

A STUDY ON THE METHODS  
OF  
MULTI-CRITERIA EVALUATION  
OF  
PUBLIC POLICIES

*A Dissertation*

SUBMITTED  
IN  
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF  
MASTER OF PHILOSOPHY IN ECONOMICS

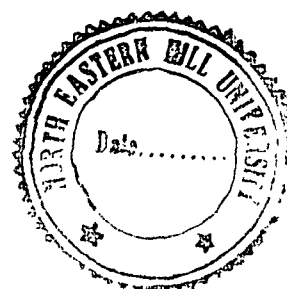
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To



DEPARTMENT OF ECONOMICS  
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DECEMBER, 1988



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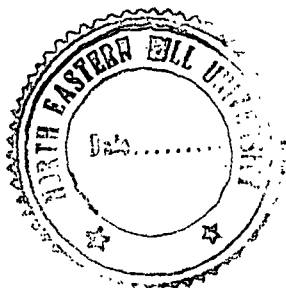
## CERTIFICATE

This is to certify that Ms. Kankana Bhattacharjee has worked under my supervision for her M.Phil Dissertation entitled "A Study on the Methods of Multi-Criteria Evaluation of Public Policies" and no part of it has been submitted elsewhere for the award of any degree. This dissertation, in my opinion, is worthy of an award of the Degree of Master of Philosophy in Economics.

SHILLONG

THE 15<sup>th</sup> DECEMBER 1988.

  
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**C H A P T E R - I**  
**I N T R O D U C T I O N**

## INTRODUCTION

### 1. Need for Evaluation of Public Policies

In economic spheres, all government endeavours are ultimately directed to meeting a single objective - that of improving human welfare or wellbeing in the economy by accelerating economic development. No one would dispute this lofty goal but the problem arises since there is no direct measure of welfare of the people in the society and hence this single objective cannot help in giving proper guidance to the decision maker in choosing from among the various possible alternative paths of action. The objective of increased welfare has to be broken up into a number of components, and so planners base their decision making on not one but a number of objectives - all of which are instrumental in pursuing the said lofty goal. Hence during a plan period, many objectives, often conflicting, and either commensurable or noncommensurable, are simultaneously pursued. Not only this. The same objectives can be achieved through different alternatives. Some of these alternatives will be more effective than others both in terms of their direct effects and induced secondary and tertiary effects. So what if by a particular policy one lakh people are served at the cost of one million rupees over a period of time. It is also necessary to answer various other questions like - Are they the right people? Will some other policy intervention serve these people better or serve a greater num-

ber of people or the right kind of people and help in advancing social welfare and personal fulfilment? Since the aim is to choose only that set of alternatives which can be considered 'the best' in terms of achievement of the objectives as well as in terms of costs (which includes the undesired side effects), it is imperative to evaluate the various alternatives. In the absence of systematic and scientific evaluation there may be non-attainment of the goals or the goals may be achieved at a very high cost. Apart from these reasons evaluation is necessary also because it helps to minimise the personal biases of the decision maker and to make implicit value judgements explicit.

Here it would not be out of place to distinguish between evaluation and decision making, and also to highlight the relationship between the two. (Evaluation might be of two types: one before final selection of the projects/policies to be implemented, and the other, after the implementation. We may call them ex-ante and ex-post evaluations respectively. Ex-post evaluation should more appropriately be called "appraisal". In this study we are not concerned with ex-post evaluation. Hence wherever we use the term "evaluation", we mean ex-ante evaluation). Decision making necessarily involves the choice among alternatives, which in turn involves assessment. Decision making presupposes evaluation; but evaluation may sometimes lead to a fix or the state of indecision. The way

out from such a fix is to call in additional objectives, constraints or considerations. From this, it follows that all methods of decision making are basically the methods of evaluation that ultimately aim at separating the set of all feasible projects/policies/plans into two subsets,  $S_1$  and  $S_2$  such that the elements of  $S_1$  dominate over the elements of  $S_2$ . If  $S_1$  is a singleton, we have a unique optimal project/policy/plan that should rationally be accepted for implementation. If  $S_1$  is not a singleton, we have alternative optima. By invoking additional considerations  $S_1$  can always be made a singleton set.

## **2. Economist as an Evaluator and Counsellor, not a Decision Maker**

In many countries, including our own, the ultimate task of decision making is on the politicians. The task of an economist or an analyst is merely to indicate ways in which direction the decision maker might proceed in the process of decision making. It is for the economist to analyse the situation and predict a good action or a set of good actions to be taken into consideration, or to systematically rank the alternatives according to their desirability. The task of the policy analyst or the economist is to specify ways and means in which human dignity can be achieved under given circumstances so that whatever potential for progress there is, can be fully utilized. Evaluation, which is the assessment of outcomes and effects is essentially a means to this end. And this

assessment will help the decision maker in taking policy decisions. Therefore in this study we will concern ourselves with evaluation. Though evaluation can be done at different stages of the planning process we shall deal only with evaluation that is done prior to decision making, that is, evaluation that will form the basis of and aid in taking decisions.

### 3. Role of Criteria in Evaluation

Evaluation should be done on the basis of criteria. Criteria are the measures on whose scale the valuation of the worth of an alternative is made. For evaluation of public policies the criteria will be derived from the national plan. Traditionally, evaluation was done on the basis of a single criterion. This single criterion was either the maximisation of the benefit function or the minimisation of the cost function or alternatively, the maximisation of the Net Social Benefit function. A single criterion model is, however, only a simplified form of the reality and hence may lead to wrong decisions. In real world economies, public policies should satisfy more than a single criterion. Hence it is more realistic to assess the worth of the alternatives on the basis of many different measures together. Due to the diverse possible effects of even the simplest policy one must in most cases use multiple criteria for evaluation. In Single Criterion Evaluation Methods these criteria are transformed into a single composite criterion. Such a transformation, however, can only be arbitrary

because the different criteria are often noncommensurable and also sometimes conflicting. Moreover it is also argued that a Single Criterion Model involves no decision at all in the real sense of the term, for once the model is framed, it takes the place of the decision maker and a suitable solution procedure would automatically help in finding the optimal solution. Such models therefore replace the decision maker rather than directing the decision maker in his decision making which is the real aim of evaluation. Hence it was realised that evaluation to be really useful should be made on multiple criteria.

#### **4. Need for Multicriteria Evaluation Methods**

Ever since the 1960's, therefore, studies and researches were made on multi-criteria evaluation. It was realised that the nature of most criteria are such that they are conflicting. As such, no single alternative can be optimal with respect to all criteria because in case of conflicting criteria it is not possible to increase the achievement level of one criterion without a corresponding decrease in the achievement levels of some other criteria. Consequently, a number of alternatives present themselves as efficient solutions as contenders for the final choice by the decision maker. Here it would not be possible to have any one optimal solution but the solution will be the one that is chosen by the decision maker as a good compromise solution. Hence the essential feature of tradeoffs that must be made in the decision process

is explicitly taken care of in multi-criteria evaluation methods. However, in single criterion models this is not possible because in this case, as we have said, the model replaces the decision maker to find an optimal solution.

With growing awareness in this connection, various methods for carrying out multi-criteria evaluation under various situations have been developed ever since the Sixties.

Since evaluation involves expenses in terms of money and time, it should necessarily be done in a scientific and systematic manner. Otherwise it will not fulfil the very purpose for which it is done. For evaluation to be useful therefore certain conditions should be fulfilled. Firstly, the criteria should be chosen wisely. The range of alternatives from amongst which choice is to be made, is also to be chosen carefully, for the same effects could be attained by many alternative policies. Thirdly, the right method should be chosen which will suit the particular requirements of the problem.

