ECONOMIC AND EFFECTIVENESS EVALUATION ANALYSIS OF SOME RESOURCE ALLOCATION PROCEDURES

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Abstract Review of throretical models for cost-effectiveness and of procedures currently being used by different levels of decision makers to evaluate the projects or alternatives is the main objective of this article. To come to some conclussion that which theoretical model would be more effective to be applied for allocating the limited resources among different projects, the performance evaluation procedure has been deveolped. Some of the popular and commonly used models such as B/C analysis and its various improved versions, Integer Programming has been developed and critically analyzed and the suitable procedure under different levels of project funding strategy is recommended.

Key Words Optimization, Resource Allocation, Modelling, Effective Algorithms, Economic Evaluation

چکیده استفاده از مدلهای ریاضی و سنتی مطلوب در انتخاب پروژه های مختلف یکی از معضلات مدیریت تصمیم گیرنده در این موارد می باشد. با توجه به تنوع متغیرهای تصمیم گیری گوناگون، شرایط ویژه تعریف شده هر پروژه و ساختار کاربردی آنها و محدودیت بودجه های در دسترس، نیاز به مدلهای خاص و مطلوب را روشن می سازد. هدف اصلی این مقاله نشان دادن درجه موثر بودن بعضی از مدلهای سنتی رایج بکار رفته در تخصیص منابع محدود و سپس مقایسه این مدلها با مدل گسترش داده شده ریاضی و همچنین مدل جدید تعدیل و تصحیح شده ای که در این مقاله گسترش داده شده است. بر اساس نتایج بدست آمده روی یک حالت خاص نتایج با یکدیگر مقایسه و نتیجه گیری شده است . نتایج بدست آمده نشان می دهد که مدل برنامه ریزی ریاضی صفر- یک یکی از مدلهای موثر و کارآئی است که همیشه جوابهای بهتر را به همراه داشته در حالیکه ضعف مدلهای سنتی بوضوح در تخصیص منابع نشانگر عدم قابلیت آنها در تخصیص پروژهای حیاتی و مهم می تواند تلقی گردد. نتایج بدست آمده از مدل توسعه داده شده بعد از جوابهای بدست آمده از مدل ریاضی صفر- یک، نتایج امیدوار کننده ای را ارائه نموده است.

INTRODUCTION

The purpose of a cost effectiveness analysis, as the term is used in this paper, is twofold . First, it must set forth a method of comparing alternative production improvement programs or project economic analyses. Second, it is a means to simultaneously determine which alternative location, improvement, technology, etc., should be selected at each chosen location, production or plant improvement program.

The concept of Benefit and Cost Analysis has been used in this article and the B/C of project is used as a coefficient to be calculated by the user to be applied to comparison methodology. Of course, depending on the type of the project, different methodologies shall be applied. For example, if a public project is being considered, the calculated benefit would be the "user saving costs", and the govermental commitment for investment, operating cost, and maintenance would be considered its "project cost". Those figure would be shown as annual or present equivallent benefit or cost under the selected "Minimum Attractive Rate of Return"(MARR). So, these information would shape the coefficient of the pieces calculation as the B/C for different selected projects. Therefore, the principle needs are (1) to develop improved procedures for estimating the benefit rise from implementing the peoject, (2) to put weight on different types of project impacts, and (3) to have a cost effectiveness technique for selecting the more efficient and effective project. So, the main objective of this paper is to focus on this latest principle need.

A recent survey in the United States by Rolling [1], provide some disturbing evidence on this type of problems. Many of the cost-effective projects have been eliminated because of the use of unsuitable methodology. With respect to the limited resources and scarce of funds, various methods have been developed to allocate the resouces among the projects. Hircscheifer [2] proposed the Rate of Return Technique, which has many shortcommings, especially when the outcome of a project can not be exactly determined or the risk parameters are presented. For the nonmonetary impacts of the projects, McCrimmon [3] describes the Hierachical Additive Weighting Technique. In this method, the decision-maker assigns values or preferences to the higher level objective and then he assesses the instrumentalities of each of the attributes in attaining these higher level objectives. Lack of consistency, reliability in project selection, and ignoring the incremental effectivenes of alternatives are the major disadvantage of these models. Other studies such as Sequential Elimination [4]. Quasi-additive weighting [5], and the B/C analysis along with the Mathematical Programming Methods have been widely applied in these areas such as works by Marson [6], Scott [7], Shang [8], Singhal [9] and Wilson [10].

