R&D PROJECT SELECTION USING WEB ANP SOLVER

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ABSTRACT

Project selection through prioritization especially for R&D projects is a multi-criteria decision making process that involves both qualitative and quantitative criteria. It is an arduous procedure that involves predicting the future success and impacts of each candidate project and working with data having high degree of uncertainty. In these times of economic crisis the importance of this kind of decisions is elevated by the restricted budget available for research and development.

Herein an analytic network process (ANP) model for ranking R&D projects is proposed. ANP is a MCDA technique based on relative measurement on absolute scales of both tangible and intangible criteria. The proposed model comes from a case study where a Greek University research team had to select which R&D projects should be implemented from a list of alternatives. An innovative web based decision support tool for the ANP method is used to implement the model and execute all relevant calculations.

Keywords: project selection, ANP, MCDA, software tool, R&D, ANP Solver

1. Introduction

A portfolio usually refers to a collection of projects that are grouped together to facilitate effective management. Its components are not necessarily interdependent or directly related. "Portfolio management is about choosing, prioritizing and managing projects and programs in a way that is consistent with and aligned to organizational strategies" (PMBOK, , 2008). More specifically, portfolio management integrates all processes used to select the most appropriate projects and successfully manage them, in order to achieve the initially defined objectives using the allocated budget and resources in the predefined time span. Upper goal is to maximize the value of the portfolio by the careful examination and selection of the candidate projects. This procedure usually is based on the organization's strategic plan. The need to select which projects to implement usually rises when the organization has limited resources. In these cases it is essential to have a formalized method to select the projects to be initiated from a set of potential ones. Thereby, selecting which projects should compose the project portfolio is a periodic activity where on going and new projects are evaluated and

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those that maximize the total portfolio value, fit best to the organization's objectives and make optimal usage of the available budget and resources are selected (Ghasemzadeh and Archer, 2000). The problem of choosing research and development (R&D) projects to form a portfolio, is of great interest the last three decades and a variety of models, often competing, have been proposed (Reader and Wells, 1977, Lawson et al., 2006, Coffin and Taylor, 1996, Cooper, 1985, Eilat et al., 2008, Fang et al., 2008, Gutjahr et al., 2010, Jung and Seo, 2010). The majority of these approaches are based on MCDA in an attempt to take into account the multiple objectives and the subjective nature of the problem to be solved. It is inherently a multi-criteria decision problem since several factors, such as the available human resources, impact in case of success, risks of failure and other, must be considered at the time of decision making (Gabriel et al., 2006). Furthermore, the uncertainty of the available data and the probabilistic nature of data like anticipated costs, human resources, and material supplies, further complicate the process, especially when the projects under selection are R&D projects, which by definition have not an easily predictable and quantifiable evolution. This probabilistic aspect of project selection lends itself to decision analysis methods, especially methods that qualify for quantitative and qualitative analysis like the ANP method (Saaty, 1990, Kirytopoulos et al., 2011).

In order to select which projects should be implemented from a set of available alternatives, the projects have to be ranked. This evaluation is done using both qualitative and quantitative criteria. The former usually refer to financial indicators of the efficiency, quality or yield of the investment, like ROI, IRR, etc. The later concern project's features related to the project's fitting to the organizational standards, priorities and long term objectives. This problem is a typical multi-criteria decision analysis problem and an optimal solution should be harmonized to the decision maker's point of view instead of simply aggregating the limited available quantitative data. Thus herein a MCDA model is proposed that can be used by any decision maker to prioritize R&D projects and each time the results will reflect not only the inserted quantitative data but also the decision makers' experience and knowledge on the subject.

The current work makes use of the ANP to determine the rank of each potential project based on predefined objectives, which are reflected in the proposed R&D project selection model. The reasons for selecting this method concerned both its optimality in handling quantitative and qualitative criteria and the possibility to represent both simple and complex models without need of acknowledging the calculations to reach the final results (Kirytopoulos et al., 2009). The implementation was done using a model-driven web based decision support system (WEB ANP SOLVER) that provides tools for using MCDA techniques. Thus, the contribution of the current work concerns the presentation of a new formulation for determining optimal R&D project selection and its implementation using a web based ANP software tool.

The rest of this paper is organized as follows: in Section 2 a brief review of the work done in the field of R&D project prioritization and the criteria used in each case is presented. In Section 3 the proposed ANP model is analyzed. In Section 4 an illustrative case to demonstrate the usability of the model along with the DSS system used to create the model and calculate the results, are described. The last Section of the paper consists of general conclusions and further research possibilities.