##### **5. The Objectives and the Organization of the Present Study**

In this study we will not concern ourselves with the choice of the criteria. We take it that the criteria for evaluation of public policies will be obtained from the objectives laid down in the national plans. Nor will we concern ourselves with the choice of alternatives to be evaluated. This choice will be exercised by the planner and decision

making authorities themselves. In this connection, we would like to mention that while it is possible for the decision maker to have alternative policies before him for choice, each of these policies can be implemented through various projects amongst which again choice may be required to be made. So in our study, whenever we mention 'alternatives' it can be taken to mean either 'policies' or 'projects'.

At this juncture we must explicitly mention that a 'policy' is necessarily formulated and implemented through projects. Let policy A be implementable through  $(p_1, p_2, \dots, p_n)$ ,  $n$  alternative projects, and let another policy B be implemented through  $m$  alternative projects,  $(q_1, q_2, \dots, q_m)$ . Now, if we can show that a particular project  $p_i$  is not dominated by any other project  $p_j$  ( $j = 1, 2, \dots, n; i \neq j$ ), and another project  $q_k$  is not dominated by any other project  $q_j$  ( $j = 1, 2, \dots, m; k \neq j$ ), and further that  $p_i$  dominates over  $q_k$ , then policy A, implemented through project  $p_i$ , is superior to the policy B implemented through any project whatsoever. Thus, through evaluation of projects, policies can be evaluated and decisions with regard to final choice of policy through a particular project can be made. Thus when we are choosing the best one from among many alternative projects designed under policy A, we are making multicriteria evaluation of projects, and when we are choosing the best one from among the many alternative policies, we are making multi-criteria evaluation of policies.

Our concern in this study is with the choice of the appropriate method for multi-criteria evaluation. Though a large number of methods have already been developed in the literature, they can be applied usefully only when proper understanding of them is obtained. As a first step towards this end much of the work which remains to be gathered comprehensively should be compiled together. The importance of this line of study having been realised intensive research is still going on. However, the work that has been done till now is not adequate to suit all problems in the economy or even the different economies each with their special features. We can say that multi-criteria evaluation has just emerged from its infancy period and hence in most countries it is still not applied for evaluating public policies. It is realised that it would not be wise to apply some of these techniques in their present form to every economy for choosing the right policies in any situation. What is necessary at this stage is to nurse this area and to help it to fully reach its maturity. With this purpose we have undertaken our present study. We think it is very necessary to, first of all, expose the reader to the nature of the methods already developed. To achieve this we have made a comprehensive attempt to bring them together, and such an organisation of the available literature forms Chapter II of this work. We have given a fairly detailed state of the art survey of the methods already developed, and we have critically discussed their merits and demerits. Some

of these methods assume that the decision maker is able to articulate his preferences consistently, at the very start of the evaluation. Some other methods require the decision maker to articulate his preferences at every stage till a solution is reached. These are called Interactive Methods. Some methods lead to selection of one alternative considered to be the 'best' among those studied. This assumes a complete transitive comparability between pairs of actions. However, quite often we may face problems for which pairs of actions cannot be compared. For qualitative, random or noncommensurable criteria, pairs of actions cannot be compared, so as to arrive at the best solution. Hence the decision maker may want to sort out all those actions that seem 'good' among those studied. To take care of this, Nondominated solution techniques have been developed. Again the decision maker may in many cases want to rank the alternatives in decreasing order of preference. Various outranking methods have been developed for this. Some of the methods can accommodate the preferences of a single decision maker, while some others, the Group Decision Making methods, allow for considering the preferences of more than one decision maker. Sometimes the objectives and constraints are only imprecise - in such cases the Fuzzy Set Theoretic methods can be applied. Again probabilistic as well as deterministic methods are there. Also while some methods directly work with the multi-criteria, some others work by first transforming the multi-criteria into a single composite

function e.g., the Weighted Additive Methods, Multiple Objective Value Theory, Cost-Benefit and Cost-Effectiveness analyses. We should remember that single criterion methods are only a special case of multi-criteria evaluation methods.

To encourage more use and applicability of the multi criteria evaluation methods it is also necessary to go into the implicit valuations underlying the methods so that a better and more objective understanding of them can be obtained. With this objective we devote Chapter III to discuss the underlying concealed valuation and implications of using the different methods of multi-criteria evaluation of public policies.

Not only this, public policies may have to be evaluated at either the macro level or at the micro level. Since the setup at the different levels are not the same, the same methods may not be suitable for application at both levels. In Chapters IV and V we have discussed some of the characteristic features of evaluation at micro and macro levels respectively. The scope of obligations and responsibility of the decision maker at the two levels are also different. Moreover the constraints at the two levels are also not the same. What is a variable at the macro level may not be so at the micro level i.e., it may have to be taken as a constraint. It is only an understanding of such features that will help to choose the right methods at the right level.

Most of these methods that are available might certainly be useful in the institutional set up of the developed economies where the noneconomic factors are fairly adjusted with the economic system. We understand that in the underdeveloped economies, this is not the case. In these countries both economic and noneconomic factors are very important and they act and interact with each other and also sometimes stand as obstacles to development in each other's sphere. Under such conditions will the methods already developed for multi-criteria evaluation suffice for successful evaluation of public policies in underdeveloped economies also? We reiterate that evaluation involves a lot of time and money and should be carried out only to give proper direction to decision making. Unless the methods fit into the institutional set up of these countries, it would only be a wasteful practice to do such evaluation.

Even generally speaking, it is considered that the tools of economic analysis forged in developed countries, when used for analysing and solving problems of underdeveloped economies often lead to bias in the opportunistic direction. Hence we cannot recommend the methods of multi-criteria evaluation of public policies for use in the underdeveloped countries without testing their applicability to the special features and problems of these countries. Failure to root evaluation firmly in the realities of such economies would distort

decision making and hence lead to partial or total failure of planning. Such problems have been discussed in Chapter VI and we have tried to make some proposals for improvement in the methods to suit the special needs of such countries. We feel that a different framework of evaluation of public policies in underdeveloped economies is needed. However, we realise that this is difficult until more and more empirical work in this field is done, because though methods and models are an abstraction from facts yet they have necessarily to be grounded on facts, and facts in this case can be gathered through empirical work.

In Chapter VII we have presented the summary of the study, though without repetition as much as possible. We have laid open the limitations of the present work in hope of further improvements that such lacuna may call for. It does not need acknowledgement that ours is a purely theoretical study. Our conclusions and suggestions are very broad and general, flowing from reflections rather than from experiences actually encountering the problems in an empirical task of evaluation. However, we consider that even a theoretical work of this type - just a humble attempt to the task of demonstrating the inadequacies of the inherited methods and thereby showing a way to improvement - is in itself worthwhile.

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**C H A P T E R - I I**  
**REVIEW OF DIFFERENT TECHNIQUES OF**  
**MULTICRITERIA EVALUATION**

## REVIEW OF DIFFERENT TECHNIQUES OF MULTICRITERIA EVALUATION

The need for evaluation having been realised, different techniques have been developed to carry out the actual process of evaluation. In this Chapter, we will take a cursory look at the various methods that have been evolved in the literature in the field.

As it has been discussed before, while formulating a plan various objectives are pursued. Sometimes, these objectives are complementary. But often, they are competing among themselves such that attainment of one is possible only at the cost of others. Resolution of these conflicting objectives is the most difficult task in decision-making and evaluation of projects, plans, and public policies.

