A Hybrid Method for Selecting Projects by Considering Sustainability Factors

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***Abstract*—** The matter of selecting appropriate projects among the identified projects includes important decisions and strategies in almost every companies especially the project-based organizations in which the lack of planning and enough precision could have unpleasant influences on the organization This paper focuses on developing a model based on AHP and PROMETHEE method and integrating a mathematical model for solving optimal project portfolio selection problem. To achieve this purpose, at first we prioritize the projects according to sustainability factors and then use these priorities and other data for selecting the optimal project portfolio. Finally, we apply our proposed model on a project based organization as a case study,

***Keywords**:* Project selection, AHP, PROMETHEE, sustainability, mathematical programming.

I. INTRODUCTION

PROJECT selection is one of the most important issues in managerial decision making, industrial engineering, and governmental nonprofit and commercial organization. Selection of an optimal project portfolio is one of the important and strategic decisions in project-based organizations. The goal of the project selection process is to analyze project viability and to approve or reject project proposals based on established criteria, following a set of structured steps and checkpoints.

In recent years, many multi criteria decision making (MCDM) methods have been developed for optimizing project Selection problems.

Whereas the majority of studies in project portfolio selection have been considered routine factors such as financial ones, in this study we propose a complete set of criteria for selecting project portfolio which also includes financial factors as well as other factors. We propose a set of sustainability factors as indicators of selecting project portfolio.

World Bank (1996) used “Triple bottom line” which contains economic, environmental, and social to define sustainability issue. Besides Triple bottom line, in this study we also consider Technical as one of the components of selection criteria.

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In this study, we propose a hybrid decision making approach that combines two multi criteria decision making (MCDM) methods in order to prioritize projects and then select a group of projects among all proposed project to a project based organization by mathematical programming.

There are various methods on project selection in the different fields. Iranmanesh et al [1] (2008) presented a fuzzy AHP approach for project selection and considered criteria such as financial, management, organizational, environmental, technical and marketing. Among these criteria, financial is the most important one. Finally, they applied their proposed approach on a building holding company and present the outputs.

Fanai and Burn [2] (1997) proposed a new framework for project selection by considering reversibility as a sustainability criterion. They defined reversibility as the degree in which the set of impacts of a project both anticipated and unanticipated can be mitigated. They tested their new framework on a case study which is involved the transmission and distribution lines of hydropower systems. Sanchez and Lopez [3] (2010) analyzed problems which need to identify a set of indicators include every elements which is in the life style of the project. They proposed sustainability as indicator in construction projects and applied their methodology to infrastructure projects in Spain to control the weakness and strengthen of their methodology. Eventually, they developed a set of indicators for civil engineering projects. . solak et al [4] (2010) have proposed a mathematical probabilistic integer programming model in order to selecting R&D projects under uncertainty. The objective of this model is to maximize the rate of return for capital. Archer et al [5] (1999) have proposed a zero-one math programing in order to find the optimal portfolio selection model and also scheduling the portfolio by considering organizational targets and constraints . mohanty et al [6] (2005) have applied a fuzzy ANP approach for selecting optimal portfolio selection of R&D projects. This paper concentrates on developing a model based on AHP and PROMETHEE methods for solving optimal project portfolio selection problem. To achieve this purpose, the rest of this paper is organized as follows: In section 2, a set of criteria of project selection that are more common in sustainability evaluation is introduced according to literature .Section 3 discusses AHP approach for ranking and weighting criteria, In section4, by a results of AHP and also by using PROMETHEE projects are ranked and gradually the optimal projects are selected, for this purpose the developed methodology is performed in a Case Study.

