination outside the product segment's boundaries, in order to explore and identify key differentiating features as the optional areas for improvements.
- **Innovation intelligence** focused on inspiration suggestions (product architecture, new functions, materials, technologies, fields of application, etc.) partially utilizes benchmarking results, which, combined with new knowledge can be the source of new innovation ideas.

3.2. Creative methods and techniques

In the beginning of the innovation process are used to generating innovation ideas, their evaluation and transformation to innovation opportunities, and also in concept creation. Some of them play in the next phases the role of stimulating pulses for subsequent appropriate outputs routine. Here belongs a number of methods and techniques, i.a.:

- **Brainstorming (brainwriting).** Spontaneous and quick random generating of number of ideas can be useful for almost each problem solving. For example, within the many projects were solved the questions of conceptual frame, original shape design, etc. this way.
- **TRIZ.** Uses algorithmic approach (unlike random in brainstorming) to solve the contradictions using the typical solutions where the ideal final result is predetermined (set within the statement of work - SOW, according to customer standards, legal regulations etc.). Within the project development can TRIZ be used to solve the contradictions in interfaces between existing platform and new shapes, where particular elements are defined by customer as not changeable.
- **Morphologic tables / morphologic map.** As illustrated on figure 1 in an example of automotive seat development, this tool is intended to quick design alternatives creation. It has shown very useful by generating headrest, lumbar bolster shape, and additional features.

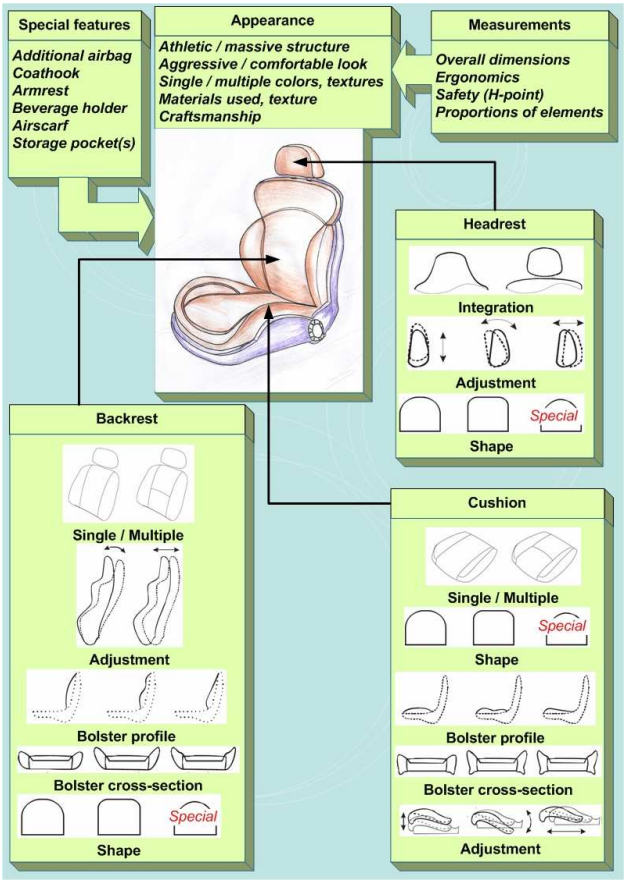

Fig. 1. Morphologic map - example

3.3. Control and testing methods and techniques

Their role is to reveal risks and possible weaknesses of actual state before and during the phases of innovation process help to eliminate them, and provide the boundaries of the acceptable innovation. For example:

- **Quality function deployment (QFD)** is an extremely powerful catalyst for driving in quality at all stages of the product life cycle. It integrates quality throughout the value chain by starting with the Voice of Customer (VOC) and working with quality until the positive impact on customer satisfaction is achieved. The VOC (customers' requirements as expressed in their own terms) is translated into final product characteristics expressed in technical terms with help of the series of matrices.
- **Failure mode and effect analysis (FMEA)** reveals the potential weaknesses of the analyzed system and suggest the recommended actions towards the critical and significant characteristics**.** The Design FMEA (DFMEA) in product design must primarily take into account following groups of product functions (ordered by descending importance): legal (legislation and standards), safety, operational (basic

functionality), comfort of use, manufacturing and assembly feasibility, ergonomics, robustness (reliability and durability), and haptic and optic functions.