To tackle this problem, either of the two approaches can be adopted:

- (1) The first approach consists in developing a single composite criterion which incorporates all the objectives of the problem. If this method of evaluation is used, it seems as if the possibility of arbitrariness and subjectivity in evaluation is reduced. But a little reflection shows that such a method requires that appropriate weights should be assigned to the different criteria in numerical terms and this assigning of weights itself would reflect the different sub-

jective values of the policy maker. And this assigning of weights is, by no means, an easy task.

- (2) The second approach tries to avoid this difficulty by going in for a multicriteria evaluation reflecting the different objectives set for the plan. This approach has the added advantage that it is possible to single out the contributions of every single policy instrument in achieving the maintained objectives.

A review of the literature shows that in the first half of the century, it was the first approach that was adopted. More precisely, in the 1930's, the first applications of Cost Benefit Analysis was made to evaluate the various alternative projects on which public expenditure could be made. However, due to the many drawbacks of this method, the first set of studies in Multi-Criteria Evaluation was carried out in 1960's and since then it has gained more and more attraction of the Decision Makers in various fields.

#### **METHODS THAT CONSTRUCT COMPOSITE OBJECTIVE FUNCTION**

We now give a description of different methods that have been developed. Let us first of all discuss the Cost Benefit Analysis which was considered the main method for evaluation over so many years.

Conceptually, let a policy  $\pi$  be such that it could be implemented through various alternatively adoptable projects

$P_1, P_2, \dots, P_k$ . Any  $P_i$  has  $Q_j$  ( $j=1,2,\dots,m$ ) as its effects according to the functional rule  $f_{ij}$ . Thus  $Q_{ij} = f_{ij}(P_i)$ . Let some of the  $Q_j$  be undesirable such that they are considered as "costs" and some others be desirable to be considered as benefits. Let us assume that the monetary weight  $m_j$  could be assigned to  $Q_j$ ,  $j \in J$ . Then

$$Z_i = \sum_{j \in S} Q_{ij} m_j - \sum_{k \in \bar{S}} Q_{ik} m_k; \quad S \cup \bar{S} = J$$

is the total net benefit (Benefit - Cost) evaluated in money terms for the  $i$ th project. Here  $J$  is the index set.  $J = (1, 2, \dots, m)$  for  $m$  effects.  $S \subset J$  such that  $S$  includes the index of all those and only those effects which are desirable.  $\bar{S}$  is the complementary set of  $S$  such that  $S \cup \bar{S} = J$  and  $S \cap \bar{S} = \emptyset$ , a null set.

According to this approach, the condition for the adoption or rejection of a project/policy is that the benefit accruing from a project should exceed its Costs where all the Benefits and Costs are evaluated in money terms, i.e. we must have:

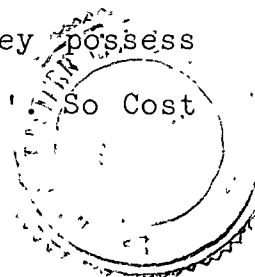
Gross Social Benefits > Gross Social Costs.

or

$$\text{Net Social Benefits} = B - C > 0 \quad \dots \dots (1)$$

This approach seems to be very logical in that any project whose Costs are greater than Benefits would hardly be viable. Public policies/projects are usually undertaken because they possess at least some of the characteristics of 'public goods'. So Cost

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Benefit Analysis is concerned with Social Benefits and Social Costs and not merely revenue and costs. The analysis attempts to quantify and describe the social benefits and costs from a project in terms of a common monetary unit. Since many of the government programmes of expenditure are such that both benefits and costs extend into the future, the analysis of 'time factor' is a very important part of Cost Benefit Analysis. Because of this factor, and because of the 'public good' nature of such projects, three basic questions arise - (1) Is it possible to identify and quantify all these benefits and costs? (2) How will future benefits and costs be identified and incorporated into the analysis? (3) If at all the benefits and costs are all identifiable, what will be their respective prices?

Before dealing with those questions let us first of all discuss the three alternative criteria that have been suggested for carrying out Cost Benefit Analysis.

#### (i) Present Value of Net Benefits Criterion

The formula for this criterion is

$$\sum_{t=0}^n \frac{B_t - C_t}{(1 + i)^t} \dots\dots\dots (2)$$

Where,  $B_t$  = Total benefits in t-th year

$C_t$  = Total Costs in t-th year

$n$  = Number of years spanned by the project

$i$  = Social Discount Rate

Here, all the projects with positive Present Value of Net Benefits (PVNB) can be adopted. If only one out of the several projects is to be chosen, then the project with highest PVNB should be chosen.

### (ii) Internal Rate of Return Criterion

The relevant formula for this method is

$$\sum_{t=0}^n \frac{B_t - C_t}{(1+r)^t} = 0 \quad \dots\dots (3) ; r = \text{rate of return}$$

Here, from the above equation, the value of the rate of return ( $r$ ) is calculated. Projects having  $r < i$  will be rejected and those for which  $r > i$  are accepted. The project with the highest  $r$  is selected.

### (iii) Benefit Cost Ratio Criterion

Here, the ratio

$$\frac{\sum_{t=0}^n \frac{B_t}{(1+i)^t}}{\sum_{t=0}^n \frac{C_t}{(1+i)^t}} \quad \dots\dots\dots (4)$$

is taken

Projects with this ratio  $< 1$  are rejected and those with this ratio  $> 1$  are considered worthwhile. The project having the highest B/C ratio is selected (B/C is benefit/cost ratio).

It becomes necessary to use the above criteria, because, in most cases, the projects are mutually exclusive and so the 'best' one has to be chosen. Also, the government's budget is

not unlimited but constrained.

The above three criteria do not always give the same results. Hence the problem of which criterion to use is also there. In this connection, the following points may be noted:

- (1) When projects are mutually exclusive, the IRR rule is misleading since it favours projects with lower capital costs than others. Here the PVNB criterion should be used.
- (2) For projects under constrained budget, the objective will be to maximise the combined NPV of projects chosen.
  - (i) If the constraint is applicable to expenditure in a single period, then projects must be ranked by Benefit - Cost ratios.
  - (ii) When funds are constrained beyond a single period, the procedure is a little complex. The objective is to maximise the combined NPV of the chosen projects but programming methods are required for the general solution.
  - (iii) If the benefits of the projects are in marketable form, and the government can use its receipts for reinvestment then IRR criterion is appropriate.
  - (iv) If the receipts outside the budget constraint are available for covering future operating cost, then Benefit-Cost ratio criterion is the most appropriate.