II. Criteria of Project Selection Probl Proposed Criteria for Project Selection

As we mentioned in introduction, we propose a complete set of criteria for selecting project portfolio which also includes financial factors as well as other factors. We propose a set of sustainability factors as indicators of selecting project portfolio. In this section, criteria and sub criteria are introduced in the following table:

Table I
Economic Criteria

	Sub criteria
Economic	Profit
	Expenditure risk or debt
	Aid from government/organization

Table II
Environmental Criteria

	Sub Criteria
Environmental	Energy consumption
	Waste production
	Water production
	Water savings
	GHG emissions
	Emission of ozone depleting substances/ other emissions
	Pollution
	Environmental incidents
	Environmental design criteria
	Land productivity

Table III
Social Criteria

	Sub Criteria
Social	Leadership/ Knowledge management
	Supply chain
	Health and Safety
	Training
	Job creation
	Traffic

Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is one of Multi Criteria decision making method that was originally developed by L. Saaty. In short, it is a method to derive ratio scales from paired comparisons. Since AHP is based on easy to understand value rankings, it has been used and applied by organizations in the real world whereas more mathematically complex models may not be easily transferred from advancing research theory into real world practice.

A classical AHP can be constructed as follows:

1. Forming the goal, criteria, and alternatives in other words decision tree.
2. Determining the overall goal and the criteria and alternatives.
3. Obtaining the pairwise comparisons based on a 1-9 scale of importance.

PROMETHEE Method

PROMETHEE is in group MADM methods and like other MCDM methods proceeds to a pair of wise comparison of alternatives in each single criterion for determining partial binary relations denoting the strength of preference of an alternative A over alternative B. The evaluation table is the first step of the PROMETHEE method. In evaluation table, on the different criteria the alternatives are evaluated. These evaluations involve mainly quantitative data. The implementation of PROMETHEE two types of information are needed, they are: the weights of the criteria considered and the information which decision maker uses when comparing the contribution of the alternatives in terms of each separate criterion.

The weights coefficients can be determined according to various methods [20].

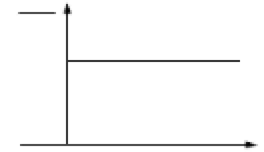
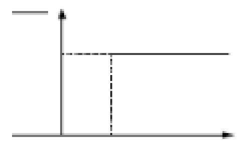
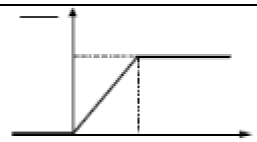
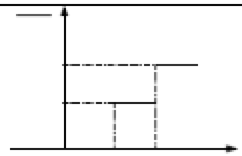
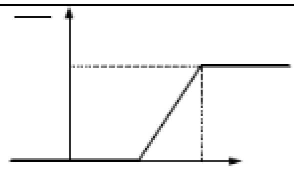
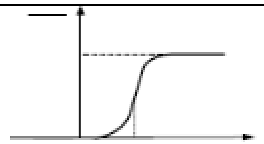
The preference function (*Pj*) translates the difference between the evaluations obtained by two alternatives (*a* and *b*) in terms of a particular criterion, into a preference degree ranging from
0 to 1.

$$p_{j(a,b)} = G_j[f_j(a) - f_j(b)]$$

$$0 \leq p_{j(a,b)} \leq 1$$

be the preference function associated to the criterion, *fj*(*i*) where *Gj* is a non-decreasing function of the observed deviation (*d*) between *fj*(*a*) and *fj*(*b*). In order to facilitate the selection of a specific preference function, six basic types have been proposed: usual function, U-shape function, V-shape function, level function, linear function and Gaussian function (as presented in Fig. 1) [19–21].

TABLE IV
PROMETHEE FUNCTION

name	parameter	shape
Usual	-	
U-shape	Q	
V-shape	P	
Level	P,q	
Linear	P,q	
Guassian	δ	

PROMETHEE permits the computation of the following quantities for each alternative *A* and *B*:
For each alternative *a*, belonging to the set A of alternatives, $\pi(a,b)$ is an overall preference index of *A* over *B*, taking into account all the criteria, $\phi+(\alpha)$ and $\phi-(\alpha)$. $\phi(\alpha)$ represent a value function, whereby a higher value reflects a higher attractiveness of alternative *A* and is called net flow. The two main PROMETHEE tools can be used to analyze the evaluation problem: the PROMETHEE and the PROMETHEE II.

