

Decision Making on Project Selection in High Education Sector Using the Analytic Hierarchy Process

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Abstract. *The prioritization of projects in higher education institutions is a complex decision-making problem. In this paper we deal with a problem of making a decision on whether to start a new project application, and if so, which project to choose in a situation where project teams have several project ideas and limited resources. The purpose of the paper is to show how to use the Analytic Hierarchy Process as a multiple criteria decision-making methodology which can be used in solving project selection problems. Finally, one case study is given.*

Keywords. project, higher education institution, decision making, Analytic Hierarchy Process

1. Introduction

The research and development (R&D) project selection is a complex decision-making problem. It involves environmental opportunities search, the generation of project options and their evaluation by different stakeholders according to multiple criteria, both tangible and intangible. What the projects bring about are not only benefits and potential opportunities, but also costs and potential risks. A new project can bring financial benefit to high education (HE) institutions, their employees, local community or society in general. Each program (grant) has different financial rules and grant amounts and therefore an institution can benefit differently

from it in terms of pay for its staff, equipment, publishing, travel and overheads. There are projects that directly contribute to the society and community, influence the development of positive attitudes towards different themes and raise critical thinking about societal and policy issues. An institution can also benefit from projects in intangible ways by using them for networking e.g. providing basis for further projects and cooperation and by promoting the institution in the international and national arena so as to make it visible in the research and education area. However, the institution is also responsible for paying organizational costs for coordination and preparation of application then re-distribution of resources among projects, programs and different institutional activities as well as for controlling costs related to enhancing skills in Financial Department, Public Relations, ICT Support, Office for International Projects and other unexpected costs. On the other hand, the allocation of resources for a new project on the institutional level can jeopardize some other projects important for the institution and lead to financial loss or uncertainty.

According to the strategic orientation of the institution (university, faculty, department, or institute) and its research mission (strategic area of research, promotion criteria for researchers, evaluation criteria for institutions) we have to look at the benefits, costs and risks coming from different kinds of projects (programs). So a comprehensive and systematic assessment is

necessary on the part of the institution's management to select the most suitable project from a number of alternatives.

In this paper we deal with a problem of making a decision on whether to start a new project application, and if so, which project to choose in a situation where project teams have several project opportunities. The decision has to be made taking into consideration different factors such as available resources, the institution's strategic plan, its financial status, well-being of its employees, satisfaction of its customers and synergy between projects and institutional requirements. The case study used in this paper is based on wide European R&D and higher education development programs, such as the Framework Program, COST, Eureka, Lifelong Learning Program and Tempus.

The purpose of the paper is to provide framework for using the Analytic Hierarchy Process (AHP) as a multiple criteria decision-making methodology on solving project selection problems.

2. State of the art

The application of the AHP in evaluating project selection problems has received considerable attention in the recent literature, as it is shown [8]. Further, Liang and Qing [9] propose decision method with regard to benefits (B), opportunities (O), costs (C) and risks (R) for an enterprise information system project selection and we use similar structure in our decision making model. Bouzaza, Arhaliass, Bouvier and Alidi [1] describe how to use the Analytic Hierarchy Process to measure the initial viability of industrial projects and how the AHP method can help the management in efficient allocation of the company's resources. Finally, Huang [16] presents a fuzzy Analytic Hierarchy Process application in government-sponsored R&D project selection and utilizes a crisp judgment matrix to evaluate subjective expert judgments made by the technical committee of the Industrial Technology Development Program in Taiwan. However it has never been reported any application at university, faculty or department in order to solve project selection problem.

3. Problem statement

Today every faculty and department has to plan its research and carefully consider new

project applications according to its research and overall institutional strategy. Therefore, not only the management, but also the research and administrative staff, has to be aware of opportunities and benefits of new projects as well as potential risks and risk-related costs.

