Project Portfolio Selection in electrical company based on the Analytic Network Process and Data Envelopment Analysis

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Abstract: Selecting the "best" project portfolio out of a given set of investment proposals is a common and often critical management issue. Decision-makers must regularly consider multiple objectives and often have little a priori preference information available to them. In this paper a new approach to prioritize project portfolio in an efficient and reliable way is presented. It is based on strategic objectives of the company and multi criteria decision methods. The method that is proposed here relies on the use of the analytical network process (ANP) and to help integrate managerial evaluations into a more quantitatively based decision tool, data envelopment analysis (DEA) is used. In this study, a portfolio selection procedure is presented to construct a desirable facility by using ANP and DEA approaches in two stages. In the first stage ANP model is used, results of this stage are inputs for the second stage. In this stage, DEA is applied to select best portfolio. The proposed method is applied on an electronic company.

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1. Introduction

Any organization to achieve its vision and desirable plotted the growth and survival of the organization, mandate to develop and implement action plans and its control. Most action plans in various organizations, will appear a series of strategic projects. Strategic projects are a means to achieve organizational goals (Gutjahr et al., 2010).

One of the troubling issues facing organizations with large projects is choosing the optimal mix of projects from the project technical have passed economic assessment. Of course this mixture is performed as for as the limitations, aims and organizational strategies in this model, so that it is possible beside these limitations and along with objectives and strategies to select a mix of projects which has the best result (GUO et al., 2009). In this field, many models and frameworks are presented. We will point to it in theatrical basics part.

The considering electrical company in this study, Electric Power Supply Company of Caracas (EDC), was until may 2007 a private power company that counts with the most comprehensive and updated data in the country; it covers about 10% of the national electric power demand and supplies electricity to Caracas and surrounding area. It is owned now by the stated owned PDVSA (Venezuelan Oil Company). EDC managers have to distribute the annual budget among the different improvement actions to be conducted on the power network system. The budget is divided into two main aspects: expenses and investment. The expenses budget includes periodical activities such as preventive and corrective maintenance services, acquisition of tools and components, wage compensations, long period contracts and services. On the other hand, the investment budget covers the execution of improvement projects. Annually, expenses and investments are planned based on the budget of the previous year (Smith-Perera et al.,2010).

An important part of the annual budget is assigned to the improvement project plans that will result in a better performance and efficiency of the system as well as in better power quality for the end users. The improvement project portfolio emerges as a response to the fact that the electric power network itself and its operation have problems and that these problems can be identified and solved. The selection and justification of the periodical activities and project portfolio by the company's management body is a task that has to be done every year. At present, the selection and justification processes are based on experience and intuition (Smith-Perera et al., 2010).

In 2010, A. Smith Pererae Proposed a Project Strategic Index, for portfolio selection in electrical company based on the Analytic Network Process; as mentioned earlier in this study, it is very difficult to develop a selection criterion that can precisely describe the preference of one portfolio over another. Many precision based methods for desirable portfolio selection have been investigated. Most of these methods have been developed, based on the concepts of accurate measurements (Smith-Perera et al., 2010). However, most of the selection parameters cannot be given precisely and the evaluation data of solid waste facility portfolios suitability for various subjective criteria is usually expressed by using the decision maker's (DM) judgments. For example, most of the cost-related criteria like the construction cost of Portfolio efficiency can be measured or estimated accurately. Moreover, when such social and political criteria as image related effects are considered, the judgments of DMs such as those of city planners or of municipalities become more important because there is not an objective or precise numerical measurement. On the other hand, the other portfolio modeling objective is to provide insights into the performance of portfolios at different potential sites. So it is necessary to find a spatial pattern that considers both portfolio performance and spatial interaction between portfolios and returns. For this purpose, analytic network process and data envelopment analysis are used. We propose a technique that can effectively take managerial preferences and subjective data into consideration, along with quantitative factors. The tool that is proposed here relies on the use of a more effective version of the analytical hierarchy process (AHP), called the analytical network process (ANP). To help integrate managerial evaluations into a more quantitatively based decision tool, data envelopment analysis (DEA) is used. Together, ANP and DEA provide synergistic advantages, primarily through the integration of qualitative and quantitative factors. Reminder of the paper is as follows: in section II ANP and DEA formulation is proposed, in section III computational results are illustrate, conclusion is discussed in section IV.

2. Materials and Methods

2.1. Portfolio

According to PMI, a series of projects form of a Portfolio to facilitate the effective management plans and other related works in order to achieve strategic objectives are in a group (PMBOK).