In this paper several methods of analysis were selected and some of them have been modified and developed to provide the better solution. These methods are:

(1) Simple benefit Cost Analysis,

(2) Incremental B/C Analysis,

(3) Modified B/C Analysis, (it is developed in this paper),

(4) Mathematical programming (it is also developed here).

Three major research needs were identified during the completion of this study: (1) to further develop the improved algorithm for use with incremental B/C analysis, (2) to compare the results of this method with those obtained with Integer and Dynamic Programming, and (3) to further evaluate the results under different levels of funding strategy to recognize the best methodology under different levels of allocated resources. As it will be shown, further study of mathematical programming methods led to the conclussion that Dynamic and Integer Programming, in addition to the incremental B/C analysis should be emphasized.

THE DEVELOPMENT OF MODIFIED INCREMENTAL B/C ANALYSIS. (MIBCA)

Incremental B/C analysis, with the use of an improved solution algorithm, MIBCA, has been developed in this paper. It offers a viable alternative to the current similar models. This method can be use to array projects in an order such that no preferable ordering of projects can be obtained for the same cumulative cost. This improved algorithm gives approximately the same choice of projects as does either the Dynamic or Integer Programming in many cases. Usually, the only difference would be in the choice of the marginal projects within the budget. The MIBCA has the advantage of ranking all increments of expenditures, from best to wrose, instead of specifying the best group of projects for a given budget. It is belived that the MIBCA is superior to the current fomulation of B/C analysis in two respects. First, it outlines an efficient way of ranking increments of expenditure for mutually exclussive alternatives for a large number of projects. Second, and perhaps the more unique aspect of the algorithm, a clear method is given for averaging successive increments of expenditure at a specific location or improvement program whenever any increments of expenditure at a location gives a higher increment B/C ratio than the next least costly increment or a combination of increments.

MIBCA Algorithm Formulation

Let:

A (i,j) : alternative project j at location or program i,

C (i, j) : present value of current and future costs of A (i, j),

MC (i,j): C (i,j) - C (i,j -1), the marginal or incremental cost of A (i, j)

B (i, j): present value of current and future benefit of A (i, j),

MB (i,j) : the marginal or incremental benefit of A (i,j),

R (i, j): MB (i, j)/ MC (i, j)

The algorithm includes the following steps:

(1) For each location i, array the A (i,j) in an increasing order of C (i,j),

(2) Calculate R (i,j) for each alternative,

(3) For each location i, delete from the array any alternative for which R (i, j) <1. If A (i, j) is deleted, then recompute R (i, j +1) using B (i, j -1), C(i, j-1) and B (i, j+1), and C (i, j +1), then renumber all A (i,j) in location i, so that there are no missing j values.

(4) For each location i, compare R (il) to R (i2). If R (i2) is greater than R (il), then combine these two increments to form the marginal B/C ratio R'(i2) = [MB(il)+MB(i2)}/{MC(il)+MC(i2)}=MB'(i2)/MC'(i2). Leave A (il) in the array, in case budget limitations exclude A (i2) from selection but allow A(il). Then compare R'(i2) to R(i3); if R(i3) is greater than R'(i2), then combine increments to form R'(i3) =[MB(il)+MB(i2)+MB(i3)]/MC(il)+MC(i2)+MC(i3)= MB'(i3)/MC'(i3). Leave A (i2) in array as before. If any R (il) is less than R(i, l-1), or R'(i,l-1), but R(il) must be combined with R (i, l+1) to form R'(i,l+1)= [MB(il)+MB(i,i+1)]/[MC(il)+MC(i,i+1)= MB'(i,l+1)/MC' (i, l+1), then compare R'(i,1+l) to R'(i, l-1). If R'(i, l+1) is greater than R'(i-1) or R' (i, 1-1), then combine increments to form R"(i, l+1)=[MB'(i,l-1)+MB'(i,l+1)]/[MC' (i, l+1) + MC'(i, l+1)] in which can be: = MB" (i, l+1)/MC"(i, l+1).

Continue this combination procedure as long as an R (il) or R'(il), etc., is greater than an immediately proceding incremental ratio [R(i,l-1), R'(i,ll), etc.,]. This proposed procedure yields an "Average" B/C ratio and is requisite in the case of increasing R(ij) values, since benefits from a given increment of expenditure can not be realized unless previous increments are spent. If any R(il), (or R' (il), etc) is less than the relevant preceding increment, then no combination is necessary.

(5) Array all alternatives along with their relevant corresponding marginal costs MC (i,j), MC' (i,j), etc., in decreasing order of their relevant (R (ij), R (ij), etc.) incremental B/C ratios.