- (3) The IRR criterion shows a bias towards projects with short economic life and against those with long economic lives.
- (4) The IRR shows bias against project with long gestation period which does not yield benefits for a number of years in the beginning.
- (5) Many projects are such that the entire investment outlay is not made in the start itself. Here IRR becomes difficult to calculate. Also IRR is suitable only if the projects are wholly independent of each other.
- (6) While applying IRR criterion we have to solve the polynomial

$$D_0x^0 + D_1x^1 + D_2x^2 + \dots + D_nx^n = 0$$

Where  $D_t = B_t - C_t$ , and  $x^t = \frac{1}{(1+r)^t} = \left(\frac{1}{1+r}\right)^t$ ;

$$t = [0, n].$$

The solution of the above polynomial can be made easier by transforming it into the eigen value problem. Dividing both sides of the polynomial by  $(-D_n)$  we get,

$$\frac{D_0}{-D_n} x^0 + \frac{D_1}{-D_n} x^1 + \dots + \frac{D_n}{-D_n} x^n = 0$$

The companion matrix of order  $n \times n$  can be constructed with the coefficients of the polynomial.

$$D = \begin{bmatrix} 0 & 0 & 0 & \dots & 0 & d_0 \\ 1 & 0 & 0 & \dots & 0 & d_1 \\ 0 & 1 & 0 & \dots & 0 & d_2 \\ 0 & 0 & 1 & \dots & 0 & d_3 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & 1 & d_{n-1} \end{bmatrix}_{n \times n}$$

Where  $d_j = \frac{D_j}{-D_n}$ . With this companion matrix,

the solution of

$DZ = xZ$  (where  $x$  is eigen value and  $Z$  is the associated vector)

for  $x$  gives  $\frac{1}{1+r}$  and hence  $r = (\frac{1-x}{x})$ . However, the solution will have  $n$  eigen values; some may be negative and some others may be complex. We will be interested in the positive  $r$  only. A real problem, however, may arise when none of  $r$  are positive. Among the positive values of  $r$ , the choice depends on the assessment of the rate of discount which we may give for future net benefits.

(7) BCR criterion has the advantage that it can highlight the role of uncertainty.

To overcome the problems associated with IRR criterion an interesting rule of 'normalisation' is suggested (Mishan, E.J. 1967), by which Benefits and Costs are compounded forward

to a 'terminal value' such that

$$TV(B_t) = B_t(1 + i)^{n-t} \dots\dots\dots (5)$$

Where,  $TV(B_t)$ : terminal value of benefits in time period 't'

$i$  : compound rate

$(n-t)$  : number of years between 't' and terminal year 'n'

Reinvestible benefits are compounded at rate  $k$ , the opportunity cost rate, and consumption benefits at rate  $s$ , the social time preference rate (STPR).

Then the normalised IRR is given as

$$r^* = \sqrt[n]{\frac{TV(B)}{PV(K)}} - 1 \dots\dots\dots (6)$$

The relationship between NPV criterion and IRR criterion can be understood from the figure overleaf. The curve AB shows investment of a project. As NPV falls, Rate of Discount increases and after a time NPV touches 0 and then becomes negative. The rate at which the NPV changes from positive to negative is the IRR.

After having discussed the three criteria, we now come back to our first three questions which we have raised.

### **Identification and Measurement of Benefits and Costs**

The first question is about the identification of all the relevant social benefits and social costs. The direct benefits

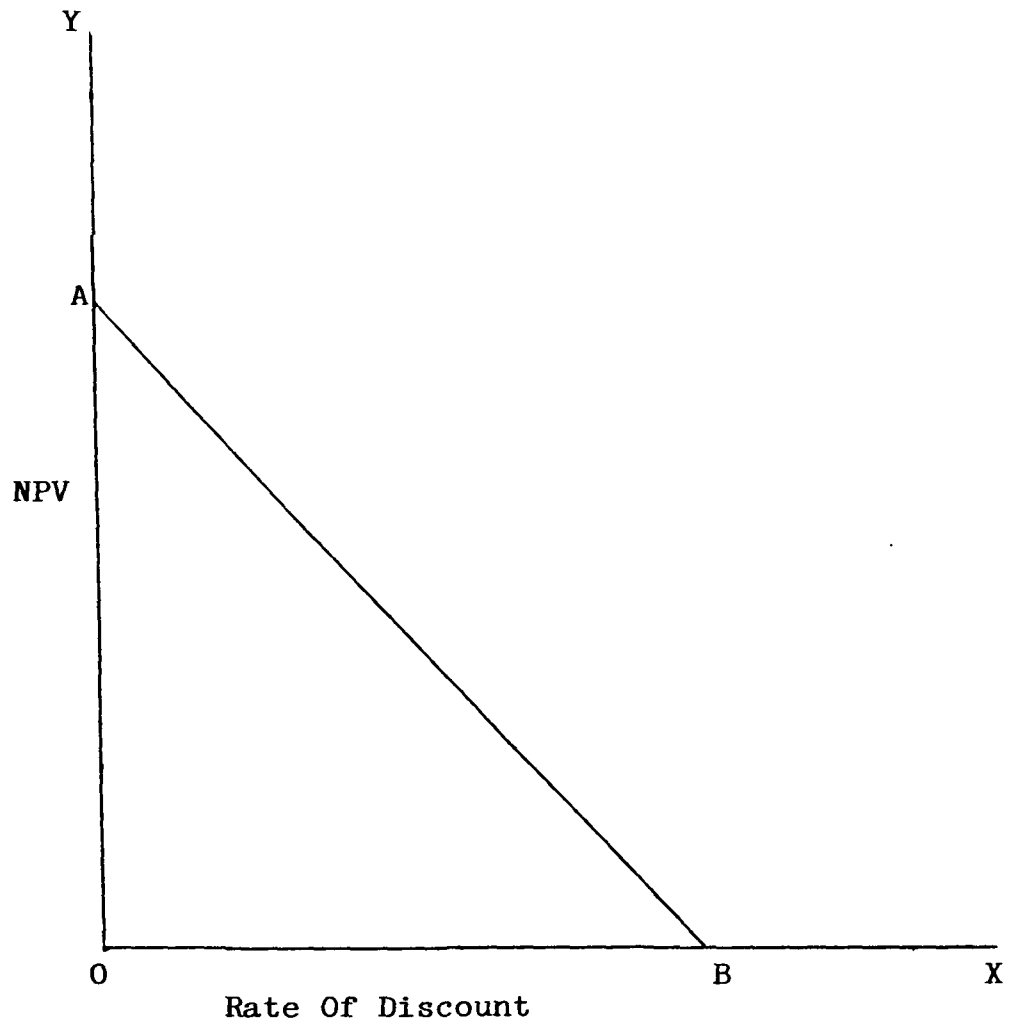


FIG - 1.

of a project/policy are not difficult to identify. But the difficulty arises because most of the projects/policies have a number of external effects too and these are as important as the direct effects and must therefore be accounted for. Air and water pollution due to industrialisation, deforestation, noise due to increased traffic, etc. are all external effects of projects/policies. These effects are usually incidental and unintended at the time of undertaking the projects. Nevertheless, such effects cannot be ignored. External effects directly influence the welfare of others and not indirectly through the price system. Hence the presence of external effects may lead to equilibrium solution which may not be Pareto optimal (Mishan, 1972). One way of treating external effects is to 'internalise' them, i.e., to treat the external effects as a joint product. However, not all external effects can be internalised. Another way to treat external effects is to consider the amount of compensation that has to be paid to each individual, affected by the external diseconomies, in order that they may be willing to put up with it, and the amounts that each individual deriving desirable external effects are willing to pay for it. If the net of this sum is positive then the project is worthwhile.

External effects should not be confused with 'intangible' benefits and costs. 'Intangibles' are those benefits and costs which are not quantifiable in money terms, even though they may be the intended products of a project/policy, e.g. policies

for increasing health and education. Ronald and McKean (1958) have given a method for dealing with such unvalued benefits and costs.

In identifying benefits and costs, care should be taken to exclude transfer payments because they are neither benefits nor costs. Only if Cost-Benefit Analysis is undertaken at international level, should transfer payments be taken into account. Sometimes transfer payments are counted as both costs and benefits and this leads to the error of double counting. Double counting can also arise by counting real costs and benefits more than once. This error of double counting must be avoided. Due to these problems, identifying of all relevant costs and benefits is difficult and even more difficult is the identification of future benefits and costs.