The concept of portfolio management for the first time was proposed in 1952 Markowitz the appropriate stock exchange (Fasihi, 1386). In PMI definition of in portfolio management Standard project, projects portfolio management, is a centered management of one or more project portfolio in organization in which applied through control projects, programs and other related work to meet specific strategic business objectives (Blomquist and Muller, 2006).

In 1964 Baker and Pound began to examine how art and science of assessing and selecting projects, R & D (Baker and Pound, 1964) each of the two exclusively on projects related R & D, but subsequent studies have led to some conclusions about the past, present and future methods of project selection.

The use of structured procedures and numerical, for evaluation and selection of projects is recent phenomenon which is widely used after World War. Return period and the average used annual rate of return on such criteria as the most.

During the 1950s and 1960s gradually spread the use of structured models. At this time many of the models used exclusively models of profit / utility had. The models of the short time horizon for investment decisions, project mark were emphasized.

After a decade of significant growth in the use of models of structured and open Brmdlhay profit was also stressed. But these models are several criteria for deciding intervention they were given. The trends toward the use of information systems decision were made. In the 1990s, significant progress in the development processes of the preferences of the input data used for ranking - were found to be. The models in like Armani and planned allocation models were used.

Talebi optimized portfolio selection problem via two different methods from two major optimization approaches, Heuristic and Classic (Talebi et al., 2011). Ghasemzadeh and Archer proposed a framework for project portfolio selection that offer 3 main phases, as well as suggestions for selecting the optimal portfolio of projects (Archer and Ghasemzadeh, 1999). Graham and England suggested a framework and systematic pattern of "rational decision-making process" for selecting a portfolio of development projects (Englund and Graham, 1999). Thereafter models like the model of Chang (Wei and Chang, 2011), variable neighborhood search algorithm (VNS) was submitted (Gutjahr et al., 2007) for the projects portfolio selection. Further, Amiri applied AHP and Fuzzy TOPSIS for the projects portfolio selection in Oil Corporation (Amiri, 2010).

Boot (2004) applied a risk-based approach to providing portfolio of projects in the state of uncertainty. This model is efficient and low risk (Butts, 2004).

2.2. The Analytic Network Process

The analytic network process (ANP) is the most comprehensive framework for the analysis of public, governmental and corporate decisions. It allows the decision maker to include all the factors and tangible or intangible criteria that have a significant effect on making a best decision. The ANP allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). Such feedback best captures the complex effects of interplay in human society, especially when risk and uncertainty are involved (Saaty, 2003). The elements in a cluster may influence other elements in the same cluster and those in other clusters with respect to each of several properties. The main object is to determine the overall influence of all the elements. In that case, first of all properties or criteria must be organized and they must be prioritized in the framework of a control hierarchy. Then the comparisons must be performed and synthesized to obtain the priorities of these properties. Additionally, the influence of elements in the feedback system with respect to each of these properties must be derived. Finally, the resulting influences must be weighted by the importance of the properties and added to obtain the overall influence of each element. Only under the assumption of no feedback as in the AHP, are the results from both the AHP and the ANP the same. With feedback, the alternatives can depend on the criteria as in a hierarchy, but they may also depend on each other. Furthermore, the criteria themselves can depend on the alternatives and on each other. Feedback also improves the priorities derived from judgments and makes prediction much more accurate (Saaty, 1996, 1999). For more information related with determining weights and implementing the feedbacks in the ANP, Saaty (2003) can be studied. Actually the ANP consists of a combination of two parts. The first includes a control hierarchy of criteria and sub criteria controlling the interactions. The second is a hierarchy of influences among the elements and clusters. The overall priorities of the alternatives with respect to each of these are then combined by forming the ratios to obtain their final overall priorities for a decision (Saaty, 2001a, b). A detailed definition of the ANP can be reviewed through a series of ten steps (Saaty, 1999).

Step 1: Describe the control hierarchies in detail including their criteria for comparing the components of the system and their sub criteria for comparing the elements of the system.

Step 2: Determine the hierarchy or network of clusters (or components) and their elements. To better organize the development of the model, number and arrange the clusters and their elements in a convenient way (perhaps in a column). Use the identical label to represent the same cluster and the same elements for all the control criteria.

Step 3: For each control criterion or sub criterion, determine the clusters of the general feedback system with their elements and connect them according to their outer and inner dependence influences. An arrow is drawn from a cluster to any cluster whose elements influence it.

Step 4: Determine the approach you want to follow in the analysis of each cluster or element, influencing the preferred approach other clusters and elements with respect to a criterion, or being influenced by other clusters and elements. The sense of influencing or being influenced must apply to all the criteria for the four control hierarchies for the entire decision.

Step 5: For each control criterion, construct the super matrix by laying out the clusters in the order they are numbered and all the elements in each cluster both vertically on the left and horizontally at the top. Enter in the appropriate position the priorities derived from the paired comparisons as sub columns of the corresponding column of the super matrix.

