

A MULTI-STAKEHOLDER INDUSTRIAL PROJECTS SELECTION: AN ANALYTIC HIERARCHY PROCESS AND ZERO-ONE-GOAL PROGRAMMING APPROACH

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ABSTRACT

This study uses Analytic Hierarchy Process (AHP) and Zero-One Goal Programming (ZOGP) to select the most favorable industrial projects from the viewpoints of three stakeholders, namely, government, consultants and academics. Therefore, it is the purpose of this paper to help reach a consensus among the stakeholders for selecting certain projects using weights obtained by AHP as inputs to (ZOGP) model. This is first done by identifying the projects from each individual stakeholder's viewpoint. Further, an aggregate model that simultaneously combines the viewpoints of the three stakeholders is built assuming that the three stakeholders have equal weights. Results show that the aggregate model does strike a balance not only among the conflicting criteria, but more importantly, it strikes a balance among the different stakeholders. Therefore, the aggregate model would make it easier for stakeholders to reach a consensus.

Keywords: *Multi Criteria Optimization; Project Prioritization; Integrated AHP-ZOGP; Multi-stakeholder.*

1. Introduction

Traditional methods used in project selection usually justify the projects using low level capital budgeting which works well for investments with clearly defined benefits as monetary values, but do not work well for longer term strategic investments [1]. This is because intangible criteria, such as environmental, social cannot be converted into exact monetary values [2]. Thus traditional methods ignore intangible benefits and long-term perspectives.

Alidi [3] used analytic hierarchy process to evaluate the initial viability of industrial projects where he used hypothetical data to apply the methodology from the viewpoints of board of directors, company management, and public using twelve criteria. No results were separately given for each of the three stakeholders. It was not clear how these results were combined to give a single performance measure for each industry. Virginia and Tabucannon [4] used goal programming to identify priority areas in pulp industries. Nothing in the study was mentioned regarding how the weights of the criteria were obtained to get the coefficients in the objective function. Clearly, most of these methods fail to account for the presence of more than one stakeholder. In addition, most of these studies considered a limited number of criteria and sub-criteria, whereas this study considered almost 34-39 sub-criteria for each stake holder. The proposed approach attempts to reconcile the conflicts among the different criteria and simultaneously the different stakeholders.

Industrial projects selection is essentially a Multiple Criteria Decision Making (MCDM) problem. One of the (MCDM) approaches, the Analytic Hierarchy Process (AHP) is particularly suitable for modeling both quantitative and qualitative criteria [5]. The selection of AHP in this research can be attributed to the fact that it provides a realistic description of the problem by incorporating all aspects in the hierarchy. Moreover, AHP provides a useful mechanism for checking consistency of the evaluation measures and thus reducing bias in decision-making [5].

This paper proposes a methodology that uses a combination of Analytic Hierarchy Process (AHP) and Zero-One Goal Programming (ZOGP), not only to formulate individual models to reach the most suitable outcome from the viewpoint of each individual stakeholder but also to strike a balance among

the possibly different outcomes obtained from individual ZOGP models to reach optimum project selection. AHP- ZOGP models have the AHP advantage of generating approximate weights. In addition, ZOGP models are capable of resolving conflict, fulfillment of both tangible and intangible criteria from different stakeholders' view points, to achieve the different goals.

In this view, as well as the usual real constraints which form the constraints of ZOGP models, such as budget limitations, there are constraints which have a one-to-one relationship between criteria. The aim of these kinds of constraints is not only to take into account the intangible criteria in the model by their quantification using pair wise comparison of AHP, but also to provide a way to measure how well an alternative performs against a criterion. At the same time, GP cannot also be used alone, because it still requires calculation of the weights of various criteria to use in the objective function of the model. One of the most suitable solutions to this dilemma is to use a combination of Analytic Hierarchy Process (AHP) and Zero-One Goal Programming (ZOGP) in order to obtain a "good" solution that is close to the ideal one.

The paper is organized as follows. In section 2, a brief description of AHP is given. Section 3 discusses the Goal Programming Model. The paper methodology is described in section 4. The application and discussion are given in section 5. Section 6 concludes the paper.

2. Analytic Hierarchy Process (AHP)

AHP is a method developed by Saaty [6] as a multi-criteria decision making tool. It involves decomposing a complex problem into a hierarchy, assessing the relative importance of decision criteria, comparing decision alternatives with respect to each criterion, and determining the overall priority for each decision alternative. The first step in AHP is to construct the hierarchy in such a way that the overall decision goal is at the top level, decision criteria and sub-criteria are in the middle level(s), and decision alternatives at the bottom. Once the hierarchy is constructed, AHP method provides a structured framework for setting priorities on each level of the hierarchy using pair wise comparisons that are quantified using 1–9 scale [6].