Roughly speaking, projects can be characterized as purely scientific projects, then typical R&D projects with a strong research base and potential for application and, finally, market-oriented projects with an innovation component. Since universities also have a strong educational mission, projects that enhance the development of higher education must also be taken into account. In Table 1 these basic types of projects are shown, accompanied with examples of each of them as well as with their basic characteristics. The examples of related programs are taken from the European research and higher education area since we are familiar with it and our case study is prepared in this environment. On the other hand we are aware that similar examples can be found in other research and educational systems as well. These programs differ in their characteristics, five of which are identified here: duration of typical projects in the program, typical participants (partners), way of initiating projects, level of budget and sources of funds for setting up project budget. Let us explain these characteristics. The duration of a project correlates with the project type. The closer the project is to the market, the shorter its life cycle will be, since competition is very high and the product must be on the market as soon as possible. If a pure research is carried out, it usually contributes to the acquisition of new knowledge and the emphasis is on cooperation rather than on competition, such a project will take more time than a market-oriented one and in most cases funds are pretty low. In supporting fundamental research national resources must be mobilized. On the other hand, industry is more interested in applied and market-oriented research and therefore ready to contribute to the project budget.

The European Union established a central fund for financing high quality research that enhances university-industry cooperation (Framework Program – FP) and another that supports the development of education and lifelong learning in general (Lifelong Learning Program – LLP – for EU member states and Tempus program for EU neighboring countries). All members of EU and candidate countries (like Croatia) pay a fee into those funds, but grants are

given to competitive project proposals that meet the set priorities and that correspond with published calls (top-down approach). As a consequence they usually involve a great deal of administration and a relatively low success rate and therefore small and medium-size enterprises (SMEs) and industry in general are not willing to participate. In contrast to that, the Eureka network rests on the bottom-up approach where the proposal can be submitted anytime and in almost all research and application areas.

Table 1 can be used as a reference point to structure a discussion about a project selection at the faculty/department/university level and especially as a tool for identifying the appropriate program for a certain project idea. Finally, they present the alternatives in the AHP model.

The next step in the decision-making process is to understand and consider benefits, risks and costs related to certain project type. Table 2 contains criteria and sub-criteria in the AHP model (benefit, risk and cost) as well as their additional explanations. They are selected based on the R&D project management literature and experiences gained in the Centre for international project at FOI.

Table 1. Alternatives of programs in the AHP model

Type	R&D-strong research and potential appl.	Market-oriented with innovation component	Development of higher education	Purely scientific/fundam.
Example	FP Framework Program [7]	Eureka [3]	Lifelong Learning Program [10]/ Tempus [15]	COST [2], European Science Foundation [4]
Charact.				
Duration	1-4 years	1-3 years	1-3 years	3-6 years
Particip.	University/inst. + industry	Industry/SME + university/institutes	University + public bodies + NGO + industry	University/instit.
Approach Initiating	Top-down	Bottom-up	Top-down	Bottom-up
Budget/Grant	Large	Medium – Large	Medium	Small
Financ./Co-financing	Central fund + partners co-financing (between 1-20%)	National resources + venture capital + partners co-financing (10-50%)	Central fund + partner or state co-financing (5-10%)	National resources + central fund