The PROMETHEE I partial ranking is for ranking of alternatives. In some cases, this ranking may be incomplete. This means that some alternatives cannot be compared and they are not in a complete ranking. This occurs when the first alternative obtains high scores on particular criteria for which the second alternative obtains low scores. The use of PROMETHEE I, then, suggests that the decision maker should engage in additional evaluation efforts.
PROMETHEE II provides a complete ranking of the alternatives from the best to the worst one.

III. THE PROPOSED MODEL

The proposed model for the project selection problem, based on a hybrid decision making method, integrating AHP and PROMETHEE, consists of these basic stages: at first, by applyin AHP we can derive weight for each criteria and sub criteria. In the second stage, we use the results oof AHP in performing PROMETHEE for prioritizing the projects and each project gain a specific weight. The last stage, is a mathematical programming which select projects and allocate resources according to the constraint of budget and resource in the project-based organizations.

Case study

In this study, we consider an organization which manage just construction projects. A numerical example is selected from the information and experts of this organization prioritize and select the optimal portfolio. There are 10 propsed project for this organization and some constraints such as:

1. At least 3 projects should be selected.
2. Budget constraint
3. Resource constraint

First stage: AHP results

In this study, we ask ten experts in project management to do pairwise comparison related to the importance of sustainability factors in project-based organizations for selecting consruction projects. So we apply a group AHP for this purpose. The results are in th following tables:

TABLE V
FINAL WEIGHTS

Criteria	Weight
Economic	0.297
Environmental	0.618
Social	0.086

TABLE VI
FINALL WEIGHTS

Sub Criteria (Ecoonomic)	Weight
Profit	0.243
Expenditure risk or debt	0.669
Aid from government/organization	0.088

TABLE VII
FINAL WEIGHTS

Sub Criteria (Environmntal)	Weight
Energy consumption	0.153
Waste production	0.066
Water production	0.075
Water saving	0.097
GHG emissions	0.099
Emission of ozone…	0.104
Pollution	0.136
Environmental incidents	0.082
Environmental design criteria	0.115
Land productivity	0.072

TABLE VIII
FINAL WEIGHTS

Sub Criteria (Social)	Weight
Leadership...	0.07
Supply chain	0.184
Health and Safety	0.186
training	0.166
Job creation	0.259
Traffic	0.135

Second stage: PROMETHEE results

By applying PROMETHEE, we can derive a prioritization for the projects which are proposed to the organization. That is to say, projects, namely P1,…, P10, are ranked according to sustainability criteria and experts judgments. We can see the results in the following table and figure.

TABLE IX
PROMETHEE OUTPUT

	Phi+	Phi-	Phi
P1	0.3519	0.2593	0.0926
P2	0.3333	0.3889	-0.0556
P3	0.2593	0.4630	-0.2037
P4	0.3519	0.2593	0.0926
P5	0.2222	0.5000	-0.2778
P6	0.4630	0.1481	0.3148
P7	0.4815	0.1481	0.3333
P8	0.3889	0.2593	0.1296
P9	0.1111	0.5926	-0.4815
P10	0.4074	0.2963	0.1111

According to the results, it is obvious that P7 has the biggest Phi, so it is prior to others. The priority vector of projects is (P7, P6, P8, P10, P1=P4, P2, P3, P5, P9). It means that P7 is the prior one and P9 is the last one in the priorities.

