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R&D projects, Fuzzy AHP, TOPSIS

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COMPUTER AIDED TEAM BUILDING FOR RESEARCH AND DESIGN PROJECTS

Abstract

Building teams has a fundamental impact for execution of research and development projects. Often the success of the project depends on the competence of employees implementing these projects. Therefore, it becomes essential to build the team where skills complement each other in terms of knowledge, personality and practical skills. On the other hand an important element is the process of assessing the candidate. The person dealing with recruitment often bases its decisions on intuition / subjective impression and they tend to be unreliable. The article presents a proposal to use Fuzzy AHP and TOPSIS methods in team building for R&D projects on the basis of employees skills using for this process the most well-known tool, namely spreadsheet.

1. INTRODUCTION

Employee team building is one of the first stages of execution of an R&D project. This process is essential for correct execution of the whole project, quite often implemented for the first time. Quality of jobs assigned depends on experience and personalities of cooperating team members within the R&D project, while correct implementation in accordance with approved plan depends on project leaders. Work sharing, controlling the essential aspect of the project, as well as monitoring progress at various stages, are the key milestones of R&D

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project management. “This is the art that requires the ability to function in many job roles and to understand the importance of the ‘human factor’ for the success of the project” [8]. “Individuals decide on everything – this statement repeated multiple times is always true when it comes to implementation of R&D projects” [9]. Described in the article simulation was carried out in a spreadsheet. Based on this experience, the authors plan to create a dedicated IT tool [12].

This publication has two sections – theoretical and practical. The article in chapter one and two presents the concept of R&D projects and describes individuals – the fundamental job roles in regards to implementation of an R&D project. The next two chapters present Fuzzy AHP and TOPSIS methods and describe the use of presented methods in relation to the process of team building in R&D projects.

2. RESEARCH AND DEVELOPMENT PROJECT – DESCRIPTION

The definition of a project has been known for a hundred years. “Already in the ancient times great monuments were built on the basis of detailed unique technical and organisational plans, which specified in details the tasks and management arrangements of contractors work” [16]”. The word project originated from Latin word ‘proiectus’ back then meant ‘to put forward’ which is explained by modern researchers as an intended development of a proposal. Nowadays, the term ‘project’ can be defined as “an endeavour made within the organisation, which is a new and extraordinary idea, different from routine activities, that the organisation has not dealt with ever before [19]”. James P. Lewis describes project as ‘a one-off job, which has a certain commencement date and deadline, clearly defined aims, scope and (in general) a fixed budget [13]”. The reference literature often assumes that a cause of project commencement is a personal need or a given assignment from a client [22]. In the aforementioned definitions of the project, the authors emphasize that the main goal of a project is to achieve an aim, which is a defined result, and they skip the uncertainty and risk issues within the project implementation. It means that the general definition of the project shall not be used to describe research and development project. The authors of this article have chosen, for further consideration, one type of projects – research and development projects that are describe the source literature as R&D projects.

“The research and development activity is a systematically conducted creative work, undertaken in order to increase knowledge (...), as well as to discover new ways to apply this knowledge. It covers three types of research: basic research (theoretical and experimental work basically non-targeted, to provide particular practical uses) and applied research (research work conducted in order to gain new knowledge that has particular practical use), as well as development research (that consists of application of the existing knowledge in order to develop new

or significant improvement of existing products, processes or services) [8]". The above mentioned definition is similar to the definition recommended by the OECD from Frascati's book [21].

A research and development project is defined as implementation of a particular goal with a risk factor, not always precisely set out, in most of the cases allowing to obtain new knowledge about the reality that surrounds us for whose achievement we have the necessary resources, including highly qualified team of contractors, specified amount of time and knowledge regarding all the requirements [9].

The management of research and development project is a sustained search of causes for success and roots of failures [3]. The management consists of a chain of decisions, which lead to meeting the goals specified during the defining of objectives stage. "In accordance with the principles of implementation and management theory, the process of R&D project management consists of four basic relationships occurring during definition and implementation of the project. These are the following: planning, organising, motivating and controlling [9]". The management of R&D projects is classified as an adaptive and extreme way of project management, as goals of R&D projects are not precisely set out and can be modified during the project implementation [25].