- **Cause – effect diagram** is the fishbone shape diagram heading to negative state and describing the groups of negative factors leading to the negative state. The more clearly and accurate reason is defined, the best chance is to eliminate it fast and cheap.
- **Design to cost (DTC), Design for manufacturing/assembly (DFM/A), etc.** are so called "design for X" methodologies, where X may correspond to one of dozens of quality criteria such as reliability, serviceability, environmental impact, manufacturability, etc., or particular costs within specified boundaries. Basic general principles for achieving any of the Xs in DFX are: detail design decisions can have substantial impact on product quality and cost; development teams face multiple, and often conflicting, goals; it is important to have metrics with which to compare alternative designs; dramatic improvements often require substantial creative efforts early in the process. A well defined method assists the decision-making process.
- **SWOT analysis** despite the lack of measurement accuracy, it can be very useful e.g. for technical meetings for brief description of actual results.

3.4. Support techniques and tools

- **CA technologies** accelerate, simplify, and enhance quality of outputs of routine procedures, and allow limited testing via simulations.
- **Integrated cycle of shape design refinement:** Optimization – Model fabrication, prototyping – Reverse engineering. As soon as the geometry is defined, the physical model can be built as a first visualization. There are a number of methods and techniques available to make a mock-up, e.g. clay modelling, foam blocks hand tooling, epoxy resin laminating, silicone moulding and urethane casting etc. For the further development of the car, the CAD model is needed. To get a CAD model, the reverse engineering phase has to be performed. This involves the preparation of the model (fixing the mock-up and the definition of the reference points in order to stitching the surfaces correctly), digitizing (obtaining the point cloud) and final corrections and conversion (smoothing and stitching the surfaces and export to the interchangeable CAD file format).
- **Rapid prototyping** means not only use of computer-aided manufacturing (whether CNC machining or layered manufacturing), but the quickest and cheapest way of fabrication of prototypes (or mock-ups) with optimum quality, which means to sufficiently fulfil the needs in current state of product development. In addition to conventional technologies and materials, the use of easy formable materials (polyurethane or polystyrene foams and blocks) makes good.
- **Network-based development** represents one of the paradigms of innovative approaches to product development in cooperation with various partners within the network. Selected of involved partners are engaged in the individual phases and there are created virtual sub-teams ad hoc in order to create outputs needed (concept frame, QFD, benchmarking, FMEA, analyses, surveys, documentation, optimizing, etc.). General paradigm of such as network for product design is shown on figure 1. Advantage of this approach is lean and flexible team with clearly defined competences and responsibility of each team member. Result is the save of time since

every member takes part only on assigned work tasks. Thanks to IT support is each involved partner informed about current progress of single tasks, which can comment, or consult the correspondence with own task results and further proceedings. Combined with parallel solving of several partial tasks is there applying the simultaneous engineering approach that brings saves of time and costs, and brings competitive advantage in terms of advanced design robustness.

- **E-community**. According to purpose of the community and structure of the team, the specific needs and requirements, as good as the levels of utilization of the specific tools often vary. The reasons are various: sometimes are the skills of the team members insufficient to use some of the tools, the nature of the project may not allow using them or it will only complicate the work, or the specific tool may be too simple to support the solution of advanced tasks or it doesn't provide the results as it is required and needed. That's why the crucial role of the community manager (project team leader), in addition to planning, scheduling and coordinating the community activities and motivating the team members, is to adjust the environment and available tools to gain an optimum profitability. The software support of e-community can be also various according to the conditions mentioned above. The highest and most complex level of integration of these tools is within the frame of so called CMSs (Content management systems).