Step 6: Perform paired comparisons on the elements within the clusters themselves according to their influence on each element in another cluster they are connected to (outer dependence) or on elements in their own cluster (inner dependence). The comparisons are made with respect to a control criterion or sub criterion of the control hierarchy.

Step 7: Perform paired comparisons on the clusters as they influence each cluster to which they are connected with respect to the given control criterion. The derived weights are used later to weight the elements of the corresponding column clusters of the super matrix corresponding to the control criterion. Assign a zero when there is no influence. Thus obtain the weighted column stochastic super matrix.

Step 8: Compute the limiting priorities of the stochastic super matrix according to whether it is irreducible (primitive or imprimitive) or it is reducible with one being a simple or a multiple root and whether the system is cyclic or not. Two kinds of outcomes are possible. In the first, all the columns of the matrix are identical and each gives the relative priorities of the elements from which the priorities of the elements in each cluster are normalized to one. In the second, the limit cycles in blocks and the different limits are summed and averaged and again normalized to one for each cluster. Although the priority vectors are entered in the super matrix in normalized form, the limit priorities are put in idealized form because the control criteria do not depend on the alternatives.

Step 9: Synthesize the limiting priorities by weighting each idealized limit vector by the weight of its control criterion and adding the resulting vectors for each of the merits.

Step 10: Perform sensitivity analysis on the final outcome and interpret the results of sensitivity observing.

2.3. The structure of Data Envelopment Analysis

2.3.1 The basic CCR model

(Charnes, Cooper, and Rhodes, 1998) proposed the initial DEA model, referred to as the CCR model, for evaluating the relative efficiencies of a homogenous set of decision making units (DMUs). The CCR model incorporates multiple inputs and outputs in evaluating the relative efficiencies of alternative DMUs, where efficiency can be defined as the ratio of weighted output to input. Using the notation of (Doyle and Green, 1994), the general efficiency measure that is used by DEA can best be summarized by Eq. (1).

$$E_{ks} = \frac{\sum_{y=1}^{Y} O_{sy} v_{ky}}{\sum_{x=1}^{X} I_{sx} u_{kx}} \qquad (1)$$

where is the efficiency or productivity measure of portfolio s, using the weights of test portfolio k, where the test portfolio is the unit whose efficiency is to be evaluated; is the value of output y for portfolio s; is the value for input x of portfolio s; is the weight assigned to Portfolio k for output y; and is the weight assigned to portfolio k for input x.

For the basic CCR model, the objective is to maximize the efficiency value of a test portfolio n k, from among a reference set of portfolio s, by selecting the optimal weights associated with the input and output measures. The maximum efficiencies are constrained to 9. The formulation is represented in expression (2).

$$\begin{aligned} &\mathit{Maximize}\ \ E_{ks} = \frac{\sum_{y=1}^{Y} O_{sy} v_{ky}}{\sum_{x=1}^{X} I_{sx} u_{kx}} \qquad (2) \\ &\mathit{subject\ to}\ \ E_{ks} \le 1\ \ \forall \mathit{portfolio}\ s \\ &\qquad u_{kx}, v_{ky} \ge 0 \end{aligned}$$

This non-linear programming formulation (3) is equivalent to the following linear programming formulation (2),

$$\begin{aligned} &\mathit{Maximize}\ \ E_{KK} = \sum_{y=1}^{Y} O_{ky} v_{ky} \\ &\mathit{subject\ to}\ \ E_{ks} \le 1\ \ \forall \mathit{portfolio}\ s \qquad (3) \\ &\qquad \sum_{x=1}^{X} I_{kx} u_{kx} = 1 \\ &\qquad u_{kx}, v_{ky} \ge 0 \end{aligned}$$

The transformation is completed by constraining the efficiency ratio denominator from (2) to a value of 1. This is represented by the constraint

$$\sum_{x=1}^{X} I_{kx} u_{kx} = 1 \; .$$

The result of formulation (2) is an optimal-technical efficiency value that is at most equal to 1. If $(E^*_{kk}) = 1$ then it means that no other Portfolio is more efficient than Portfolio k for its selected weights. That is, $(E^*_{kk}) = 1$ has Portfolio k on the optimal frontier and is not dominated by any other Portfolio. If $(E^*_{kk}) \le 1$, then Portfolio k does not lie on the optimal frontier and there is at least one other Portfolio that is more efficient for the optimal set of weights determined by (2). The formulation (2) is executed s times, once for each Portfolio. Since the basic DEA model may provide a number of alternative Portfolios that are efficient, it would be difficult for a decision maker or organization to decide on a single Portfolio if there is more than one efficient unit. Many of these efficient units occur when the basic CCR approach is used.