2. Literature Review on Selecting R&D Projects

R&D project selection methods as shown in Henriksen and Traynor's (1999) usually fall into one of the following main categories: peer review, scoring, mathematical programming, economic models, Multi Attribute Utility Theory (MAUT), artificial intelligence and interactive methods. In spite of the wide range of methods there is a common ground concerning firstly the objectives to be achieved and secondly the criteria that should be taken into account.

More specifically, project selection aims at one or more of the following objectives (Lawson et al., 2006, Coffin and Taylor, 1996, Graves and Ringuest, 1992, Jiang and Klein, 1999, Mohanty, 1992, Archer and Ghasemzadeh, 1999): a) maximizing profits, b) increasing market share, c) maximizing usage of available human and equipment resources, d) optimizing company profile, e) fitting in organizational strategic goals, f) creating synergies with existing projects, g) achieving optimal level of portfolio risk.

To achieve these goals, projects are ranked against several criteria, which could be summarized as shown in Table 1. It should be noted here that qualitatively measured criteria prevail because they expedite the decision maker in describing his/her desired value and the importance of each criterion in the specific context instead of limiting the decision maker to use strictly quantifiable project indices (Lin et al., 2007) as opposed to the limited usage of quantitative criteria that in R&D projects is quite difficult to get accurate values due to the innovativeness of the projects.

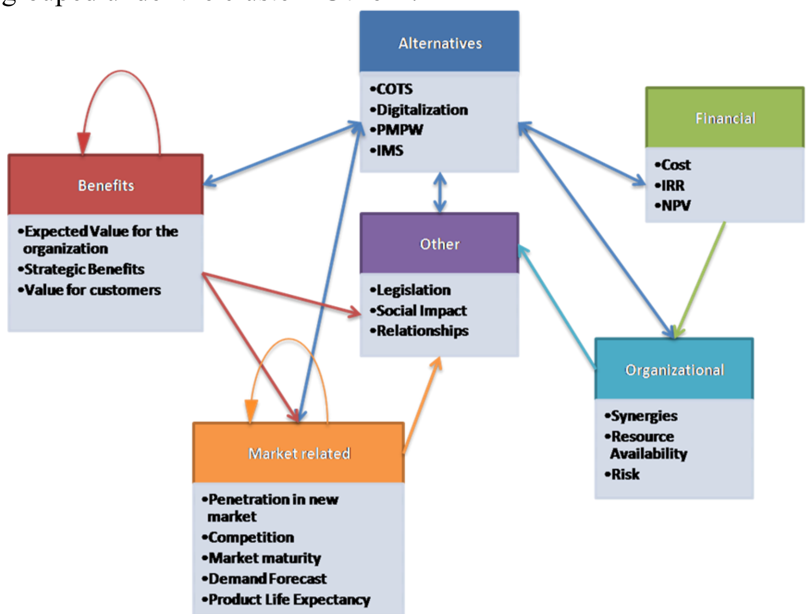
Table 1 R&D selection criteria literature summary

Quantitative Criterion	References
Resource requirements availability	(Coffin and Taylor, 1996, Eilat et al., 2008, Gabriel et al., 2006, Jung and Seo, 2010, Lawson et al., 2006, Mohanty, 1992, Reader and Wells, 1977, Wang et al., 2009)
Benefit/cost ratio	(Mohanty, 1992, Reader and Wells, 1977)
NPV	(Mohanty, 1992, Reader and Wells, 1977, Huang et al., 2008)
Cost	(Chiang and Che, 2010, Chu et al., 1996, Coffin and Taylor, 1996, Fang et al., 2008, Huang et al., 2008, Jung and Seo, 2010, Mohanty, 1992)
Length of product life cycle	(Eilat et al., 2008, Mohanty, 1992)
Completion time	(Coffin and Taylor, 1996, Mohanty, 1992)
Profit	(Chang and Lee, Chiang and Che, 2010, Coffin and Taylor, 1996, Mohanty, 1992, Wang et al., 2009)
Qualitative Criterion	**References**
Project Profile	(Chu et al., 1996, Huang et al., 2008, Jiang and Klein, 1999)
Usability of results	(Chu et al., 1996, Huang et al., 2008, Jiang and Klein, 1999, Lawson et al., 2006)
Project objectives	(Chu et al., 1996, Gabriel et al., 2006, Reader and Wells, 1977, Wang et al., 2009)
Potential synergies	(Chu et al., 1996, Eilat et al., 2008, Jiang and Klein, 1999, Lawson et al., 2006, Wang et al., 2009)
Impact on collaborations	(Chu et al., 1996, Eilat et al., 2008, Jung and Seo, 2010)
Fit into strategic goals	(Gabriel et al., 2006, Jiang and Klein, 1999, Lawson et al., 2006, Wang et al. 2009)
Technology growth	(Chang and Lee, Chiang and Che, 2010, Eilat et al., 2008, Huang et al., 2008, Jiang and Klein, 1999, Jung and Seo, 2010, Mohanty, 1992)
Market growth	(Chang and Lee, Huang et al., 2008, Jiang and Klein, 1999, Lawson et al., 2006)
Competition	(Jiang and Klein, 1999, Wang et al., 2009)
Market maturity	(Chiang and Che, 2010, Huang et al., 2008, Lawson et al., 2006)
Governmental policies	(Huang et al., 2008, Jiang and Klein, 1999, Wang et al., 2009)
Legislation	(Jiang and Klein, 1999, Lawson et al., 2006, Mohanty, 1992)
Environmental issues	(Huang et al., 2008, Jiang and Klein, 1999, Wang et al., 2009)
Society	(Wang et al., 2009)
Risk	(Chiang and Che, 2010, Chu et al., 1996, Coffin and Taylor, 1996, Fang et al., 2008, Huang et al., 2008, Jiang and Klein, 1999, Lawson et al., 2006, Mohanty, 1992, Reader and Wells, 1977)