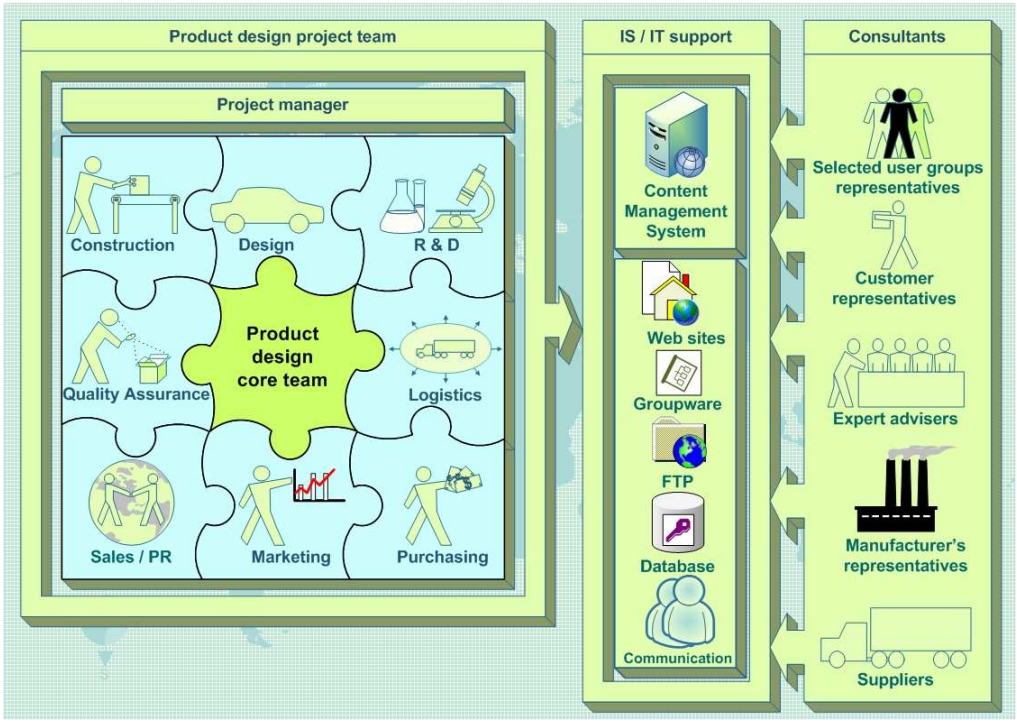

Fig. 2. General paradigm of a network for product design

4. PRODUCT DESIGN CASE STUDY: COMPLEX PRODUCT – EXPERIMENTAL CAR ICAR 2010

The main goal of the development of experimental vehicle ICAR 2010 was to design and realize a functional prototype of a sports car for leisure. Within the frame of the project were involved student teams under the leadership of assistants and researchers of the Department of technology and materials and Innovation centre of automotive production at Faculty of Mechanical Engineering, Technical university of Kosice., automotive and department of innovation centers. The statement of work for team tasks contained well-defined procedures for the development. Among the car body components under the development were e.g. front and rear hood, bumpers, fenders and car skeleton. There have also been proposals for the interior, which got a corresponding new look in order to match the new look of the exterior. Adjustments did also not avoid the vehicle chassis and engine with the exhaust system, which was completely rebuilt. The whole project was based on the chassis and basis of the body frame of Skoda Fabia 1.9 TDi, production year 2001 (Fig. 3). Since it was a prototype vehicle, the body was made of fiberglass and composite materials, followed by surface coating in order to gain the ultimate visual experience.

Fig. 3. Škoda Fabia 1.9 TDi, production year 2001

4.1. Philosophy, design and development process

In the beginning of the development of concept were clarified certain ideas to project kick-off. The car should have sporty roadster look with dynamic features, aggressive grillee and also should excel in elegance that would have taken every sports car enthusiast. Pilot task in project management was to divide the different roles, responsibilities and hierarchical positions of the development core team. The production itself was preceded by a series of developmental preparation with concept design frame of the overall shape of the car. An analysis of competing solutions from different designers from around the world brought to the process of design an inspiration that led to the exact specifications of the design boundaries. It was important vehicle to maintain the linear structure of the two-seat roadster, obviously with regard to performance, safety and future operation of the car. There was crucial to keep these features within the boundaries of limited resources (budget and available means of production – tools, technologies, etc.).