To help discriminate among efficient Portfolios and to help rank them, DEA ranking approaches may be used. One such approach is recommended here.

2.3.2. A DEA Ranking model.

A DEA approach that is useful for ranking is a variation of the CCR model proposed by (Andersen and Petersen, 1993). In their model they simply eliminate the test unit from the constraint set. The new formulation is represented by (4).

$$\begin{aligned} &\mathit{Maximize}\ \ E_{KK} = \sum_{y=1}^{Y} O_{ky} v_{ky} \\ &\mathit{subject\ to}\ \ E_{ks} \le 1\ \ \forall \mathit{portfolio}\ s \ne k \qquad (4) \\ &\qquad \sum_{x=1}^{X} I_{kx} u_{kx} = 1 \\ &\qquad u_{kx}, v_{ky} \ge 0 \end{aligned}$$

Expression (4), which we call the "reduced" CCR (RCCR) formulation, allows for technically efficient scores to be greater than 1. This result allows for a more discriminating set of scores for technically efficient units and can thus be used for ranking purposes.

2.3.3. Integrating managerial preference for the *DEA ranking approach*

Constraining the "flexibility" or range of weights (u and v) provides an approach for integrating managerial preferences into the RCCR models. The use of assurance regions (AR) for restriction of weights is one approach to better map managerial preferences to DEA. The concept of AR is described in detail by (Thompson, Langemeier, Lee, Lee, and Thrall, 1990). The process of setting AR begins by defining the upper and lower bounds for each input and output weight. The upper and lower bounds for each weight can help define constraints that relate the weight values of various factors. These LB and UB values may be ranges for preference weights for each of the factors as defined by the decision makers. The AR constraints relate the weights and their bounds to each other. The generalized AR constraint sets that are derived from LB and UB data are:

$$v_i \ge \frac{LB_i}{UB_j} v_j \quad \mathit{and} \quad v_j \le \frac{UB_i}{LB_j} v_j \qquad (5)$$

These constraints can be added to expression (4) to form the RCCR with assurance regions (RCCR/AR) model. From a computational perspective, the number of additional constraints required to help define the AR is equal to $\frac{I*(I-1)}{2}+\frac{O*(O-1)}{2}$, where I and O represent the number of inputs and outputs, respectively.