In Cost-Benefit Analysis, all the benefits and costs are measured in terms of a common monetary unit by which process the problem of multi-criteria evaluation gets converted into a single criterion optimisation problem. Let us therefore turn to the question of measurability. Some of the benefits and costs are marketable and others are non-marketable goods and services. Even for the marketed benefits and costs the market prices do not always reflect social valuations. Hence, it is thought more appropriate to use 'social opportunity costs' of goods and services, i.e. their 'shadow' or accounting price. Shadow prices should reflect the externalities also. Though

the more popular method is to separately make social valuations of externalities, actual market prices do not reflect such externalities. However, if market prices are fixed on the principle of Marginal Cost pricing, then such prices can be used for valuing benefits and costs.

Next we consider the question of how to treat future benefits and costs. It is believed that future benefits and costs do not hold the same value as present benefits and costs. Hence the procedure (as we have seen in the three formulae discussed above) is to discount the future benefits and costs by a Social Discount Rate (SDR). It is presumed that all benefits and costs, whatever their nature, must be discounted at the same time using SDR and the SDR must remain constant over time. Three rules of deriving SDR are:

- (1) The SDR should reflect the society's time preference rate (STPR).
- (2) According to the second rule, the SDR should reflect the opportunity cost of the project, rather than STPR.
- (3) According to the third rule, both STPR and opportunity cost should be reflected in the SDR. Hence it is suggested that a synthetic rate be used.

Apart from the fact that the method carries out a single criterion evaluation, it has other defects due to the difficulties in assessment of costs and benefits, determination of

SDR, neglect of joint benefits and costs and also external effects.

In the methods enumerated above we have seen that  $B_t$  and  $C_t$  are considered as discrete quantities. However,  $B_t$  and  $C_t$  could have been flow rather than stock variables. In such a case the formulation of the problem could have been something like:

$$PVNB = \int_0^T \frac{B_t - C_t}{(1+i)^t} dt = \int_0^T \frac{B_t}{(1+i)^t} dt - \int_0^T \frac{C_t}{(1+i)^t} dt$$

or

$$B/C = \int_0^T \frac{B_t}{(1+i)^t} dt \Big/ \int_0^T \frac{C_t}{(1+i)^t} dt$$

or

find  $r$ , the internal rate of return by solving

$$\int_0^T \frac{B_t}{(1+r)^t} dt = \int_0^T \frac{C_t}{(1+r)^t} dt$$

At least two of these cases can be reasonably approximated by converting them in discrete models. For example,

$$\begin{aligned} PVNB = \int_0^T \frac{B_t - C_t}{(1+i)^t} dt &= \int_0^{t_1} \frac{B_t - C_t}{(1+i)^t} dt + \int_{t_1}^{t_2} \frac{B_t - C_t}{(1+i)^t} dt \\ &+ \int_{t_2}^{t_3} \frac{B_t - C_t}{(1+i)^t} dt + \dots + \int_{T-t_{n-1}}^T \frac{B_t - C_t}{(1+i)^t} dt \end{aligned}$$

Each of the subintegrals can be approximated suitably for  $t = 0, 1, 2, 3, \dots, n$  and the earlier formula,

$$PVNB = \sum_{t=0}^T \frac{B_t - C_t}{(1+i)^t}$$

can be applied with acceptable accuracy.

Vinod, H.D. (1988) has argued that by allowing for timing aspects and by considering cumulative dynamic BCRs it is possible to have an optimal and impartial ranking of projects for selection. In his dynamic version of Benefit Cost Ratio criterion, he has used a modified function (Meyer form) which allows for assigning egalitarian weights and he has used the Pontryagin's 'maximum principle' and the 'bang-bang' control solution for ranking cumulative BCRs.

#### **METHODS THAT NEED NOT CONSTRUCT COMPOSITE OBJECTIVE FUNCTION**

As we have said earlier, since the 1960's emphasis has been laid on multiple-criteria evaluation and till date many methods have been developed in this line to deal with problems of different nature. Let us now consider these methods under different categories. This categorisation, however, may not be strictly binding but there may be overlappings. One of the reasons of overlapping is that the methods described earlier are special cases of the methods we are proceeding on to describe.

##### **I. Method for Generating a Nondominated Set**

The methods that generate the nondominated set, work by

considering the multiple objective functions and then by identifying a set of non-dominated solutions in the initial feasible region. A solution vector  $x_1 \in X$  (where  $X$  is feasible) is said to dominate over another solution vector  $x_2 \in X$  if at least one of the elements of  $x_1$  is preferred to the corresponding element of  $x_2$  and no element of  $x_2$  is preferred to the corresponding element of  $x_1$ . More clearly, if  $x_1 = (x_{11}, x_{12}, \dots, x_{1n})$  and  $x_2 = (x_{21}, x_{22}, \dots, x_{2n})$ , then if

$x_{1k}$  pref. to  $x_{2k}$ , and

$x_{2j}$  not pref. to  $x_{1j}$  for all  $j$

it will imply that  $x_1$  dominates over  $x_2$ .

A set  $x_i$  is nondominated if and only if there exists no  $x_k$  ( $i \neq k$ ) that dominates over  $x_i$ . Both  $x_i$  and  $x_k$  belong to  $X$ .

In the process of generating nondominated sets, however, only the physical constraints and not the Decision Maker's preferences are taken into account. This set helps the DM to gain some insight into the problem and from this set he chooses the most satisfactory solutions by either making implicit trade-offs between criteria or by some other technique.

There are several methods which can generate such nondominated sets. We will discuss them in brief. But before going into these methods we shall first briefly consider the Kuhn-Tucker conditions for nondominated solution on which the weighting method is based.

Kuhn and Tucker (1951) in their well known paper on conditions for optimal solutions, extended their work to give the following necessary conditions for a solution  $x^*$  to be a nondominated solution:

$$x^* \in X \quad \dots\dots\dots (7)$$

$$\lambda_i g_i(x^*) = 0; i = 1, 2, \dots, m \quad \dots\dots\dots (8)$$

$$\sum_{k=1}^p W_k \nabla_{Z_k}(x^*) - \sum_{i=1}^m \lambda_i \nabla_{g_i}(x^*) = 0 \quad \dots\dots\dots (9)$$

Where  $X$  is the feasible region,  $Z_k(x^*)$ ,  $k = 1, \dots, p$  are objective functions,  $g_i(x^*)$  are the constraints,  $\nabla$  is the gradient operator,  $W_k$ ,  $k = 1, \dots, p$  are the weights and  $\lambda_i$ ,  $i = 1, \dots, m$  are the Lagrange multipliers.

### 1. The Weighting Method

In this method, weights are assigned to the various objective functions to combine them into a single overall objective function. The problem can be stated as:

$$\text{Max } Z(x) = W_1 Z_1(x) + W_2 Z_2(x) + \dots\dots\dots + W_p Z_p(x)$$

$$\text{subject to } x \in X \quad \dots\dots\dots (10)$$

where  $W_i > 0$  for all  $i$  are the weights satisfying

$$\sum_{i=1}^p W_i = 1$$

(Kuhn and Tucker, 1951; Zadeh, 1963; Gal and Nedoma, 1972)

By varying the vector of weights  $(W_1, W_2, \dots, W_p)$ , the set of nondominated solutions is generated. Here the  $W_i$ 's are only parameters that help generate the solution of nondominated solutions. If they are interpreted as reflecting the preferences of the DM, then we will get a best compromise solution; the optimal solution relative to a particular preference structure (Goicoechea, 1982). If the feasible region  $X$  is convex, then a systematic variation of the vector  $(W_1, W_2, \dots, W_p)$  results in the generation of complete nondominated set. For linear multi-objective problems, it is possible to generate the entire nondominated set from the nondominated extreme points. If  $(x_1, x_2)$  and  $(x_1^1, x_2^1)$  are two adjacent nondominated extreme points, then other nondominated extreme points can be obtained by taking

$$\theta(x_1, x_2) + (1-\theta)(x_1^1, x_2^1); 0 < \theta < 1.$$

For MOLP (Multiobjective Linear Programming) problems, the convexity requirement is fulfilled and so by using this method, the entire set of nondominated solutions can be found.