The core team in this phase consisted of 6 members. The initial brainstorming included the assignment of responsibilities for certain project parts / car components of each team member. The car body as a system was divided into separate parts (front, rear, doors), each part was assigned to two team members.

The specific parts were solved individually in a number of variants. The solutions were subsequently integrated using the technique of morphology. By eliminating the unsatisfactory combination was refined the conceptual overall look of the vehicle. After the evaluation and assessment of the proposals was approved the final design as the basis for start-up of the prototype fabrication. An important part of this project phase was the choice of material and technologies. Based on the selection of appropriate solution was realized the manufacturing process of body construction. There were defined enhanced teams with identification of positions in the workplace and set the production schedule. The precise scheduling of work was an important part of production in order to coordinate the specific activities. In the case, when delay in specified deadlines occurred, was necessary to find the cause and subsequent solution and further prevention of the problem. It was also necessary to ensure logistic flow of material for the production of components and functional units.

Technical preparation of manufacturing included set of technical, technological, organizational and economic measures, intended to gain the excellent technical level of the results, streamline the organization of the prototype fabrication, optimal economic results, and to keep the scheduling of manufacturing of required components just in time. Before the manufacturing kick-off were set the control milestones. A failure to meet these deadlines would result in a problem, so in such cases the root cause had to be detected and the appropriate measures were taken. This way, the student teams were able to verify the functionality of the system in real conditions and on real product. If any conflict situation, or a variety of issues related to realization of such an extensive project occurred, each team member was able to directly intervene in the manufacturing process and thus affect the outcome of both his own work and the work of the whole team, or even other teams on the other hand.

The next step was the distribution of labor in the workplace individually for each member of each team. Finally, it was necessary to ensure the logistics of manufacturing that included the continuous supply of material to prevent the waste of time and ensure the continuous workflow. It should be appreciated the cooperation of the management of the Faculty of Mechanical Engineering, under auspices of which was this project realized. The project was financed solely by the faculty, without any sponsorship donations, since it was an effort to gain the clean, independent design and realization without the external interventions, as the original work of students and staff of the Department of Technology and Materials and Innovation center of automotive production.

Characteristics of the experimental vehicle

- As the platform was chosen Škoda Fabia,
- Designed and manufactured new styling of car body and interior,
- Duration of preparatory activities, concept creation a technology preparation: 1 school year,
- Duration of manufacturing: 1 school year,
- Materials used: glass and carbon fiber laminates, urethane foam, polystyrene foam.

Specific features

- Type: two-seat roadster,
- Original car body with wing doors, built-in steel reinforcements, laminated body parts – glass fiber and carbon fiber,
- Original interior,
- Enhanced engine power.

Technical parameters

Tab.1: Technical parameters

Length/width/height [mm]	**4180/1700/1395**
Wheelbase axle [mm]	2462
Track width front/rear [mm]	1485/1475
Cylindres/valves/fuel	4/8/D
Engine displacement [cm^3]	1896
Engine power [kW/HP]	88/120

5. LAYOUT, PRODUCTION AND FINAL VERSION OF ICAR

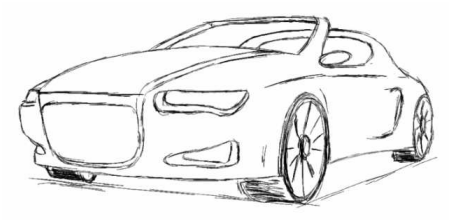

Fig. 4. Initial sketching

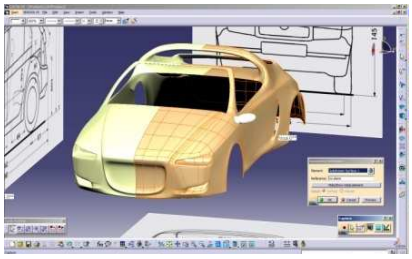

Fig. 5. CAD modelling (CATIA)

Fig. 6. Final CAD model

Fig. 7. Mockup fabrication (scale 1:4)

Fig. 8. Platform preparation

Fig. 9. Model fabrication and preparation of laminating molds (scale 1:1)