2.4. The proposed methodology

2.4.1. The desirable portfolio selection process

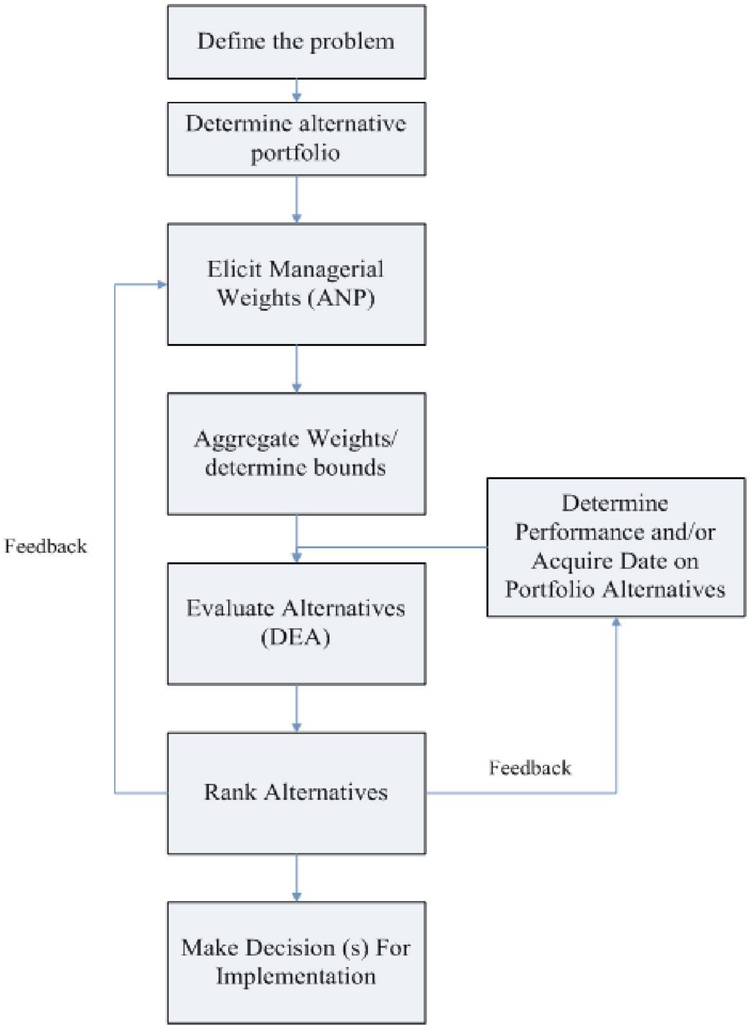

Fig. 1. the desirable portfolio selection process

The desirable portfolio selection process contains several steps as presented in Fig. 1. As can be seen in this figure, the first step is related with the identification of the problem. It is a fact that understanding the problem better naturally provides better solutions for the decision makers. Therefore, this step is the most important phase of the selection process. The below should be comprehensively stated at this step: the type of the desirable facility; the facility specific nuisances, etc. the facility specific requirements, etc. The second step is the identification of the potential desirable portfolios. During this phase, alternatives should be stated with a logical elimination, because calculation time is directly affected by the number of the alternatives. Then the criteria should be selected based on the data acquired from the previous steps. This should be followed by the collection of related data, considering the criteria requirements. Then, weights from managerial insights into the various factors of the ANP models need to be determined. We shall assume that more than one user, decision maker, etc., are involved in the decision process. The next step in the process is to aggregate these weights. Even though the aggregation can be completed as a group decision making effort, we assume that each decision maker goes through the ANP approach. The decision maker weights provide the bounds for the DEA assurance regions. That is, the upper and lower bounds are determined from the ranges of the manager importance weights. A couple of approaches may be used to determine the ranges. One approach is to take an average and use some standard deviation measure to provide the ranges for the weights. The other approach would be to use maximum and minimum weighting scores for AR limits. The answers may come out differently depending on the distribution of the responses. The use of statistical ranges may be dependent on the number of decision makers. We assume the minimum and maximum weighting scores, since; in many cases the number of decision makers is limited.

As part of this framework, we have to assume that performance data for the portfolio alternatives are available. This assumption is not trivial and may require significant effort by analysts to acquire this information. The use of simulation, modeling, benchmarking, and estimation tools is recommended in this situation, since the selection needs to be made before the actual implementation. Later, in the auditing stages, this same framework can integrate actual post-implementation data to evaluate the performance of portfolios among each other.

The DEA evaluation is then completed, integrating both the performance data and managerial preference bounds. The results are a ranking of the alternatives based on relative efficiency scores, using the RCCR/AR model. Sometimes, going through the decision process, analysts and decision makers learn more about the alternatives, factors, and process. Thus, a feedback loop is included to help managers structure their decision more effectively.

2.4.2. Proposed ANP model

The model developed is a two-layered ANP model, the first layer of which has two clusters. The ANP model resembles the AHP model due to its hierarchic structure. This layer includes a control hierarchy of criteria and sub criteria. The goal is placed at the top of this hierarchy. In this study, the goal of ANP is elicit managerial weights for using at the other steps.

The second layer of the model consists of the sub networks which represent the interactions between the clusters of alternatives and the criteria.

The clusters of the sub networks and the elements placed in the clusters are shown in detail in Table 1.

These sub networks for considering electrical company are shown in Figs. 2.