3. TEAMS IN RESEARCH AND DEVELOPMENT PROJECTS. DESCRIPTION OF POSITIONS AND SKILLS.

Members of the team should have appropriate education and experience to carry out their tasks. They should also easily be able to cooperate, to lead and have other qualities for effective team work in the given research and development project.

The reference literature distinguishes three strategies of team building:

- creation of an R&D department in a company and designated project teams within this department, continuously working on assigned tasks,
- creation an independent team sin a company, whose members spare most of their time working on the project,
- the individuals chosen for implementing the project are those, who carry out their main duties in different departments, and they work on the particular project when they have free time.

As has been demonstrated in a research conducted by A. Gryzik, A. Knapinska, A. Tomczynska, R&D activities are most effectively carried out within a separate R&D unit, created in a company. It is more difficult to implement projects, when members of a team have numerous responsibilities, work in more than one team, or work on a large number of projects [5].

The main personnel that is necessary for R&D projects implementation are, inter alia, an author, a project manager, tasks managers and individuals responsible for implementing [9].

"The author is an individual that developed a project, which is original and has cognitive values" [17]. This individual has right to undertake decisions in regards to, e.g. circumstances of project implementation, or determining public announcement of results of the whole R&D project. It is commonly assumed that the author specifies individual and cognitive values of the whole project, and thereby she or he has a key role in its implementation. A popular event occurring in manufacturing companies is hiring author, also as a manager of research and development project.

The manager of R&D project, is often in the companies that implement R&D projects, also called a project leader or a project manager. The reference literature, in the subject of project management skills and features, is very comprehensive. It describes both "hard" and "soft" skills of an individual, employed in this capacity, as well as project management styles, which depend on the way the company does business. This literature also very often indicates the wide range of tasks, which must be completed by a manager. Jobs most frequently carried out by a project manager include:

- planning tasks, activities and results by creating, inter alia, appropriate work share amongst members of a team, schedules, budgets,
- choosing and organising the team,
- establishing and maintaining relationships with stakeholders,
- team building of all the employees that are working on the project;
- monitoring of project progress,
- identifying and direct solving of problems, or searching for ways to resolve them,
- dealing with the crisis and conflict management,
- decision-making or giving recommendation to stop the project in case when achievement of the set objectives is not possible [18, 9, 5].

The project manager skills are also described by four global standards:

- PMCDF – Project Manager Competency Development Framework (Project Management Institute),
- NOS PM – National Occupational Standards for Project Management (Engineering Construction Industry Training Board),
- AIPM PCSPM – Professional Competency Standards for Project Management (Australian Institute for Project Management),
- ICB – IPMA Competence Baseline (International Project Management Association) [5, 8, 9, 24].

The most popular standard is the ICB-IPMA standard. It lays down three groups of skills, which each individual on a project manager position shall have. "Behavioural competencies are associated with the expected attitudes and behaviours, as well as values presented by the manager. This includes, for example, leadership, motivation, self-control, assertiveness, openness, creativity, crisis management, compliance with ethical principles, etc. Technical skills enable starting a project, management of implementation and its successful completion. Their fundamental meaning is emphasized, however simultaneously, it is pointed out that they are not sufficient to eliminate the possible risks during the project implementation. Contextual competences are associated with the wider context in which the project is done, for example, the process of implementation, personnel, occupational health and safety managements, finance, law" [5]. Additionally, due to the fact that more and more research and development projects being implemented in international consortia, it is recommended that the project manager has the ability to operate in a multicultural environment, which means, inter alia, knowledge of foreign languages and, if necessary, even knowledge of the history and culture of other countries.

Task manager is an individual that has essential knowledge to carry out a particular activity and, additionally, he manages team of subordinated employees, performing assigned jobs. In general, he shall have similar qualifications and a project manager. However, his scope of activity and power is limited only to defined task to fulfil. Individuals responsible for implementing are those, who perform assigned jobs in R&D project. „The composition of a team decides on results and effectiveness on this team, where members have range of duties that are well established, related to the traits of their personalities" [23] . It is described by M. Belbin, who distinguishes in his works types of personalities that could be assigned to appropriate job roles. In R&D projects useful are individuals like creator, explorer of sources, engine and assessor [2]. It is often proven in practice that the most effective are teams whose members differ from each other, e.g. in their origin, education, experience, qualifications and personality traits.