3. Goal Programming

Goal programming is a well-known modification and extension of linear programming, developed in the early 1960s by Charnes and Cooper [7]. It became a widely applied technique due to its ability to handle decisions of multiple conflicting goals. Also, the objective function of a goal programming model may consist of non-homogeneous units of measure. If the decision maker is more interested in direct comparisons of the objectives, then weighted or non pre-emptive, goal programming is used. In this case, all the unwanted deviations are multiplied by weights reflecting their relative importance, and then added together as a single sum to be minimized.

4. Proposed AHP -ZOGP Methodology

The proposed methodology includes the following steps:

- a) Identifying criteria, sub-criteria from the view points of the three stakeholders in this study and identifying the alternatives.
- b) Building the hierarchy for each stakeholder
- c) Using the well known AHP method
- d) Using the global weights for the sub-criteria and performance of the alternatives with respect to the sub- criteria as inputs to the Zero-One-Goal Programming model.
- e) In the ZOGP model, the global weights of sub criteria obtained using the AHP become the coefficient of the objective function. The constraints coefficients represent the relative importance of the alternatives when they are compared with respect to the sub-criteria as derived from AHP. While, the right hand side of the constraint is the greatest relative importance of alternatives with respect to the corresponding sub criteria.

The ZOGP formulation for a given stakeholder is constructed as follows:

$$\text{Min } \sum_{i=1}^I w_{hi}^g d_{hi}^{+/-} \quad (h=1, 2, 3) \quad (1)$$

Subject to:

$$\sum_{k=1}^K w_{hki}^{AHP} x_k - d_{hi}^+ + d_{hi}^- = b_{hi} \quad (i = 1, 2, \dots, i) \quad (2)$$

$$\sum_{k=1}^K x_k = m \quad (3)$$

Where:

w_{hi}^g : The global weight of sub criteria i from the viewpoint of stakeholder h .

$d_{hi}^{+/-}$: Undesirable deviation variable with regard to sub criteria i from the view point of stakeholder h

$x_k = 0, \text{ or } 1$ for $k=1, 2, \dots, \dots, 7$

w_{hki}^{AHP} : Relative importance of alternative k with respect to criteria i from the view point of stakeholder h obtained from AHP

b_{hi} : Greatest relative importance of alternatives with regard to sub criteria i from the view point of stakeholder h obtained from AHP

The first statement is the objective function which minimizes the undesirable deviation of the variable with respect to the (i^{th}) sub criteria. Each deviation variable is multiplied by the global weight of its corresponding sub criteria.

The second equation represents the sub criteria constraints. The selection of a given number of alternatives is represented in the third equation. The third equation is used to identify the alternatives that better achieve the objective function given a certain number of alternatives. To use this constraint, its right hand side is set equal to the number of the desired alternatives.

5. Application

The data needed for in this study includes identifying and ranking of criteria, sub criteria, and the industries existing in Gaza Strip. The following sections will describe the methods used in data collection.

5.1 Criteria, Sub criteria and Alternatives Identification

To identify the criteria and sub criteria of industrial projects selection, literature review was conducted and criteria were identified. These criteria and sub criteria were then discussed separately with academic, consulting, and governmental stakeholders. Each stakeholder group has four experts who were asked for their input regarding the criteria and sub criteria. After thorough and intensive discussions with the experts, a refined list of criteria and sub criteria was obtained. Experts from the Palestinian Federation of Industries were interviewed to identify the main industries in Gaza Strip. These industries are as follows: chemical, plastic, food, garment, metal, wood, and construction industries.

Experts were further asked to perform pair-wise comparisons between criteria with respect to their contribution to the objective function. Moreover, experts compared sub-criteria with respect to their contribution to the criteria and finally, they compared the alternatives with respect to their contribution to the sub-criteria using the 1-9 scale proposed by Saaty [6]. Pair-wise comparisons were also checked for consistency.

Due to space limitations, only a sample of the results is shown in Table (1). This sample represents the criteria, sub-criteria, global weights of sub-criteria and the performance of two alternatives out of the seven with respect to sub-criteria from governmental point of view. Similar tables were obtained for each stakeholder. For more elaborate details on these criteria, sub-criteria and alternatives; analysis, and complete AHP results, the reader is referred to [8, 9].

Table (1) Criteria; sub-criteria and their global weights and performance of chemical and plastic industries with respect to sub-criteria.