(6) Array all alternatives, along with their relevant corresponding marginal costs MC (i,j), MC' (i, j), etc., in decreasing costs, to determine which alternatives to include in the budget. If some A(i,j) can not be accepted without exceeding the budget limit, then exclude that A (i, j) from consideration and proceed until another one is accepted.

If should be noted that, if a fixed budget is allocated such that any funds not spent on one or more alternatives can not be reallocated to a different use, then this algorithm may not select that set of projects yielding maximum benefits for allocated budget.

Integer Programming Algorithm Developement

Integer programming algorithm has been developed in this paper for the purpose of comparison. A modified 0-1 knapsack algorithm has been used to concern choosing the best combination of variables from the total solution set to maximize the total benefit associated with the variables, while acting under a resource constraint.

The general problem can be described as follows:

$$\text{Max. } \Sigma b(i)\, X(i,j) \quad (1)$$

$$\text{Subject to: } \Sigma C(i)X(i) < B \quad (2)$$

$$\Sigma X(i,k) = 1. \quad (3)$$

$$X(i) = 0,1 \quad (4)$$

$$K \varepsilon G(i) \quad (5)$$

where b(i) is the benefit coefficient for X (i), C (i) is the cost coefficient for X(i) and B is the total amount of resource available. G(i) is the Generalized Upper Bound (GUB) constraint for variable X(i). There is a GUB constraint for each location considered.

Using the GUB constraint, there exists a possibility of elliminating one or more alternatives. If an alternative has a lower benefit coefficient but a higher cost coefficient than another alternative within the same GUB constraint, then that alternative may be elliminated from the problem without affecting the optimal solution.

Illustrative Application

To help describe the effectiveness of different methodologies, real data have been extracted from a project with more than 21 alternatives related to a safety program named as "TRANSPORTATION SAFETY IMPROVEMENT PROGRAM (TSIP)", implemented in Tehran for comparison purpose. The input data are given in Table 1.

Using the simple B/C analysis, the following steps are taken in this procedure:

(a) Calculate the ratio of benefits to costs for each at each location.

(b) Select the alternative with the highest B/C ratio at each location and array these alternatives in order of decreasing B/C ratios.

(c) Beginning with the highest B/C ratio, select alternative until the available budget is exhusted. These processes are shown in Table 2.

With the budget of 10000 units, the locations and alternatives chosen would be 4-A, 5-D, 3-A, and 2-A with the associated benefit of 78000 units and unexpended funds of 50 units.

We can also use the other techniques such as Incremental and Modified B/C analysis with the same data input. The results of applying the men-

TABLE 1: Input Information.

Location	Alternative	Benefit	Cost	B/C
(1)	A	50000	15000	3.33
	B	35000	12000	2.92
	C	22000	5000	4.40
	D	15000	3000	5.00
	E	9000	2000	4.50
(2)	A	42000	6200	6.77
	B	27000	4000	6.75
	C	20000	3000	6.67
	D	16000	2500	6.40
(3)	A	14000	1500	9.33
	B	35000	5600	6.25
	C	37000	6000	6.17
(4)	A	6000	550	10.91
	B	13000	1400	9.29
	C	15000	1500	10.00
	D	17000	1690	10.06
	E	18000	1750	10.29
(5)	A	8000	900	8.69
	B	9000	1100	8.18
	C	12000	1300	9.23
	D	16000	1700	9.41

** All Figure are in Present Value (Million Rials)

TABLE 2. Alternative Selection under Various Levels of Resources.

Budget	Selected Alter.	Cost	Cumul.Benefit
1000	4-A	550	6000
2000	4-D	550	6000
3000	4-A, 5-D	2250	22000
4000	4-A, 5-D, 3-A	3750	36000
5000	4-A, 5-D, 3-A	3750	36000
6000	4-A, 5-D, 3-A	3750	36000
7000	4-A, 5-D, 3-A	3750	36000
8000	4-A, 5-D, 3-A	3750	36000
9000	4-A, 5-D, 3-A	3750	36000
10000	4-A, 5-D, 3-A, 2-A	9950	78000

TABLE 3. Process of Implementing the Incremental B/C Analysis.