Fig. 10. Dashboard fabrication

Fig. 11. Dashboard – final look

Fig. 12. Interior ergonomy evaluation

Fig. 13. Finished vehicle – front view

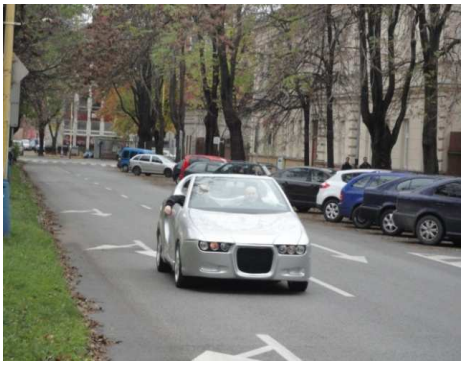

Fig. 14. Driving tests

Fig. 15. Core development team

6. PRODUCT DESIGN CASE STUDY: COMPONENT – FRONT BUMPER DESIGN FOR ICAR 2010

6.1. Design development process

After defining the basic requirements (mission statement) were generated various proposals and visualized in the form of sketches. It was crucial to take into account the default dimensions of the body and individual body elements of the Skoda Fabia. It has to be avoided excessive expansion or contraction of the component. To ensure the overall concept of the car, it was necessary to decide on the overall appearance using the pre-drawn quick proposals. Final selection was based on the evaluation of three proposals that were shortlisted from number of the original proposals. Crucial criteria were to reflect the overall shape, which had to correspond with the rest of the body and form optically one whole, and of course, to take into account the functionality of the various elements that had to be implemented in the area of the front bumper. The proposals selected for complete evaluation already included slight differences, but also gave more space for corrections in the draft.

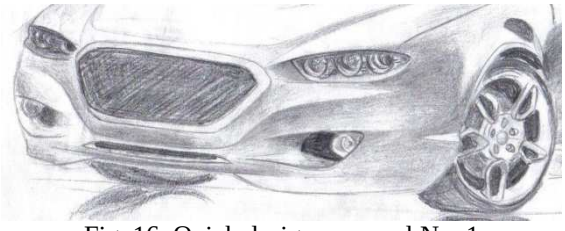

Fig. 16. Quick design proposal No. 1

In this phase, the bumper has been appropriately adapted to hood and fenders. The hood should be characterized by a slight curve, which smoothly passes through to the bumper (Fig. 16). At the bottom of the bumper on both sides were strong lines that extended the spoiler. At the bottom sides, the bumper passed in the middle up from bottom, making the impression of spoiler. There were anticipated the large holes for fog lights.

Fig. 17. Quick design proposal No. 2

Other proposal for the evaluation presented a significant and massive bumper with a massive grille (Fig. 17). This proposal required the shortened hood, thus the front bumper continuously run into it. Lights in the proposal were embedded inside, and therefore the forehead of the bumper on both sides turned toward the grille. Fog lights were outlined in a narrow hole at the bottom.

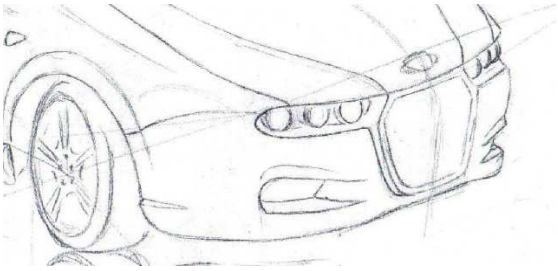

Fig. 18. Quick design proposal No. 3

Using the gallery tool combined with concept testing and evaluation tools mentioned above, was decided that the ultimate final proposal suitable for elaboration and realization will be design solution, as shown in Fig. 18. As shown, this proposal has a smooth shape of the front bumper. Its clearance is based on the original design, the bumper outer curve continues fluently through the fender area to lamp holes, where it allows setting off the hood. Headlamps are slightly vanishing into the bumper holes and slightly hidden under the bonnet. The curves of the bonnet continuously disappear in curves of the grille, which has a symmetrical shape. Conspicuous are also the holes for fog lights that are embedded and vanish in the bumper in the middle of its cross-section.