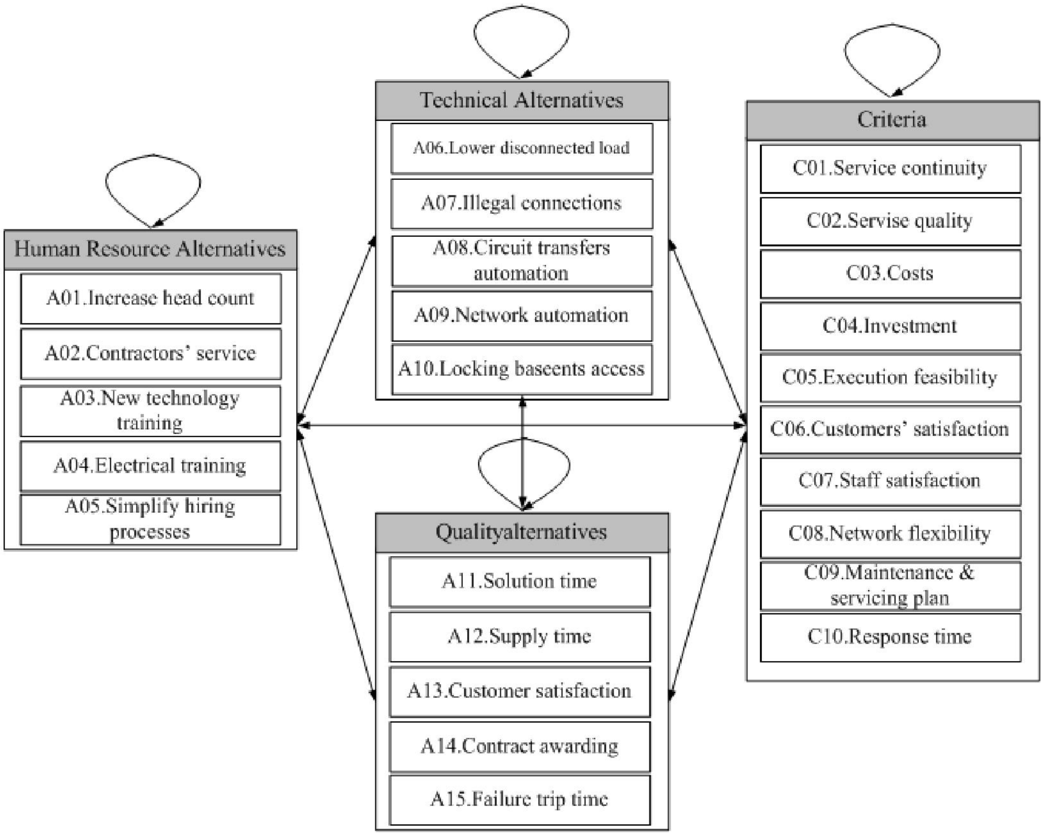

Fig. 2.interactions between the clusters of alternatives and the criteria (Smith-Perera et al.,2010)

Table 1: Sub clusters and element (Smith-Perera et al.,2010)

Action	Elements	Action	Elements
A01	Increase head count	A14	Contract awarding
A02	Contractors' service	A15	Failure trip time
A03	New technology training	C01	Service continuity
A04	Electrical training	C02	Service quality
A05	Simplify hiring processes	C03	Costs
A06	Lower disconnected load	C04	Investment
A07	Illegal connections	C05	Execution feasibility
A08	Circuit transfer automation	C06	Customers' satisfaction
A09	Network automation	C07	Staff satisfaction
A10	Locking basements access	C08	Network flexibility
A11	Solution time	C09	Maintenance and servicing plans
A12	Supply time	C10	Response time
A13	Customer satisfaction		

Table 2: Unweighted super matrix for the case study (Smith-Perera et al.,2010)

		Human resources					Technical					Quality					Criteria									
		A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	A11	A12	A13	A14	A15	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10
Human resources	A01	0	0	0.5	0	1	0.161	0.469	0	0	0	0.128	0	0.124	0	0	0	0.168	0	0	0	0	0.111	0	0.096	0
	A02	0	0	0	0	0	0.24	0.531	0	0	0	0.142	0	0.275	1	0	0.537	0.278	0	0	0.26	0.888	0.067	0.182	0.224	0.274
	A03	0.25	0.5	0	0.125	0	0.24	0	0	0	0	0.198	0	0.066	0	0	0	0.033	0	0	0.308	0	0.111	0.126	0	0
	A04	0	0.5	0	0	0	0.359	0	0	0	0	0.437	0	0.441	0	0	0.427	0.521	0	0	0.432	0.112	0.287	0.693	0.295	0.726
	A05	0.75	0	0.5	0.875	0	0	0	0	0	0	0.096	0	0.094	0	0	0	0	0	0	0	0	0.424	0	0.385	0
Technical	A06	0	0	0	0	0	0	0	0	0	0	0.143	0	0.153	1	1	0	0.255	0	0	0.302	0.565	0.191	0	0.417	0.094
	A07	0	0		0	0	0.059	0	0	0	0	0	0	0.284	0	0	0	0	0	0	0	0.067	0.427	0.095	0.057	0
	A08	0	0	0	0	0	0.297	0	0	0	0	0.571	0	0.065	0	0	0.346	0.279	0.152	0.274	0.239	0.167	0.191	0.3313	0	0.307
	A09	0	0	0	0	0	0.644	1	0	0	1	0.286	0	0.086	0	0	0.112	0.131	0.216	0.726	0.41	0.091	0.191	0.494	0.368	0.508
	A10	0	0	0	0	0	0	0	0	0	0	0	0	0.412	0	0	0.542	.335q.632	0	0.048	0.11	0.11	0	0.098	0.158	0.092
Quality	A11	0	0		0	0	0.067	0.112	0	0	0	0	0	0	0.274	0.542	0	0.084	0	0	0	0.461	0.057	0.046	0.046	0.028
	A12	0	0.152	0	0	0	0.467	0.112	0	0	0	0	0	0.274	0.726	0	0.299	0.742	0	0.291	0.25	0.222	0.58	0.336	0.331	0.408
	A13	1	0.291	0	1	0	0	0	0	0	0	0.306	0	0	0	0.458	0	0.081	0.5	0.067	0	0.132	0.057	0.042	0.286	0.072
	A14	0	0	0	0	0	0.467	0	0	0	0	0	1	0.726	0	0	0.649	0	0.5	0.641	0.75	0.117	0	0.517	0	0.408
	A15	0	0.557	0	0	0	0	0	0	0	0	0.447	0	0	0	0	0.052	0.093	0	0	0	0.069	0.306	0.059	0.337	0.084
Criteria	C01	0.085	0	0	0	0	0.033	0.063	0	0	0	0.027	0	0.066	0	0	0	0.387	0	0	0	0.385	0	0	0	0
	C02	0.047	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.111	0	0	0	0
	C03	0	0.5	0.635	0.556	0	0.188	0.753	0.304	0.304	0	0.16	0.274	0.209	0	0	0.078	0.201	0	0	0.5	0	0	0.315	0.644	0
	C04	0.382	0.5	0	0.338	0.112	0.394	0	0.633	0.633	0	0.114	0.726	0.189	0	0.5	0.203	0.067	0	0	0.5	0	0	0.333	0.297	0
	C05	0	0	0	0	0	0	0	0.063	0.063	0	0.021	0	0	0	0	0.022	0.021	0	0	0	0	0.068	0	0	0
	C06	0	0	0.05	0	0	0	0	0	0	0	0	0	0.028	0	0	0	0	0	0	0	0	0	0	0	0
	C07	0.277	0	0.24	0.051	0	0	0	0	0	0	0.181	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0
	C08	0.074	0	0	0	0	0.088	0	0	0	0	0.093	0	0.087	0	0	0.213	0.05	0	0	0	0	0.308	0	0.059	0
	C09	0	0	0	0	0	0.232	0	0	0	0	0.071	0	0.376	0	0	0.432	0.273	0	0	0	0	0.624	0.352	0	0
	C10	0.135	0	0.075	0.055	0.888	0.064	0.184	0	0	0	0.334	0	0.045	0	0.5	0.052	0	0	0	0	0.474	0	0	0	0