Loc. /Alte.	Cost	Benefit	INCR. Cost	INCR. Benefit	IB/IC
(1) E	2000	9000	2000	9000	4.50*
D	3000	15000	1000	6000	6.00.(5.27)
C	5000	22000	2000	7000	3.50.
B	12000	35000	7000	13000	1.86.*
A	15000	50000	3000	15000	5.00.(2.8)
(2) D	2500	16000	2500	16000	6.40.(6.67)
C	3000	20000	500	4000	8.00
B	4000	27000	1000	7000	7.00.
A	6200	42000	2200	15000	6.82.
(3) A	1500	14000	1500	14000	9.32.
B	5600	3500	4100	21000	51.2.
C	6000	37000	400	2000	50.0
(4) A	550	6000	550	6000	10.91
B	1400	13000	850	7000	8.24*
C	1500	15000	100	2000	20.00 (9.48)
D	1690	17000	190	2000	10.52*
E	1750	18000	60	1000	16.67(12)
(5) A	900	8000	900	8000	8.89
B	1100	9000	200	1000	5.00*
C	1300	12000	200	3000	15.00
D	1700	16000	400	4000	10.00 (10)

*Incremental Benefite (IB). Incremental Cost (IC).

tioned procedures are shown in Tables 3 and 4, using the same data inputs. The developed algorithm for the Modified Incremental B/C analysis (MIBCA), was shown in section "MIBCA Algorithm Formulation"

The last column gives inceremental B/C ratios in Table 3. In six cases the incremental B/C ratio of a more costly alternative was higher than the next lower alternative. The first case is 1-E with an incremental B/C ratio of 4.5 which should be combined for an average incremental B/C ratio of 5 with the next alternative 1-D which is shown in parentheses and is the ratio used for ranking this combined increment. Similarly, 1-A, 2-D, 4-B, 4-D, 5-B are combined to give the ratios as indicated in Table 3.

Following the indicated algorithm procedure, the selected alternatives are shown in Table 4.

TABLE4. Selection of Alternatives with Incremental Procedure.

Loc/Alter	Cost	Benefit	IB/IC	Cumul. Cost
4-E	1750	18000	12.00	1750
5-C	1300	12000	10.00	3500
3-A	1500	14000	9.33	4550
2-B	4000	27000	7.00	8550
1-D	3000	15000	5.00	11550

Using different levels of budgests, the process of project selection can be performed as it is shown in Table 5.

Again the same data have been input to the MIBCA algorithm developed in this paper. The results are shown in Tables 6 and 7.

The results of implementing the MIBCA are shown

TABLE 5. Selected Alternative Using Incremental B/C Analysis.

Budget	Selected Alter	Cost	Cumul. Benefit
1000	-	-	-
2000	4-E	1750	18000
3000	4-E	1750	18000
4000	4-E, 5-C	3050	30000
5000	4-A, 5-D, 3-A	4550	44000
6000	4-A, 5-D, 3-A	4550	44000
7000	4-A, 5-D, 3-A	4550	44000
8000	4-A, 5-D, 3-A	4550	44000
9000	4-A, 5-D, 3-A, 2-B	8550	71000
10000	4-A, 5-D, 3-A, 2-B	8550	71000

TABLE 6. The Input Data Arrangement for MIBCA Algorithm.

Loc./Alter.	Cost	Benefit	IB/IC
4-E	1750	18000	12
4-A	550	6000	10.91
4-D	1690	17000	10.53
5-C	1300	12000	10.00
5-D	1700	16000	10.00
4-C	1500	15000	9.48
3-A	1500	14000	9.33
5-A	900	8000	8.89
4-B	1400	13000	8.24
2-B	4000	27000	7.00
2-A	6200	42000	6.82
2-C	3000	20000	6.67
2-D	2500	16000	6.40
3-B	5600	35000	5.12
1-D	3000	15000	5.00
3-C	6000	37000	5.00
5-B	1100	9000	5.00
1-E	2000	9000	4.50
1-C	5000	22000	3.50
1-A	15000	50000	2.80
1-B	12000	25000	1.86

in Table 7.

Returning to the previous example, the integer programming Algorithm can be developed for the above data as follow:

Max: Z =50000 [1-A] + 35000 [1-B] + 22000 [1-C] + 15000 [1-D] + 9000 [1-E] + 42000 [2-A] + 27000 [2-B] + 20000 [2-C]+ 16000 [2-D] + 14000 [3-A] + 35000 [3-B] + 37000 [3-C] + 6000 [4-A] + 13000 [4-B] + 15000 [4-C] + 17000 [4-D] + 18000 [4-E] + 8000 [5-A] + 9000 [5-B] + 12000 [5-C] +16000 [5-D]

SUBJECT TO: 15000 [1-A] + 12000 [1-B] + 15000 [1-C] + 3000 [1-D] + 2000 [1-E] + 6200 [2-A]+ 4000 [2-B] + 3000 [2-C]+ 2500 [2-D]+ 1500 [3-A]+ 5600 [3-B] + 6000[3-C] +550 [4-A] + 1400 [4-B]+5600 [3-B]+6000 [3-C]+ 1750 [4-E]+
900[5-A] + 1100 [5-B] + 1300 [5-C]+1700[5-D]<=AVAILABLE BUDGET