Tab. 1. Personality traits of the best project managers according to the senior management of a given organization [1]

Personality traits most often indicated as the qualities of the best project managers	Personality traits pointed out very rare as the quantities of the best project managers
meticulous, conscientious	independent
energetic	conventional
undertaking control; leader	modest
self-confident, open	theoretical
reasonably evaluating situation	worried, becoming easily emotional
convincing, emphatic	

The ability and effectiveness of activity of the whole project team depends greatly on complementing each other in the team. In his work S. Gregorczyk writes with co-authors that general requirements regarding team members may include:

- susceptibility to the project management influence,
- team work skill,
- ability to cooperate with other team members with different level of education and experience,
- high level of technical skill,
- problem solving and results achieving orientated,
- high self-evaluation and ability to acknowledge mistakes and failures [4].

4. FUZZY ANALYTICAL HIERARCHY PROCESS AND FUZZY TOPSIS METHOD

FAHP (Fuzzy Analytic Hierarchy Process) – the method of fuzzy analytic hierarchy process is based on AHP method, which is widely used in development of decision-making models. FAHP uses experts opinions in order to establish the weighting factors that determine the validity of features and, additionally, eliminates the features of least importance, when it comes to question of linear ordering of objects [13]. The importance of a feature in this case is established on the basis of fuzzy opinions of experts, so-called, soft opinions (soft opinions), which are more viable than hard opinions (hard opinions) [14].

TOPSIS Method (Technique for Order Preference by Similarity to an Ideal Solution) is a statistical process leading to linear ordering of objects described by metric and non-metric features – professional order [14]. This method is used to establish order and rank of various alternatives [10]. The mail goal of the TOPSIS method is that determines a solution with the shortest distance to the ideal solution and the greatest distance from the negative-ideal solution [19].

5. FUZZY AHP AND TOPSIS

The assessment process of strategic factors for selection of personnel essential to implement the R&D project, was based on the fuzzy analytical hierarchy process that is the method used to solve multi-criteria problems with decision-making. This process was implement in various business situations studying the selection of excellence from the performances of multiple companies' [6, 7].

In this direct case - this method was conducted according to four stages. In stage 1, on the basis of survey sent out to 30 research and development project managers, implemented within manufacturing companies, established in Poland,

the criteria of skills assessment for the position of project manager. In the survey the five grades of evaluation in the Likert Scale, where 5 is very important, 4 – important, 3 – neutral, 2 – unimportant and 1 – criteria is irrelevant, had been specified, criteria which were considered to be the most important. The effectiveness of the conducted survey was 73% (the feedback contained 22 surveys with answers). The results were presented in Table 1.

	A	B	C	D	E	F	G	H
1	Project manager competency criteria analysis							
2								
3		**Technical competencies**	**Number of Scoring**					
4			**5**	**4**	**3**	**2**	**1**	
5	C1	project management effectiveness	14	6	2	0	0	
6	C2	project requirements	13	8	1	0	0	
7	C3	risk and responsibility	10	8	4	0	0	
8	C4	timeliness	11	9	0	0	2	
9	C5	interpersonal communication,	6	7	6	1	2	
10	C6	knowledge of foreign languages	15	5	1	0	1	
11	C7	analytical thinking	9	7	3	0	3	
12		**Behavioral competencies**	**Number of Scoring**					
13			**5**	**4**	**3**	**2**	**1**	
14	C1	leadership qualities	12	10	0	0	0	
15	C2	involvement and motivation	5	17	0	0	0	
16	C3	assertiveness	10	7	3	1	1	
17	C4	creativity	15	2	2	1	2	
18	C5	effectiveness	11	8	2	1	0	
19	C6	conflict management	13	6	2	1	0	
20	C7	flexibility and availability	15	5	2	0	0	
21		**Contextual competencies**	**Number of Scoring**					
22			**5**	**4**	**3**	**2**	**1**	
23	C1	project oriented	8	10	3	1	0	
24	C2	business, economic indicators	12	10	0	0	0	
25	C3	personnel management	5	13	1	2	1	
26	C4	health, safety and environment	7	14	0	0	1	
27	C5	knowledge of financial and legal policy	3	6	8	3	2	
28								