Table 2. Criteria and sub-criteria in the AHP model

Criteria/Subcrit.	Explanation
Strategic factor	
Research mission	According to the strategic orientation of the institution (faculty, department, institute or even a small university) and its research mission (strategic area of research, promotion criteria for researchers, evaluation criteria for institution, filling the gap between the institution and its peers) we have to consider the benefits coming from different kinds of projects (programs).
Educational mission	According to the strategic orientation of the institution (faculty, department, institute or even a small university) and its educational mission, we have to consider the benefits coming from different kinds of projects (programs) and the opportunity to use them in educational process and informal learning for project participants.
Contribution to society	According to the strategic orientation of the institution (faculty, department, institute or even a small university) and its mission, we have to consider the benefits coming from different kinds of projects (programs) and the opportunity to use them to contribute to the society from the economic and social point of view.
Organizational costs	
Management support	Projects require coordination of application preparation and re-distribution of resources during implementation (among projects, programs and different institutional activities) and therefore need a certain amount of management support.
Academic support	Some projects must provide co-financing from the faculty/university and a part of it can be included here as academic work which is paid out of regular salary for permanently employed researchers. Additionally, enrichment of research capacity (scientific/professional publications, self-financed research, conference participation) for project application and implementation can be placed here.
Technical and administrative support	There are costs related to enhancing skills in Financial Department, PR, ICT Support, Office for International Projects and other unexpected costs. In other words there is a need for enhancement of administrative capacity for project application and implementation. In some projects these costs are covered in full amount as indirect costs and in some of them, partner investment (co-financing) is required.
Economic factor	
Economic benefit for institution	Each program (project) has different financial rules and therefore the institution can benefit differently from it in terms of pay for the staff, equipment, publishing, travel and overheads.
Econom. benefit for employees	Each program (project) has different financial rules and applies different rates for costs beneficial for employees (staff cost, travel etc.).
Econom. benefit for society	In some projects there are activities that represent economic benefit for the society as they contribute to the market-oriented research or finance different activities important for the community (for example inclusion of underrepresented groups).
Risks	
Financial risks	Risks that can lead to financial loss or uncertainty occur in a project. For example in some projects there are financial instruments of assurance of fulfillment of project goals (penalty, guarantees). On the other hand, allocation of resources for a new project on the institutional

	level can jeopardize some other projects important for the institution.
Legal risks	Risks that come out of obligations due to a partner/project agreement and assurance of intellectual property rights can jeopardize intellectual or physical property of the institution or result in legal responsibility of the institution.
Security risks	Physical security - work on some projects can threaten physical security of employees working on them, for example, in a laboratory, in field research or due to a big amount of travel. ICT security - work on some projects can threaten ICT security (data protection, intellectual property, "know how") at the institution.
Human resources related risks	Risks coming from the lack of experience of the project manager and/or R&D project coordinator at the institution or his/her unavailability for a new project time-span.
Communication risks	Risks that occur since project partners come from different backgrounds, use different languages or are not equally skilled in "lingua franca" (English) and risks that occur since physical meetings are not always possible when necessary because of geographical distance.
Social factor	
Networking and promotion	The institution can benefit from projects in intangible ways by using them for networking (basis for further projects and cooperation) and for promoting the institution in the international/national arena so as to make it visible in the research and education area.
Development of society	There are projects (programs) that directly contribute to the society and community, influence development of positive attitudes towards different themes and raise critical thinking about societal and policy issues.

4. Research methodology - the Analytic Hierarchy Process

The Analytic Hierarchy Process is one of the most widely exploited decision making methods in cases when the decision (the selection of given alternatives and their prioritizing) is based on several criteria/subcriteria.

The method application can be explained in four steps [11-14]:

1. The hierarchy model of the decision problem is developed in such a way that the goal is positioned at the top, with criteria and subcriteria on lower levels, and finally alternatives at the bottom of the model.
2. After the hierarchy has been constructed, on each hierarchy structure level the pair-wise comparisons should be done by comparing all pairs of the elements belonging to the same node, starting with the top of the hierarchy and working this way to the lowest level. This procedure is supported by Saaty's fundamental scale of absolute numbers by which the ratios of relative importance are represented. On the basis of the pair-wise comparisons, local importance (expressed as priorities for alternatives and weights for

criteria) of elements of the hierarchy structure are calculated.

3. Finally, these results are synthesized into an overall priority list of alternatives. Decision maker is allowed to change preferences and to test the results if the inconsistency level is considered high.
4. The sensitivity analysis is also carried out. Sensitivity analysis is used to determine how the priorities of the alternatives change with respect to the importance of the criteria or sub-criteria.