Though this method seems to be simple, yet there are some difficulties. Many different vectors of weights may lead to the same solution. Again, in moving from one vector to another, it is possible to miss out some nondominated solutions. The result would be that the methods may yield a set of points which is only a close approximation to the actual nondominated

border. A method of making systematic variation of the weights and some of their implications has been given by Cohon (1978). In most cases, the entire set of nondominated solutions generated is too large for the DM (Decision-maker) to tackle. In such cases a subset of the nondominated set is presented to him.

## 2. The $\epsilon$ -Constraint Method

In this method, the DM is allowed to specify bounds to each criterion except, say, the  $i$ th one. If the bounds are given as  $e_k$  ( $k = 1, 2, \dots, i-1, i+1, \dots, p$ ) then the problem can be formulated as

$$\begin{aligned} \text{Max } & Z_i(x) \\ & x \in X \quad \dots\dots (11) \\ & Z_k(x) \geq e_k \end{aligned}$$

A systematic variation of the  $e_k$ 's helps to generate the set of nondominated solutions (Benayoun et al, 1971). However, this method leads to nondominated solutions only under a set of conditions, given, for example, in Szidarovszky (1979).

When the objective function and constraints of this problem are linear it can be solved by the simplex method itself. Since the DM specifies the minimum or maximum levels for the  $p-1$  objectives which appear in the constraint set, therefore, the solution obtained is a preferred solution. Out of the many

nondominated solutions, the DM may choose the solution by making appropriate trade-offs. If the feasible range of values of each objective function is not known, it is difficult to systematically vary the  $\epsilon$ -constraints. If the variations are made in small increments, the computational requirements will be huge. On the other hand, if the increments are big then it is possible to miss out the feasible points. Cohon (1978) has presented an algorithm for systematically generating nondominated solutions. Goicoechea et al. (1976) have presented a hybrid algorithm combining elements of  $\epsilon$ -constraint and weighting method for finding nondominated solutions. This method forms the basis of the Surrogate Worth Tradeoff method also.

This method and its variants have been used by many authors in different situations. Marglin (1967) has suggested its use in public investment problems. Haimes, Lasdon and Wismer (1971) have, through the 'Equivalence Theorem', related the vector optimisation to the  $\epsilon$ -constraint problem. Cohon and Marks (1973), Haimes (1975), have applied it to water resources problem. Goicoechea et al. (1976) have applied a variation of it to a problem in watershed management. Cohon et al. (1980) have used it for power plant siting in a region of U.S.

### **3. Adaptive Search Method**

This is a method for generating a set of representative nondominated solutions. If  $x_i^*$  is the global optimum of the

ith criterion  $Z_i(x)$  then  $x_i$  belongs to the set of all non-dominated solutions. This method, which is based on the gradient method, searches for nondominated solutions by passing from one nondominated solution to another, starting from any  $x_i^*$ . Though the  $Z_i(x)$  need not have continuous derivatives, however, each  $Z_i(x)$  must be differentiable in  $X$  (Beeson and Meisel, 1971).

#### 4. The Multiobjective Simplex Method of Zeleny

This method can be used only for problems with linear objective functions and constraints. The method proceeds by moving from one extreme nondominated solution to another till the entire set is obtained. The method is based on the argument that the set of nondominated points is a connected set and any nondominated point can be obtained as a convex combination of the set of nondominated points (Zeleny, 1974a). This method is similar to the single objective simplex method. Only, in this case, there are  $p$  objective functions and  $n$  decision variables and  $m$  slack variables. With each of the  $p$  objective functions is associated a row of 'reduced costs' for each variable, which shows the rate of change of an objective function if a nonbasic variable is brought into the basis. The information contained in these reduced costs are made use of in this method to move from one basis to another, in the search for the entire set of nondominated solutions. Details of the method can be found in Zeleny (1974a), Goicoechea et al. (1982).

## 5. The Multiobjective Simplex Method of Philip

This method, like the multiobjective simplex method of Zeleny, operates directly on the multiple objectives to generate the nondominated set, rather than by transforming the multiobjective problem first into a single objective one. In this method, first of all a feasible solution is found. Then search is made for weights that would make this particular solution to be the maximum. If such weights exist then such a solution is nondominated. Then the procedure is used to decide whether it is the only nondominated point or not. If it is not the only nondominated solution, then, the other such solutions are also found, either by bringing  $x_k$  to the basis to obtain another nondominated solution or alternatively the other nondominated solutions can be obtained as a convex combination of the adjacent nondominated points. Details of this method can be found in Philip (1972), Goicoechea et al. (1982).

Other such methods have been developed by Steuer (1979) who has presented a Goal Programming version of MOLP technique, Kornbluth and Steuer (1980), who have discussed a method to solve multiple objective linear fractional programming problem that can be applied to decision problems in corporate planning.

Though these MOLP techniques are mathematically sound, yet it is found that in real world situations, more often than not an unworkably large number of nondominated points are generated by these methods, which limits the application of these

methods to real world problems. Moreover, they can be used only when objectives and constraints are linearly expressed.

## II. Methods for Selecting the 'Best' Global Solution

Once the set of nondominated solutions is generated, it is possible for the analyst to use the methods in this section to choose the 'best' global solution. We will divide this section into two parts consisting of:

A. Continuous Methods, and

B. Discrete Methods (Outranking Methods).

### A. Continuous Methods

#### (i) Goal Programming

The 'best' solution that will be chosen should satisfy not only the constraints of the problem but also the preference structure of the DM. In this context, we will first discuss the method of goal programming which was developed by A. Charnes and W.W. Cooper (1961). In this method, the DM is allowed to subjectively specify a target for each objective function. This specification gives the aspiration point (or goal)  $a^*$ , which is represented by an  $n$ -tuple  $(a_1^*, a_2^*, \dots, a_n^*)$ . However, this goal point may or may not lie in the feasible criterion space. Goal programming is a variation of the simplex procedure in which the DM is allowed to specify multiple goals (objective functions) in order of priority. The objective function may be single dimensional or multi-dimensional;

the given set of constraints must be expressed in linear form and both the objective function as well as constraints must be well defined analytic functions of decision variables. (The method requires that all the goals be incorporated into the overall objective function and those factors that are outside the control of the D.M./Evaluator be considered as constraints) Goal Programming can deal with decision variables that are discrete or even continuous variables.

Since it is difficult to have a feasible solution that achieves all the targets simultaneously, the aim is to come as close as possible to the goal  $(a_1^*, a_2^*, \dots, a_n^*)$ . This is done by minimising the difference or deviation between the goal and the actual achieved point. Goal Programming methods differ from one another by the way in which this difference (or closeness) is measured.

$$\text{Min } \sum_{i=1}^n \text{Abs}(F_i(x) - a_i^*) \quad \dots\dots\dots (12)$$

$x \in X$ ;  $\text{Abs}(\cdot)$  = absolute value of the argument.