2.4.3. Pair wise comparisons

Before performing pair wise comparisons, all criteria and clusters compared are linked to each other. There are three types of connections, namely one-way, two way and loop. If there is only one-way connection between two clusters, only one-way dependencies exist and such a situation is represented with directed rows. If there is a two-way dependence between two clusters, bi-directed arrows are used. Loop connections indicate the comparisons in a cluster and inner dependence. After forming the network model and required connections, pair wise comparisons were carried out in our study. The comparisons were made depending on the 9–1 scale recommended by Thomas L. Saaty, where 1, 3, 5, 7 and 9 indicate equal importance, moderate importance, strong importance, very strong importance and extreme importance, respectively, and 2, 4, 6 and 8 are used for compromise between the above values. In order to perform the pair wise comparisons, a lot of face-to-face interviews were held with the DMs by making use of a comprehensive questionnaire. As a result of these interviews and judgments, weights of the main criteria were determined in the first stage of the analysis. Furthermore, 143 pair wise comparison matrices were found comparing the other connections for the whole of the model. These matrices constitute a complex system which is difficult to solve by using a spreadsheet program. Because of this difficulty, Super decisions software 1.6.0 was used to solve and analyze the model. All the above mentioned steps and the remaining steps given in Section 2 are realized in Super decisions Software in the order of judging the criteria with respect to the goal node, judging the alternatives with respect to each of the criteria nodes, checking completed comparisons. In this illustration, we shall assume that maximum and minimum values for each factor from among all the decision makers provide bounds for the assurance regions, which are to be used in the next phase of the framework. Tighter bounds mean greater agreement by managers on the importance of these measures. Looser bounds mean more uncertainty and inconsistency in the importance of the measures and as the last step, obtaining the results with the Synthesis command in the main model view. The results are also examined by the sensitivity analysis module of the program to see the reactions to changes in judgments in the next section.

2.4.4. Proposed DEA model

Table 3: The List of Elements

Elements	Input / output
C01: Service continuity	Output
C02: Service quality	Output
C03: Costs	Input
C04: Investment	Input
C05: Execution feasibility	Output
C06: Customers' satisfaction	Output
C07: Staff satisfaction	Output
C08: Network flexibility	Output
C09: Maintenance and servicing plans	Output
C10: Response time	Input

In this step we evaluate the performance of portfolio alternatives using DEA models and the factor weight restrictions derived from the ANP technique normally in DEA (Zeynep Tohumcu and Esra Karasakal, 2010). It is also a common practice in DEA to use measures with which “less is better” as inputs and “more is better” as outputs (Joseph Sarkis et al. 2002).