We will broadly explain the second step using the mathematical notation. Let n be the number of criteria (or alternatives), which weights (priorities) w_i have to be determined on the basis of estimated values of their ratios $a_{ij} = w_i/w_j$. These ratios form the matrix A . In case of consistent estimates, i.e. where $a_{ij} = a_{ik} a_{kj}$ holds, the matrix A satisfies the equation $Aw = nw$. The matrix A has the following properties: (i) all its rows are proportional to the first row, (ii) all elements are positive and (iii) $a_{ij} = 1/a_{ji}$ holds. Therefore, only one of its eigenvalues differs from zero and it is equal to n . The corresponding eigenvector has real, positive components which are priorities (weights) of alternatives (criteria). By additional constraint $\sum w_i = 1$ the vector w became unique and normalised. If the matrix A contains inconsistent estimates, and it is usually so in real cases, vector of weights w is obtained by solving the equation $(A - \lambda_{\max} I)w = 0$ under the condition $\sum w_i = 1$, where $\lambda_{\max}$ is the biggest eigenvalue of the matrix A . Even matrix A is no longer consistent, the facts that all elements of A are positive and $a_{ij} = 1/a_{ji}$ holds, are enough to assure that $\lambda_{\max}$ is real and all components of corresponding eigenvector are real and positive. In this case we have $\lambda_{\max} > n$, and the difference $\lambda_{\max} - n$ is used as a base for measuring of consistency of estimates. Consistency of estimates is measured by the consistency index given by $CI = (\lambda_{\max} - n)/(n-1)$. By this index we calculate the consistency ratio $CR = CI/RI$, where RI is random index defined as consistency index of $n \times n$ matrix randomly generated by pair-wise comparisons.

If for the consistency ratio $CR \leq 0.10$ holds, then the estimates of relative importance of criteria, and therefore calculated priorities of alternatives, are considered acceptable. In the opposite case it has to be investigated why inconsistency of estimates is unacceptably high.

5. The BCR (Benefits (B), Costs (C), Risks (R)) AHP hierarchy model for project selection

In this study, we propose the AHP model in evaluating projects (programs) as a tool to help managers in higher education to apply for projects which bring the most benefits and the lowest possible costs and risks. We have determined the control criteria and subcriteria in the AHP model, concerning benefits, costs and risks of the decision and obtained their priorities from paired comparison matrices. We have built the AHP model according to our knowledge and experience as well as literature review. An expert in international project management evaluated the model. Further, case study based on the given framework was prepared by the Vice Dean for Research, Development and Science at the Faculty of Organization and Informatics [6], who made the judgments according to the aims, needs and opportunities of the Faculty. The main fields of research at the Faculty of Organization and Informatics are Information Science and Applied ICT. The strategic activities of the Faculty of Organization and Informatics are: scientific research in the field of Information Sciences and related areas, organizing and implementing undergraduate, graduate and postgraduate studies in the field of Information Sciences as well as carrying out research and demanding professional projects in the field of Information Sciences and related areas. There are several versions of software which make the AHP computation, but in this paper a version of the *ExpertChoice* software for the AHP [5] was used. Figure 1 shows the result of decision making of the expert produced by the *ExpertChoice* software.

6. Interpretation of the results

The *Strategic factor* (0.431) was recognized as the most influential criterion in the AHP model (Figure 1). Further, it follows *Organizational costs* (0.221), *Economic factor* (0.145) and *Risks* (0.131). Finally, *Social factor* (0.072) is prioritized as the last. Among subcriteria in the *Strategic factor*, the highest importance has subcriteria *Research mission* (0.265). In the *Organizational costs*, almost equal importance have *Management support* (0.101) and *Academic support* (0.092). The subcriteria *The Economic benefit for institution*

(0.086) is ranked as first in the criteria *Economic factor*. The criteria *Financial*, *Legal* and *Security risks* are recognized as the most threatening in the *Risk* category. In the *Social Factor*, we find that *Networking and promotion* (0.054) is more important than *Development of society* (0.018) (Figure 1).