Where  $F_1(x)$ ,  $F_2(x)$ ,  $\dots$ ,  $F_n(x)$  are the  $n$  criteria represented by  $n$  objective functions.  $a_i^*$  is the target set for the  $i$ th objective and  $X$  represents the feasible region.

A more general formulation of Goal Programming is obtained by taking the weighted sum of the  $p$ -th power of the deviation  $\text{Abs}(F_1(x) - a_1^*)$ . Such a formulation has been called

generalised goal programming (Ignizio, 1976, 1981; Szidarovszky, 1979).

However, the above objective function is nonlinear and hence it is transformed into a linear form, so as to reduce Goal Programming to a variant of Linear Programming. For this transformation, Charnes and Cooper (1961) introduced slack variables  $d_i^+$  and  $d_i^-$ , which indicate the overachievement and underachievement of the  $i$ th objective and they are defined as:

$$d_i^+ = \frac{1}{2}[\text{Abs}(F_i(x) - a_i^*) + (F_i(x) - a_i^*)]$$

$$d_i^- = \frac{1}{2}[\text{Abs}(F_i(x) - a_i^*) - (F_i(x) - a_i^*)]$$

The goal variable  $d_i$  associated with the  $i$ th objective is given by

$$d_i = d_i^+ + d_i^- = \text{Abs}(F_i(x) - a_i^*) \quad \dots\dots (13)$$

Where  $d_i^+, d_i^- \geq 0$  and  $d_i^+ \cdot d_i^- = 0$  which implies that we cannot have both underachievement and overachievement at the same time. The simplex method has the advantage that it automatically fulfils this condition, because the objective function will drive either (or perhaps both)  $d_i^+$  or  $d_i^-$  to zero for all  $i$ .

Hence the non-linear objective function (12) given above can be replaced by a linear objective function (14) by using

the slack variables  $d_i^+$  and  $d_i^-$ .

The problem can now be reformulated as

$$\text{Min } W = \sum_{i=1}^n (d_i^+ + d_i^-) \dots\dots\dots (14)$$

subject to  $x \in X$

$$F_i(x) - d_i^+ + d_i^- = a_i^*$$

$$d_i^+, d_i^- \geq 0 \quad i=1, \dots, n.$$

The achievement function  $W$  can take various forms using Minkowski metric ( $L_p$  metric). These are discussed below following Nijkamp and Spronk (1979).

$$\begin{aligned} W &= \left[ \sum_{i=1}^n \text{Abs}(F_i(x) - a_i^*)^p \right]^{1/p} \quad ; \quad p \geq 1 \\ &= \left[ \sum_{i=1}^n (d_i^+ + d_i^-)^p \right]^{1/p} \quad \dots\dots\dots (15) \end{aligned}$$

Since  $d_i^+ \cdot d_i^- = 0$ , we have

$$\begin{aligned} W &= \left[ \sum_{i=1}^n (d_i^+ + d_i^-)^p \right]^{1/p} \\ &= \left[ \sum_{i=1}^n (d_i^+)^p + (d_i^-)^p \right]^{1/p} \quad \dots\dots\dots (16) \end{aligned}$$

For solving the problem of income distribution using Goal Programming, Bartels and Nijkamp (1976) have introduced the Minkowski metric, as a norm. By this we have,

$$W = \left[ \sum_{i=1}^n (d_i^+ / a_i^*)^p + \sum_{i=1}^n (d_i^- / a_i^*)^p \right]^{1/p} \dots\dots (17)$$

Here  $d_i^+ / a_i^*$  and  $d_i^- / a_i^*$  are the positive and negative deviations of the  $i$ th objective aspiration level  $a_i^*$ .

The value of  $p$  is based upon the utility function chosen by the analyst.

In the above formulations  $d_i^+$  and  $d_i^-$  are assigned equal weights. Though the aim is to achieve the target levels for each objective, it may not be possible to do so. In such a case the above formulation does not tell us whether the DM would prefer underachievement or overachievement. Moreover, all the goals have been assigned equal weights. In reality, however, it is likely that the DM would like to assign different weightage to different goals. This also can be allowed for with a slight modification of the above formulations. To take care of this, two approaches can be adopted.

- (1) Method of assigning cardinal weights
- (2) Method of assigning ordinal weights.

### 1. Method of Assigning Cardinal Weights

In this method, each of the  $d_i^+$  and  $d_i^-$  are assigned cardinal weights in the objective function  $W$  in (16) and (17). These weights establish the relative importance of the  $n$  criteria. Thus corresponding to (16) and (17) we have

$$W = \left[ \sum_{i=1}^n (w_i^+ d_i^+)^p + \sum_{i=1}^n (w_i^- d_i^-)^p \right]^{1/p} \dots\dots (18)$$

and

$$W = \left[ \sum_{i=1}^n (w_i^+ \cdot d_i^+ / a_i^*)^p + \sum_{i=1}^n (w_i^- \cdot d_i^- / a_i^*)^p \right]^{1/p} \dots\dots (19)$$

Now, the Goal Programming model for a multicriteria evaluation problem can be stated as:

Minimise  $W$

Subject to  $F_i(x) + d_i^- - d_i^+ = a_i^*$ ; for all  $i$

$$f_j(x) \leq b_j; j = 1, 2, \dots, m$$

$$\left. \begin{array}{l} d_i^+ \cdot d_i^- = 0 \\ d_i^+, d_i^- \geq 0 \end{array} \right] \text{ for all } i \dots\dots\dots (20)$$

Thus, the problem reduces to a single criterion optimisation problem and can be tackled by a straight simplex procedure if  $p = 1$  and  $F_i(x)$  and  $f_j(x)$  are all linear.

Most of the available literature on theory and applications of Goal Programming deals with the Linear Programming formulation because it is easy to use (Charnes and Cooper, 1961; Ijiri, 1965; Ignizio, 1976; Lee, 1972; Nijkamp and Spronk, 1979). Goal Programming using  $L_2$  metric has been solved by using Generalised Inverse, by Ijiri (1965).

## 2. Method of Assigning Pre-emptive Priority (Ordinal Weights)

In some cases the DM may feel that some goals are so important that other goals cannot be considered unless these goals are achieved. Then the DM assigns pre-emptive priorities  $P_i$  ( $i=1, \dots, n$ ) to each of the criteria, i.e., he ranks the criteria in order of preference such that the criterion ranked 2 will be considered only after the first has been fulfilled. The factors  $P_i$  are conceptually different from weights since they do not assume cardinal values but only indicate the priority status of each  $d_i^+$  and  $d_i^-$ ,  $i=1, \dots, n$ . There may be more than one criterion with the same pre-emptive priority. In case of such lexicographical ordering, such a solution is considered as the best which has the greatest achievement for the most important criterion. Only when there is a tie on the first, does the second criterion come into consideration. In figure 2 we given an idea of lexicographic ordering in 2-criteria case where criterion 'x' is assumed to be more important.