Based on this definition of inputs and outputs, we have selected a total of three inputs and seven outputs with ten elements of the ten measures or competitive priorities which is referenced in Fig. 2. Inputs and Outputs are shown in Table 3.

3. Results and discussions

3.1. Weight and bounds determination

To illustrate the proposed framework, the total of desirable elements is considered for evaluation. To determine the managerial weights, each set of relationships needs to have pair wise comparisons completed. The relative efficiency scores are then aggregated into a super matrix, whereupon a stable set of weights are determined, by “converging” the super matrix.

After carrying out all the comparisons, consistency ratios of all the pair wise comparison matrices and those of the judgments were calculated. The consistency measure is very useful for identifying possible errors in judgments. If the inconsistency ratios of all the pair wise comparison matrices are less than 0.1, all comparison matrices are consistent and the judgments are reliable. In our study, the inconsistency ratios of all the comparison matrices were less than 0.1 and so all of the judgments were accepted as reliable. Additionally, for tangible criteria, real quantitative data was used in the ANP to improve the overall consistency. The weights of the main criteria are shown in Table 4. Social perception criterion has the highest weight according to the DM preferences. These weights will have an influence on the determination of the best desirable portfolio in the following stages of the study.

Table 4: weights of the main criteria

Clusters	Elements	Lower Bound	Upper Bound
Service continuity	C01	0.0007	0.0402
Service quality	C02	0.0014	0.0064
Costs	C03	0.1002	0.1037
Investment	C04	0.0180	0.3334
Execution feasibility	C05	0.0902	0.1997
Customers' satisfaction	C06	0.0013	0.0016
Staff satisfaction	C07	0.0004	0.0185
Network flexibility	C08	0.0056	0.0245
Maintenance and servicing plans	C09	0.0017	0.0499
Response time	C10	0.0014	0.0163

3.2. DEA evaluations

In this step we evaluate the performance of desirable portfolios alternatives using DEA models and the factor weight restrictions derived from the ANP technique. Normally in DEA, inputs encompass any resources utilized by DMUs, and outputs include the range of performance and activity measures. It is also a common practice in DEA to use measures with which “less is better” as inputs and “more is better” as outputs. Based on this definition of inputs and outputs, we have selected a total of three inputs and seven outputs as shown before.

In the execution of the DEA models, RCCR/AR model were run to show the variations in the results as managerial preferences are included.

Table 5: RCCR/AR results

Alternatives	Action	Elements	RCCR/AR
Human Resources	A01	Increase head count	0.3291
	A02	Contractors' service	0.0921
	A03	New technology training	0.1343
	A04	Electrical training	0.126
	A05	Simplify hiring processes	0.3236
Technical	A06	Lower disconnected load	0.0701
	A07	Illegal connections	0.0111
	A08	Circuit transfer automation	0.1806
	A09	Network automation	0.5810
	A10	Locking basements access	0.1572
Quality	A11	Solution time	0.039
	A12	Supply time	0.317
	A13	Customer satisfaction	0.035
	A14	Contract awarding	0.010
	A15	Failure trip time	0.0401

To show the sensitivity of the preferences, the RCCR/AR model is executed. The ARs for this decision environment are chosen from the ANP analysis described in the previous section. The RCCR/AR model also identified desirable element A09: Network automation (see column 4 of Table 5) to be the best performer. For example, the second best performer according to RCCR/AR model is element A01: Increase head count. This ranking of projects proves extremely useful for the decision maker in selecting the best choice.

4. Conclusion

In this article, we have provided a decision framework for project portfolio selection. Our methodology utilized a combination of ANP and DEA models for this purpose. We have effectively demonstrated the use of these techniques in incorporating both soft preferential information from qualitative data and hard numerical information from quantitative data into the decision making process.

Qualitative, quantitative measures need to be considered in the evaluation of any portfolio. This framework brings these issues together. The illustrative example showed the importance of integrating managerial preferences and judgments into decision models and their impact on the final selections made. The detailed networks, elements, and components were illustrative and may include fewer or additional clusters, factors, and relationships. But, additional clusters and factors can greatly increase the effort and complexity of the model, lessening its practical utility. The ANP technique not only helps to quantify factors and incorporate managerial preference, but also helps management think through the decision. The network helps the decision process for management, structuring their decision environment in a logical relationship. Also, the final measures for the DEA/AR model had to be quantified for the model to work. There are DEA models that considered categorical and ordinal factors. Reformulating these models to incorporate managerial preferences is another research direction. Another approach to get truly qualitative measures into the decision framework would be to evaluate the alternatives using ANP or AHP. The evaluation weights can then be used as input and output values instead of bounds. Also, fuzzy logic and fuzzy mathematical can be used for future researches.

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