Main Criteria	Sub Criteria	Global Weight	Chemical	Plastic
Economic	Employment creation	0.081	0.043	0.117
	Vertical integration percent	0.081	0.057	0.099
	Industrial correlation	0.081	0.055	0.151
Financial	Annual revenues	0.046	0.770	0.165
	Capital investment	0.087	0.308	0.198
	% of operat. Surp.\value added	0.033	0.157	0.145
	Payback period	0.038	0.111	0.056
	Breakeven point	0.043	0.039	0.024
	Percent of value added(VA)	0.014	0.149	0.261
	Percent of wages to VA	0.011	0.059	0.145
Technical	Project scale	0.009	0.125	0.146
	Project complexity	0.018	0.446	0.133
	Project type	0.016	0.335	0.149
	Easiness of having license	0.024	0.023	0.247
	Resources availability	0.016	0.089	0.131
	Product quality standards	0.017	0.398	0.106
	Marketing	Internal market share	0.145	0.255
External market share		0.072	0.056	0.056
Environmental	Impact on environment	0.016	0.043	0.101
	Legal issues	0.017	0.04	0.110
	Environmental strategy	0.017	0.053	0.132
	Cross boarder issues	0.015	0.136	0.079
	Relevant conviction	0.016	0.05	0.065
Political & Social	Political conviction	0.030	0.201	0.155
	Governments' support	0.016	0.320	0.129
	Public support	0.018	0.257	0.099
	Donors support	0.025	0.315	0.148

5.2 Individual and Combined AHP-GP Solution

Three individual ZOGP models representing different stakeholders' viewpoint were built. These individual models were solved using LINDO software [10]. The individual stakeholders' models were then aggregated to find a single outcome that satisfies all stockholders' criteria as much as possible.

For brevity, only parts of the government stakeholder model are given below:

Min

$$0.081dnG1+0.081dnG2+0.081dnG3+0.046dnG4+0.087dnG5+0.033dpG6+0.038dpG7+0.043dpG8+0.014dnG9+0.011dnG10+0.009dnG11+0.018dpG12+0.016dpG13+0.024dnG14+0.016dnG15+0.017dnG16+0.145dnG17+0.072dnG18+0.016dpG19+0.017dpG20+0.017dnG21+0.015dpG22+0.016dpG23+0.03dpG24+0.016dnG25+0.018dnG26+0.025dn27$$

Subject to:

$$0.043x1+0.117x2+0.088x3+0.323x4+0.088x5+0.183 x6+0.159 x7-dpG1+dnG1= 0.323$$

$$0.057x1+0.099x2+0.101 x3+0.263 x4+0.132 x5+0.210 x6+0.137 x7-dpG2+dnG2= 0.263$$

$$0.055x1+0.151x2+0.070 x3+0.188 x4+0.121 x5+0.210 x6+0.205 x7-dpG3+dnG3= 0.21$$

Where dpG1and dnG1 are the positive and negative deviations of the first sub criteria (goal) respectively

Table (2) Alternative selection for different stakeholders

# of alternatives	Consultant	Academic	Government	Aggregate
1	x2	x4	x4	x4
2	x6,x7	x4,x7	x1,x6	x3,x7

3	x5,x6,x7	x2,x4,x7	x2,x3,x7	x2,x5,x7
4	x1,x5,x6,x7	x2,x3,x4,x7	x2,x3,x4,x7	x1,x2,x5,x7
5	x1,x3,x4,x5,x6	x1,x2,x3,x4,x7	x2,x3,x4,x6,x7	x1,x2,x3,x4,x7
6	x1,x2,x3,x4,x5,x6	x1,x2,x3,x4,x5,x7	x1,x2,x3,x4,x6,x7	x1,x2,x3,x4,x6,x7
7	ALL	ALL	ALL	ALL

x1 Chemical, x2 Plastic, x3 Food, x4 Garment, x5 Metal, x6 Wood, x7 Construction

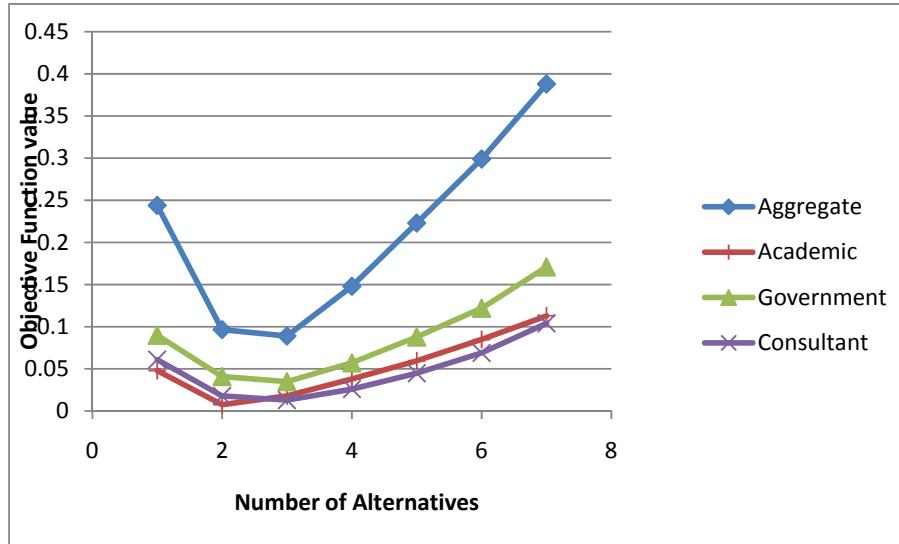


Figure (2): The objective function value for different stakeholders for different number of alternatives.