Fig. 1. Stage 1: determination of criteria for assessing competence for the position of Project Manager [source: own study]

Based on the theoretical description of the method of Fuzzy AHP and TOPSIS presented in the article by A. Łuczak and F. Wysocki [10] and C. Kahraman, U. Cebeci and Z. Ulukan [7], consecutively in the stage 2, the following steps were carried out:

Step 1. Developing a hierarchical structure for problems with multiple criteria for objects assessment Developing structure is made through comparison of pairs of tasks of lower priority. On each level of hierarchy the importance of critical elements is determined by pairwise comparisons, using in this process the fuzzy 9-grade evaluation scale (Table 2). These comparisons are analysed in respect of its importance in the making of decision. Using the scale, the comparisons of importance of lower priority are made, in regards to main objective and tasks in the scope of every lower priority objective (Table 2). The pairwise comparisons of importance of critical elements on each level of hierarchy are conducted by professionals (decision makers) who are directly involved in meticulous decision-making process.

Tab. 2. The 9-grade evaluation scale of importance of pairwise elements [11]

The superiority of importance of critical elements	**Explanation**	**Priority Scales** $(\tilde{a} = (l, m, u))$
Equivalence	Both factors contribute equally to achieve the objective.	$\tilde{1} = (1,1,1)$
Poor or moderate	Importance does not convince or poor priority of one factor over another factor.	$\tilde{3} = (1,3,5)$
Important, fundamental strong	Fundamental or strong meaning, or strong priority of one factor over other factors.	$\tilde{5} = (3,5,7)$
Vast or very strong	Vast meaning or very strong priority of one factor over other factors.	$\tilde{7} = (5,7,9)$
Total	Total meaning or total priority of one factor over others.	$\tilde{9} = (7,9,9)$
For comparisons compromising between values stated above	Sometimes a numerical interpolation of compromising opinions must be carried out for lack of appropriate vocabulary to describe them. That is the reason for using intermediate values between two adjacent grades.	$\tilde{2} = (1,2,4)$ $\tilde{4} = (2,4,6)$ $\tilde{6} = (4,6,8)$ $\tilde{8} = (6,8,9)$
Transitivity of grades	If a factor A has assigned one of the above grades, during a comparison with a factor B, then factor B has opposite value, when being compared to A factor.	Opposition of above values

		C1			C2				C6			C7		
C1	1,00	1,00	1,00	3,00	5,00	7,00	...	5,00	7,00	9,00	3,00	5,00	7,00
C2	0,14	0,20	0,33	1,00	1,00	1,00	...	5,00	7,00	9,00	1,00	3,00	5,00
...							...						
C6	0,11	0,14	0,20	0,11	0,14	0,20	...	1,00	1,00	1,00	0,14	0,20	0,33
C7	0,14	0,20	0,33	0,20	0,33	1,00	...	3,00	5,00	7,00	1,00	1,00	1,00

Fig. 2. Stage 2: calculation of weighting factors for the features under the technical criterion [source: own study]

Step 2. Determination of the priority of criteria and features by assigning them weighting factors, derived from fuzzy analytic hierarchy process (FAHP). The results obtained are described in Figure 2, 3 and 4.