Based on the selection of appropriate proposal, the next phase was the manufacturing of the bumper. Team members were delegated with the work positions, competencies and the responsibilities within the prototyping process and the work schedule was set. The schedule was integrated into the main overall schedule in order to coordinate with design and manufacturing processes of other parts.

6.2. Manufacturing

Manufacturing of the front bumper consisted of several stages. The first is phase was the preparation of the polystyrene model, a template, as the basis for the next stage of prototyping. There was used the polystyrene block (Fig. 19) created from polystyrene plates glued together. The glued block had to cure until the next day to gain the optimal quality for further treatment

of the material. Subsequently, the desired shape outline of the bumper was drawn on the material block.

Fig. 19. Initial shape of the polystyrene block, prepared for further processing

Next phase included the cutting of the rough shape of the bumper using the resistance wire. The rough shape had to keep the machining allowance of about 20 mm. Next phase was to refine the rough shape and create the basic features - front mask, grille opening, and suction and lamp holes.

The next task was to solve the mounting of the bumper on the car body. It was necessary to propose mounting elements and whole construction to ensure rigidity and stiffness of the cross girder and assembly node on the bumper brackets. The stiffness of the bracket was ensured by designing the supporting structure with dilatation girders.

In the next phase was realized a number of adjustments to balance the trade-offs between initial concept design and issues from prototyping (design for manufacturing/assembly optimization) to get the final design of the bumper. As shown in the figure (Fig. 20), there was adjusted the side length, car was optically lowered by reducing the gap between fender arches and wheel, and the bottom section has been sunk inwards to set off the contrast and thus enhance the aggressive sports look of the vehicle.

Fig. 20. Prototype of the bumper before (left) and after the adjustments

The most difficult part of the process was the final phase of this stage; here was a crucial issue of the trade-offs between the surrounding components had to be solved. There is an area, where hood, fender, and bumper join together. Another critical part was to balance the shape of bonnet with bumper and headlamp holes. Moreover, there was necessary to adjust the fog light holes, curved at the ends to semicircle to receive a follow-up to the curve shape. All these issues had to be solved in unified procedures, the same way, what required more effort to manage and coordinate.

In the end of this phase was the polystyrene model of the bumper adjusted to its final shape and thus was ready for the final stage of its manufacturing (Fig. 21). After applying the basic coating color was model finished and ready for use as a mold for laminating, using the epoxy resin and glass or carbon fiber.

Fig. 21. Finished polystyrene model of the bumper

7. CONCLUSION

There is a growth in the need for products with higher added value, based on new knowledge implemented from research. It seems to be the only way to compete with the mass production of low-cost countries and changes in the field of technology. Lots of renowned analyses worldwide indicate that currently there is a technological turning point, which is e.g. in the automotive industry the biggest over the past 50 years. To adapt quickly to changing market conditions is in this case “sine qua non”. For companies, this means maintain the continuous product innovation, manageable number of product variants, fulfilling the unpredictable requirements of customers, shortening product life cycle and respond to significant fluctuations in sales.

The driving forces behind the network innovations are growing difficulties to maintain competitiveness in the field of technology and product development. Product life cycles are becoming shorter due to rapid technological developments and change of customer preferences. At the same time, the cost of R & D and technical requirements for new products are increasing, the availability of talented workers is decreasing and the degree of specialization increases. These three forces increase the pressure on the efficiency of research and development.

As shown in the case studies, in the beginning of the development of concept are certain ideas to be clarified before the project kick-off. The more specific is the initial vision of the project proceedings, the less space it remains for creativity, and vice versa, so it is crucial tofind the just right balance for each project. Pilot task in project management is to divide the different roles, responsibilities and hierarchical positions of the development core team and maintain an open and communicative atmosphere, leading to quick and satisfactory solutions of various issues. Project realization must be preceded by a series of developmental preparation with concept design frame. An analysis of competing solutions from different external and internal resources around the world brings to the process of design an inspiration that lead to the exact (or well refined, at least) specifications of the design boundaries. It is necessary prerequisite to elaborate a file of evaluation criteria that help to keep the project within the boundaries and gain the intended goals.

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