3. R&D Project Selection Model

The proposed model for selecting R&D projects is a generic model that could be easily used for making decisions in any similar occasion without any need of extended economic analysis or complicated quantitative methods. Financial data are taken into consideration and although numerically are fewer they are not dominated by the qualitative, since it is upon the decision maker to weight the criteria according to his/her personal point of view.

Following the criteria used to form the ANP decision model and the way that are grouped in clusters are analyzed. **Financial** indicators are used to define the economic value of each alternative, like total expected project cost, IRR and NPV. **Organizational** cluster contains criteria related to the organization profile, like the opportunity to form synergies with other ongoing or proposed projects, required resources and their availability or constraints set by conflicting demand of the same resources by different proposed and ongoing projects, and the total risk of each alternative, including technical risks, success, time and cost risks. **Market Related** cluster is used to group together criteria like the expected penetration in new market, existing competitors in the field of the proposed project, market maturity, demand forecast and product life expectancy. **Expected Benefits** for the organization like the expected usability of the results, fitting to strategic goals and possible value for its customers. Finally, the legislation that could affect positively the implementation of a project, the expected social impact and the possible implications to the relationships with current collaborators are grouped under the cluster "**Other**".



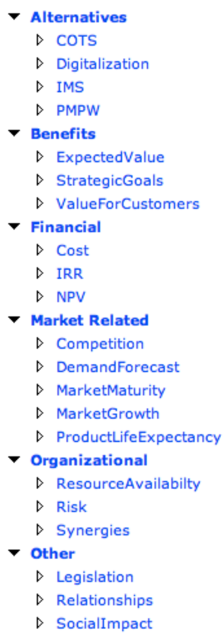


Figure 1 R&D Project Selection Model

Major importance is given to the paths of influence among the objects of the model. To view the relationships of a network a zero-one matrix of criteria against criteria can be constructed, where the number one will signify that there is a path of influence from the element of the corresponding line to the element of the corresponding column. Thus, the inner and outer relationships among the nodes are defined and the corresponding cluster relationships are computed.

4. Illustrative Example

4.1 Description of R&D programs and their objectives

To illustrate the model presented in section 3, a decision maker is asked to prioritize a group of R&D projects in order to select the one that fits best to the academic research team that s/he is affiliated with. The idea is to individuate the research projects that should be submitted for funding by the government based on the fit to the current market trends and organizational strategic goals as well as their financial indicators and expected impact. The available projects that are going to be prioritized compose the Alternatives cluster of the ANP model. Below the key features of these research projects are briefly presented:

a) **COTS**: it is a project that aims in creating a software components selection and combination method for optimizing the software development process.
b) **Digitalization**: it is a project with main objective to digitalize and add metadata to books with high cultural value.
c) **PMPW**: aims at developing a method for integrating management standards and supporting the monitoring of projects when there is a need to comply to multiple normative standards.
d) **IMS**: cooperative project aiming at the creation of a human network of excellence in the field of operations research to support joint research actions and transport of knowledge.

4.2 ANP Calculations

In this section based on the model presented in section 3 and the specific alternatives depicted in section 4.2, the ANP method (Saaty, 1996) is implemented using a web based object oriented application, WEB ANP SOLVER[1], to create the model, input the decision makers judgments and compute the final result.