	C1			C2				C6			C7		
C1	1,00	1,00	1,00	1,00	3,00	5,00	...	1,00	1,00	1,00	1,00	3,00	5,00
C2	0,20	0,33	1,00	1,00	1,00	1,00	...	3,00	5,00	7,00	1,00	3,00	5,00
...							...						
C6	1,00	1,00	1,00	0,14	0,20	0,33	...	1,00	1,00	1,00	0,20	0,33	1,00
C7	0,20	0,33	1,00	0,20	0,33	1,00	...	1,00	3,00	5,00	1,00	1,00	1,00

Fig. 3. Stage 2: calculation of weighting factors for the features under the behavioural criterion [source: own study]

	C1			C2			C3			C4			C5		
C1	1,00	1,00	1,00	1,00	3,00	5,00	1,00	3,00	5,00	1,00	3,00	5,00	1,00	3,00	5,00
C2	0,20	0,33	1,00	1,00	1,00	1,00	1,00	3,00	5,00	1,00	3,00	5,00	1,00	3,00	5,00
C3	0,20	0,33	1,00	0,20	0,33	1,00	1,00	1,00	1,00	0,20	0,33	1,00	1,00	3,00	5,00
C4	0,20	0,33	1,00	0,20	0,33	1,00	1,00	3,00	5,00	1,00	1,00	1,00	1,00	1,00	1,00
C5	0,20	0,33	1,00	0,20	0,33	1,00	0,20	0,33	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Fig. 4. Stage 2: calculation of weighting factors for the features under the context criterion [source: own study]

The third stage, according to the indicated article [14], the values of synthetic feature were determined, using fuzzy TOPSIS method (Figure 5 and 6). Next, in the stage 4, the data was put in linear order and prospective candidates for a R&D project manager were typologically classified, according to the synthetic feature value (Figure 7).

CANDIDATE	Technical competencies						Behavioural competencies						Contextual competencies					
	C1			...	C5		C1			...	C5		C1			...	C5	
	a	b	c		a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
K1	60	70	80	...	40	50	60	60	70	80	...	40	50	60	40	50	60	...	40	50	60
...	...				...			...				...			...				...		
K5	80	100	100		60	70	80	80	100	100		80	100	100	40	50	60		40	50	60
weighting factor	0.10				0.06		0.02					0.02			0.09				0.04		

Fig. 5. Stage 3: determination of synthetic feature value using the fuzzy TOPSIS method – step 1 [source: own study]

CANDIDATE	Technical competencies			Behavioural competencies			Contextual competencies		
	C1		C5	C1		C5	C1		C5
K1	0.627	...	0.000	0.457	...	0.315	0.000	...	0.000
...	...		...	...		...	...		...
K5	1.000		1.000	1.000		1.000	0.000		0.000

Fig. 6. Stage 3: determination of synthetic feature value using the fuzzy TOPSIS method – step 5 [source: own study]

Eventually, on the basis of data of all candidates, in the first place, for the R&D project should be employed candidate no. 5. In case indicated candidate will not undertake this job, the offer of candidate no. 1 shall be considered.

CANDIDATE	Technical competencies			Behavioural competencies			Contextual competencies		
	C1		C5	C1		C5	C1		C5
K1	average - upper level	...	below threshold	average - upper level	...	below threshold	below threshold	...	below threshold
...	...		...	...		...	...		...
K5	high level		high level	high level		high level	below threshold		below threshold

Fig. 7. Stage 4: Linear ordering of data and typological classification of prospective candidates according to synthetic feature values [source: own study]

6. CONCLUSION

In this study the evaluation of skills priority and particular candidate for the position of the R&D project manager was conducted, with the use of two-stage methodology based on FAHP and TOPSIS methods. Such complimentary approach eliminates weaknesses of FAHP and TOPSIS methods with their autonomous use, and ensures development of relatively simple and effective tool for making decisions regarding choosing the best candidate. The proposed approach helps to resolve examined critical problem in the hierarchical structure in more reliable way, as it includes various criteria, sub-criteria and alternatives. All begins from development of survey and opinions of experts, usage of FAHP method, which allows finding relative weigh of assessment criteria meaning in decision-making hierarchy. Subsequently, TOPSIS method uses these weighs to establish candidates classification. The use of these methods allows finding the best candidate, because it defines criteria weights, evaluates them and on the basis of these data, choses optimum. It is necessary to remember that even the most thoroughly selected sets of competencies, will not replace direct contact with prospective candidate. A proposed method has analytical approach, focusing on carefully selected criteria, which allow development of the best research team, based on employees criteria.

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