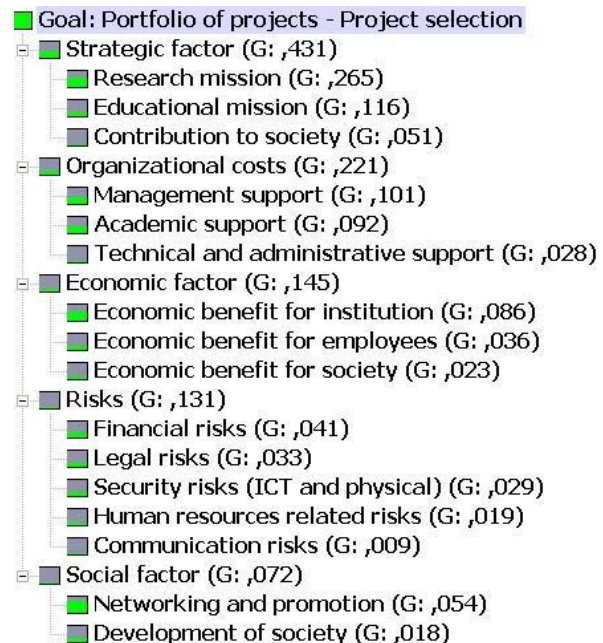


Figure 1. Priorities of the criteria and subcriteria in the AHP model

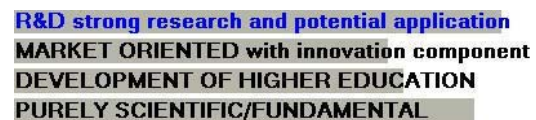


Figure 2. Overall outcome – rang of the alternatives

The most preferred alternative, according to the AHP model (Figure 2), is the alternative *R&D strong research and potential application*, while the alternative which has the lowest priority is the alternative *Market-oriented innovation*. The highest impact on the ranking of alternatives has the *Strategic factor* and according to this factor alternative *R&D strong research and potential application* is ranked as the first. However, the organizational cost for these types of projects are rather high and the least expensive project is *Purely scientific and fundamental research* (0.321), and this judgment is made having in mind fundamental research in informatics. Similarly, *Purely scientific projects* have minor risks comparing to *R&D strong research and potential application*. Finally, *R&D*

strong research & potential application projects is the best choice regarding the *Social factors*.

7. Conclusions

In our research we combined multicriteria decision analysis methods (AHP in particular) with strategic planning methods (BCR) with the domain knowledge and experience of project management. As a result we obtained the model for prioritizing projects at the faculty/department level that can be used as a tool for deciding whether to start with the proposal of a particular project. We try to manage all the important criteria and sub-criteria for problem solving in the process of decision making. The developed AHP model supports individual and group decision making but can also be used for structuring a discussion on the problem. Such a model for decision making enables multi-criteria analysis, increases and systemizes knowledge on the problem, motivates decision makers, and speeds up the decision-making process by making it less expensive. In the case presented in this paper we performed individual decision making and it is justified since the expert was the vice-dean for science and international cooperation with the broad inside view of the topic. On the other hand, group decision making can be done if we would like to share responsibility for the result of the decision making and use it for a “real” judgments. The exercise we performed shows that in the case of the Faculty of Organization and Informatics the most prioritized option for future projects are projects that combine high quality research with application of research (for example EU Framework Program). They bring the most benefits that offset the very high costs and considerable risks implied in such projects, since the success rate of such applications is rather low and the proposal phase very complex. On the other hand, such projects usually bring together a large and highly skilled and competitive project consortium and gives the first class opportunity for research and cooperation. These findings give useful inputs for the next strategic planning exercise in which we will distribute resources and create incentives to enhance development in the preferred direction. The model presented here can be further developed and modified to reflect different research environments and supporting systems. In that case the original AHP model will probably be slightly modified in accordance with different research and development systems

but the model developed in this paper can be exploited as a useful template. Finally, a logical further advancement of the AHP model is the Analytic Network Model (ANP) [5-7] that can incorporate interrelations among criteria and subcriteria in the proposed model.

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