Table (2) shows the selected alternatives given the number of alternatives. For example, if each stakeholder is to select one alternative only, ZOGP results show that consultants would choose plastics, while academics, government and the aggregate model would all select garment industry. For the case of having three alternatives, results show that consultants would select metals, wood and construction and academics would select plastic, garment and construction and government would select plastic, food and construction. As for the aggregate model, the selected industries would be plastic, metals and construction. The combined result shows kind of a balance between the results of the three stakeholders where it is clear that it selected two alternatives from each stakeholder. These two alternatives are the ones that minimize the objective function. In other words, the alternatives that were not common between the stakeholder were eliminated in the combined model and thus minimizing the deviation.

To obtain further insights into the obtained results, the objective function value of each stakeholder and the aggregate one are shown in Fig. (2) as a function of the number of alternatives. It is observed from the figure, that for consultants, the minimum occurs when they select three alternatives, namely, metal, wood, and construction, while from the view point of academics, the minimum occurs at only two alternatives, namely, garment and construction. As for government, the minimum objective function value occurs when selecting plastic, food, and construction. On the other hand, the aggregate model would require selecting plastics, metal, and construction.

It is noted that using the aggregate model helps resolve the conflict not only among the criteria, but also among the different stakeholders. Therefore, it is easier to convince the different stakeholders

of the aggregate results and consequently reaching a consensus on resource allocation and investments.

6. Conclusion

In spite of the vital role of GP in tackling the problem of multi criteria and multi stakeholders, GP methodology suffers from some limitations that need to be overcome to enhance its ability to give more accurate decisions.

The solution is sensitive to the variations in the weighting procedure. If, the pair wise comparison phase of the AHP is not made correctly, then the weights will be generated incorrectly, which directly affect the outcome of the AHP-GP approach.

The constraints in the GP greatly affect the selection process. Mistakes in the constraints will result in recommendation of an incorrect solution set. In developing the constraints, a question list may be prepared to make sure that the decision-maker considers all relevant issues.

The combination of AHP and GP model has many advantages, one of these advantages is that it forms separate models to reach the most suitable outcome from the viewpoint of each individual stakeholder, as well as extending the use of AHP approach to consider multiple conflicting goals along with resource limitations. Such a combination enables the decision-makers to see different facets of the problem and keep track of the effects of their decisions made in various stages of the solution process on the solution sets. The combined GP-AHP model possesses the flexibility of adding new constraints, aspiration levels, improvement objectives or alternative and modifying them when necessary. However, the integrated GP-AHP model does not have obvious direct disadvantages

The results of the study can be used as an aid to resource allocation in addition to promoting investments in given industries

References

- [1]. Parsaei, H., and Wilhelm, M. "A Justification methodology for automated manufacturing technologies", *Computers & Industrial Engineering*, **16(3)** (1989), pp. 363-373.
- [2]. Yang, C., and Chen, B. "Supplier selection using combined analytical hierarchy process and grey relational analysis", *Journal of Manufacturing Technology Management*, **17(7)** (2006), pp. 926-941.
- [3]. Alidi, A. S. "Use of the analytic hierarchy process to measure the initial viability of industrial projects", *International Journal of Project Management*, **14(4)** (1996), pp.205-208.
- [4]. Virginia, D. J. and Tabucannon, M. T. "Multi-objective models for selection of priority areas and industrial projects for investment promotion", *Engineering Costs and Production Economics*, **10** (1986), pp. 173-184.
- [5]. Ho, W. "Integrated analytic hierarchy process and its applications- A literature review", *European Journal of Operational Research*, **186(5)** (2008), pp. 211–228.
- [6]. Saaty, T. L. *The Analytic Hierarchy Process*, 3rd ed. New York: McGraw-Hill Inc.; 1980.
- [7]. Charnes A. and Cooper, W. W. "Goal programming and multiple objective optimization." *European Journal of Operational Research*, **1 (1)** (1977), pp. 39-54.
- [8]. Agha, S. R. , Jarbo, M., Matr, S. "A multi-criteria multi- stakeholder industrial projects prioritization in Gaza Strip", *Arabian Journal of Science and Engineering*, accepted
- [9]. Palestinian Central Bureau of Statistics
- [10]. Scharge, L. (1997). "Optimization modeling with LINDO", fifth ed., Brooks/Cole Publishing Co., Pacific Grove, CA.