Having in mind the desired goal, to prioritize a given set of R&D projects, a network structure including clusters, criteria and alternatives was configured and the dependences among all components of the previous structure were identified and listed, to define the impacts among them, as shown in Figure 1. Then, pairwise comparison matrices of the components with interval judgments were constructed and the decision maker was asked to input his judgments by responding to pairwise comparisons of the form “Which of the criteria A or B is more important in context of C and how much?” In the proposed application these questions were given in an affirmative form with the possibility to invert the cardinality of the criteria and then the preference should be entered as an integer value from 1 to 9, based on the Saaty scale (Saaty, 1996). For each comparison matrix created through the corresponding questionnaire, the consistency should be checked and judgments should be adjusted till the maximum inconsistency is less than 10% of the order of magnitude of the actual measurement. Afterwards, the relative importance weights (local priorities) from each matrix can be derived and this way the Cluster matrix and Supermatrix are formed, as shown in Figure 3. More specifically, both matrices are formed using the elicited weights from cluster and node comparisons questionnaires and then are transformed to column stochastic. Next step is to limit the Weighted Supermatrix by raising it to a sufficiently large power until it converges into a stable limit matrix. In the end, the weights of criteria and alternatives are aggregated into final priorities.

Finally, by normalizing the Alternatives cluster, as shown in Figure 2, it is possible to have a clear view of the relative priorities among the projects that were under question and based on the specific expert’s value system view that the PMPW project was the one that should be submitted for funding. By further analyzing the results of the ANP method, we can identify the criteria that were more important for the decision maker and strongly influenced the final result. In this illustrative example, as shown in Figure 4, the expected value for the organization, fit to the organizational strategic goals and the expected value for the customers where the criteria that majorly influenced the final results. This secondary information about the criteria weights can be especially interesting when having more than one decision makers with conflicting, or not, opinions because gives insight of the way that they face the decision and their value system, something that is quite difficult to extract in any other way (Voulgaridou et al., 2009).

[1] Software tool available at: http://kkir.simor.ntua.gr/Rokou/ANPWEB/default.aspx

Nodes	Results
COTS	0.084
Digitalization	0.07
IMS	0.118
PMPW	0.187
ExpectedValue	0.162
StrategicGoals	0.066
ValueForCustomers	0.043
Cost	0.021
IRR	0.026
NPV	0.046
Competition	0.011
DemandForecast	0.018
MarketMaturity	0.049
MarketGrowth	0.004
ProductLifeExpectancy	0.019
ResourceAvailabilty	0.015
Risk	0.013
Synergies	0.017
Legislation	0.009
Relationships	0.01
SocialImpact	0.013

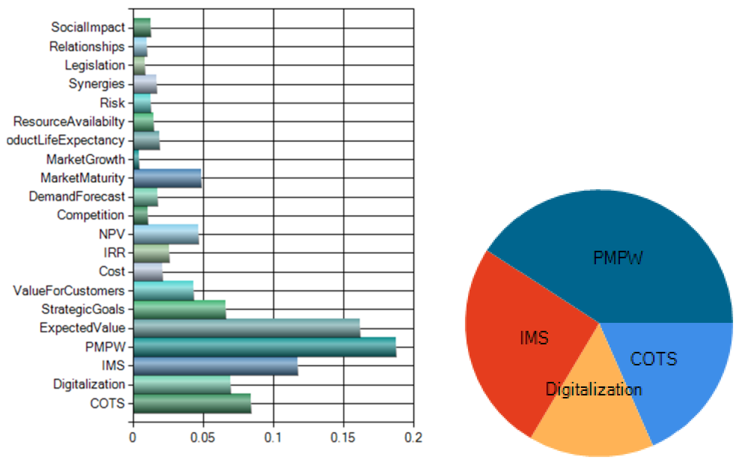


Figure 2. Final Priorities

5. Conclusions

Prioritizing R&D project to form a project portfolio is a difficult and tedious process which is further aggravated due to the limited data and the general uncertainty concerning innovative projects aiming at creating state of the art processes and products instead of using existing methods and technologies. In addition, the majority of the methods proposed by the researchers often reflect the financial perspective of the projects letting out important aspects like the social impact or the usability of the proposed project in case of success or in other cases focus is given to a specific type of R&D projects letting out other research fields. In this framework the present study proposes a simple ANP model, which offers a generic model that could be easily used to evaluate R&D in a consistent manner. Furthermore, the proposed ANP approach enables the decision maker to visualize the impact of various criteria in the final outcome. Especially when using the proposed web based application, it is very simple to communicate the results to all involved stakeholders, without time and place limitations and it is equally easy to have collaborative decision making processes by having more than one decision makers working on the same model. A secondary benefit of the research is that by using the proposed framework a valuable insight of the criteria that dominate the decision making process is given, providing value-added knowledge to the stakeholders. It would be interesting to run the same model to choose R&D projects in different scientific fields and using different groups of decision makers in order to find out patterns about the dominant criteria based on the scientific field or the decision makers' profiles.

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