[1-A] + [1-B] + [1-C] + [1-D] [1-E] < = 1
[2-A] + [2-B] + [2-C] + [2-D] < = 1
[3-A] + [3-B] + [3-C] < = 1
[4-A] + [4-B] + [4-C] + [4-D] +[4-E] < = 1
[5-A] + [5-B] + [5-C] + [5-D] < = 1
ALL VARIABLES ARE ZERO OR ONE

The Integer Programming Algorithm generated the following solution in less than a second as shown in Table 8.

Clearly, the solution obtained is superior to the one using the other techniques. Of course the mechanism of the Integer Programming Algorighm are complex, and hard solution to problems of even moderate size are intractable. However, there are many softwares that can be used with an IBM - 486

TABLE 7. MIBCA Implenentation in Resource Allocation Program

Budget	Selected Alter	Cost	Cumul.Benefit
1000	4-A	550	6000
4000	4-E, 5-C	3050	30000
6000	4-A, 5-D, 3-A	4550	44000
8000	4-A, 5-D, 3-A, 2-C	7550	64000
9000	4-A, 5-D, 3-A, 2-B	8550	71000
10000	4-A, 5-D, 3-A, 2-B	8550	71000

TABLE 8. The Out-Put of Integer Programming.

Budget	Selected Budget	Cost	Cumul. Benefit
1000	5-A	900	8000
2000	4-E	1750	18000
3000	3-A, 4-C	3000	29000
4000	3-A, 4-C, 5-A	3900	37000
5000	3-A, 4-E, 5-D	4950	48000
6000	2-D, 4-E, 5-D	5950	50000
7000	2-D, 3-A, 4-D, 5-C	6990	59000
8000	2-C, 3-A, 4-E, 5-D	7950	68000
9000	2-B, 3-A, 4-E, 5-D	8950	75000
10000	2-A, 3-A, 4-A, 5-D	9950	78000

to execute the steps of the algorithm.

Comparison of Methods

A case study as an example problem was presented for purposes of comparing four methods of solving the problem of allocating a fixed budget. The out-put of running each method is shown in Table 9.

TABLE 9. Benefits Resulted from Executing the Models.

Budget	S. B/C	I. B/C	MIBCA	Integer Prog.
1000	6000	-	6000	8000
2000	6000	18000	18000	18000
3000	22000	18000	26000	29000
4000	36000	30000	30000	37000
5000	36000	44000	44000	48000
6000	36000	44000	44000	50000
7000	36000	44000	53000	59000
8000	36000	44000	64000	68000
9000	36000	71000	71000	75000
10000	78000	71000	71000	78000

The graphical presentation of the results are shown in Figure 1.

CONCLUSION

Running the various sets of data on the models included the developed MIBCA algorithm and Integer Programming, the following conclusions can be drawn:

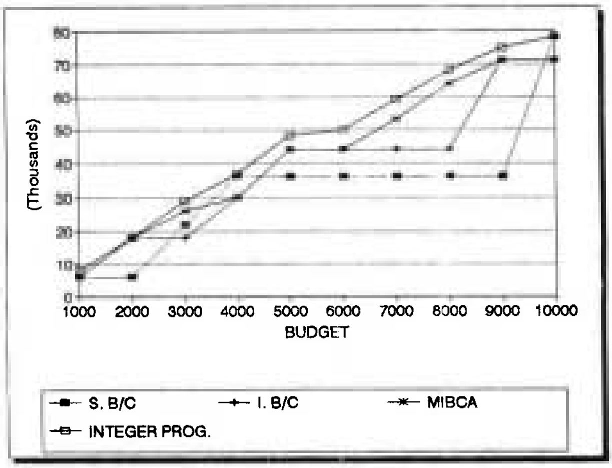

Figure1. The graphical presentation of benefits resulted from the implementing of each procedure.

a) Integer Programming will always yield the optimal solution and is insensitive to the form of B/C coefficients. Further, Integer Programming appears to be more efficient and effective regarding the computation time and the optimal solution obtained in terms of benefits conservation.

b) MIBCA developed in this paper shows a better solution results when we compare it with the Simple and Incremental B/C methods.

c)Benefit Cost Ratio Analysis should never be used when incremental B/C analysis can be applied.

d) MIBCA developed in this paper shows an acceptable solution it is compared Integer programming. It always present superior results to other available non-mathematical programming techniques, widely used in management decision processing.

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