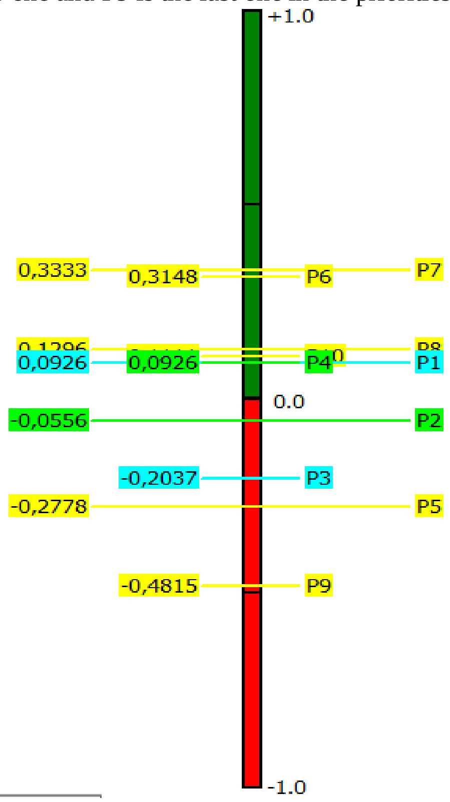


Fig. 1.PROMETHEE output

Third Stage: Mathematical Model

In this stage, we use weights derived from PROMETHEE II and some other information of proposed projects in the mathematical model. Also, we omit 4 projects which have negative Phi. So, P2, P3, P5 and P9 are omitted.

The total budget of organization is 120000 and human resource is 1500. Non- financial resource is 30000. The information of this organization is manipulated owing to confidentiality.

Model description

Parameters

c_i : Total cost of project i

s_i : Total salary for human resources of project i

w_i : Normalized weights derived from PROMETHEE

p_i : Profit of project i

Variables

x_i : A binary variable for selecting project i or not

y_i : The amount of resource should be allocate to project i if is being selected

z_i : Number of human resource for project i

$$Max \sum_{i=1}^{6} p_i x_i$$

$$\sum_{i=1}^{6} x_i y_i \le \mathrm{Re}\,source \quad (1)$$

$$\sum_{i=1}^{6} x_i \ge 3 \quad (2)$$

$$\sum_{i=1}^{6} (c_i + s_i) x_i \le Budget \quad (3)$$

$$\sum_{i=1}^{6} w_i x_i z_i \le HumanR \quad (4)$$

$$y_i \le M x_i \quad (5)$$

$$z_i \le M' x_i \quad (6)$$

$$y_i, z_i \ge 0$$

$$x_i \in \{0,1\}$$

The objective is maximizing profit of each project. Equation (1) is for allocating non-financial resources to projects. Equation (2) tells that at least 3 projects should be selected. Equation (3) allocate budget according to the prioritization of

each project. Equation (4) allocate human resource to each project. Equation (5) and (6) says that resources both financial and non-financial can be allocated to projects which are selected. Equation (7) tells that each project have minimum number of human resource to start the project.
The model is coded in GAMS 24.1.2.

IV. Numerical Example

In this part, we are going to apply our proposed model on a project based organization and the following table are data for this organization:

TABLE 20
FINAL RESULTS

	salary	cost	Profit
Project 7	9000	10000	24500
Project 6	19000	30000	43200
Project 8	16500	15000	65200
Project 10	21000	40000	43200
Project 1	16000	35000	71000
Project 4	7000	26000	31790

After solving this non-linear mathematical model following results are derived:

1. The objective function is equal 83500 which is the minimized total cost.
2. Three projects are selected P7, P8 and P4. In other words, $x_7 = x_8 = x_4 = 1$ and others are zero.
3. The amount of non-financial resource which are allocated to the selected projects are respectively 17187, 10312, 9572 for each project.
4. The amount of human resource which are allocated to the selected projects are respectively 731, 308, 402.

V. Results

In many project-based organizations, one of the most important concerns of the manager is to select the optimal projects by considering the goal of organization. If the process of selecting project be a smart and consciously ones they will be empower in the competitive environment. On the other hand, by using a mathematical programming model the best portfolio of projects for organizations could be selected and allocate resources to projects with the lowest costs and highest benefits. In this study we have proposed a non-linear mathematical programming model, a comprehensive model for project portfolio selection (for any types of projects). By applying this model, each organization can select the best projects considering resource constraints and allocate financial and non-financial resources to projects.

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