Fig. 2 presents lexicographic ordering diagrammatically. Here  $IC_2$  gives the highest achievement of 'x' and hence point

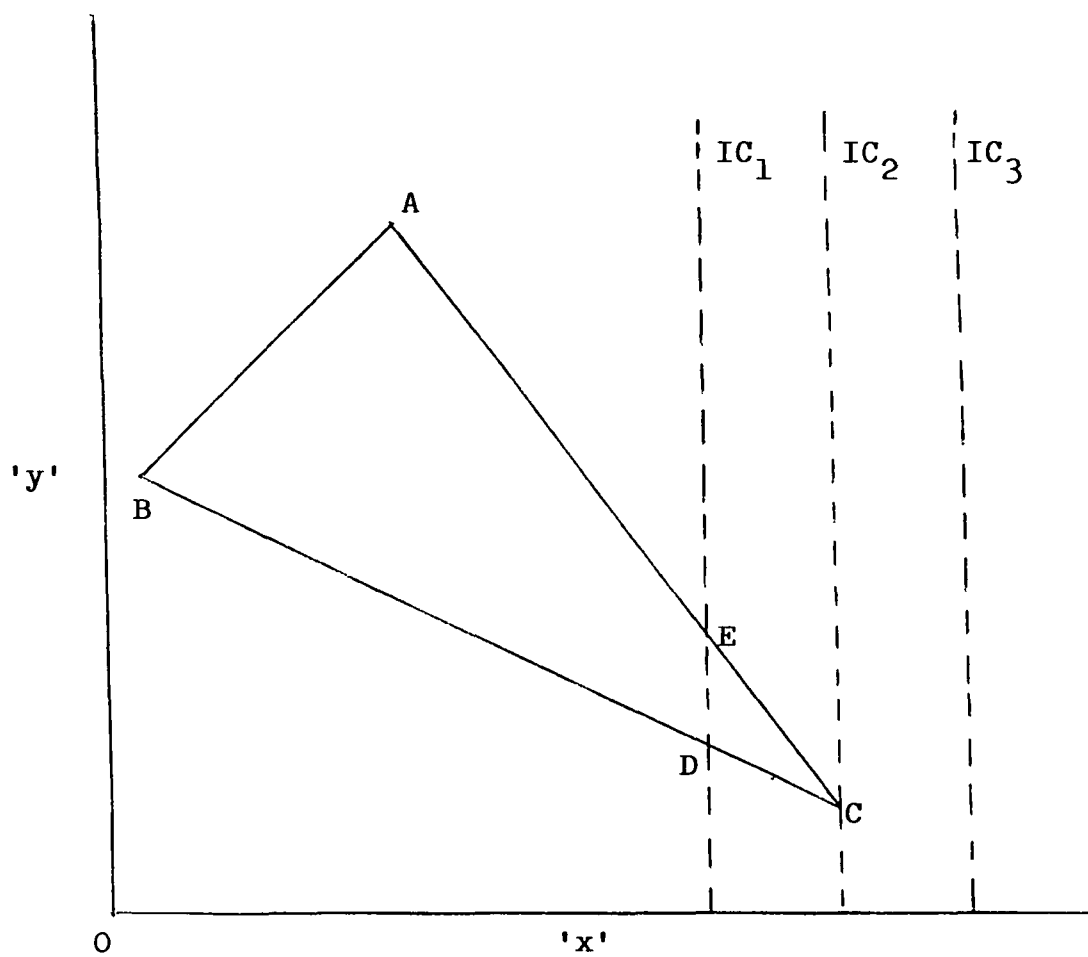


FIG - 2. LEXICOGRAPHIC ORDERING

C is the best solution in the feasible region ABC.

Lee (1972) and Ignizio (1976) have discussed a modified simplex method to solve such problems. An iterative Goal Programming method for solving lexicographic models have been discussed by Dauer and Krueger (1977). This format does not require any achievement function. The idea of nondominated solution in the lexicographic model of Goal Programming has been introduced by Ignizio (1980).

In the first method for dealing with non-equivalent criteria (case of cardinal weights), since the goals are noncommensurable, therefore the weights lose much of their significance. To do away with this problem, Kluyver (1979) and Widhelm (1980) have introduced a method for normalising the goals in case where  $F_i(x)$  are linear.

Thus, if we are given

$$F_i(x) = C^i x$$

Then the method expresses goal constraints

$$C^i(x) + d_i^- - d_i^+ = a_i^*$$

as

$$\frac{C^i(x)}{\text{Norm}(C^i)} + d_i^- - d_i^+ = \frac{a_i^*}{\text{Norm}(C^i)}; \forall i \dots\dots (21)$$

$$\text{Where Norm}(C^i) = (C_{i1}^2 + C_{i2}^2 + \dots + C_{in}^2)^{1/2}$$

Thus all deviations  $d_i^+$  and  $d_i^-$  are expressed in the same units so that the weights now hold much more significance.

Now the problem will be

Min  $W$ ; [ $W$  as in (16) and (17)]

subject to  $[(F_i(x) - a_i^*)/\text{Norm}(C^i)]$

$$+ d_i^- - d_i^+ = 0; i=1, \dots, n.$$

$$f_j(x) \leq b_j; j = 1, \dots, m \quad \dots (22)$$

$$d_i^+ \cdot d_i^- \geq 0, d_i^+ \cdot d_i^- = 0 \text{ for all } i.$$

The Goal Programming method is a useful method and it occupies a prominent place among the various multi-objective techniques. This technique which was initiated by Charnes and Cooper was extended into many fields including accounting for control by Ijiri (1965), who has discussed cardinally weighted models for achievement function in  $L_1$  and  $L_2$  metrics. Lee (1972, 76) has applied Goal Programming to problems in financial decisions, production planning, academic planning, medical planning, etc. and has made applications of the linear form of lexicographic Goal Programming models and also devised modified simplex method for solving them. He has also discussed integer Goal Programming.

## 2. The Utility Approach

The utility approach is another approach that is recommended for use to make evaluation and decisions. This analysis is based on the presumption that the individual (in this case the DM) is aware of the different alternatives placed before him and can evaluate each of them so that he can choose that alternative which gives him the greatest satisfaction/utility. Since we are here concerned with MCDM, hence in this connection the approach requires that given a vector of objectives it should be possible to construct a utility function which can incorporate the various levels of all these objectives.

The utility approach can be used for both deterministic and probabilistic cases. In order that the preferences of the DM can be expressed by a utility function in both these cases, the following axioms must be satisfied:

- (i) If  $x$  and  $y$  are two alternatives, then one of the following should be true:
  - $x$  is preferred to  $y$ ;  $y$  is preferred to  $x$ ;  $x$  is indifferent to  $y$ .
- (ii) Transitivity of preference: If  $x \text{ pref } y$  and  $y \text{ pref } z$  then  $x \text{ pref } z$ .
- (iii) Transitivity of Indifference: If  $x$  and  $y$  are indifferent,  $y$  and  $z$  are indifferent, then  $x$  and  $z$  will also be indifferent.
- (iv) There is a certainty equivalent of any gamble - If the

preference structure is such that  $x$  pref to  $y$  and  $y$  pref to  $z$  and if  $p$  ( $0 < p < 1$ ) is some probability, then the individual is indifferent between getting  $y$  with certainty and getting  $x$  with probability  $p$  and  $z$  with probability  $(1-p)$ .

- (v) Property of Preferential Independence: If the individual is indifferent between  $x$  and  $y$ , and  $z$  is any third alternative then the individual is indifferent between  $(x,z)$  and  $(y,z)$ . In the probabilistic case, this property takes the form of utility indifference - Again, if  $x$  and  $y$  are indifferent and  $z$  is any third alternative, then the individual is indifferent between
- (a) receiving  $x$  with probability  $p$  and  $z$  with probability  $(1-p)$ , and
  - (b) receiving  $y$  with probability  $p$  and  $z$  with probability  $(1-p)$ .

Szidarovszky (1980) and Keeney and Raiffa (1976) have given detailed discussion on the different axioms and their relations and implications.

Once these axioms are satisfied, it is possible to construct the utility functions of the decision maker. For multi-objective problems, the utility functions can help in ordering completely the set of nondominated solution (A solution is said to dominate another if the first has a higher value for at least one criterion and a lower value for no criterion).



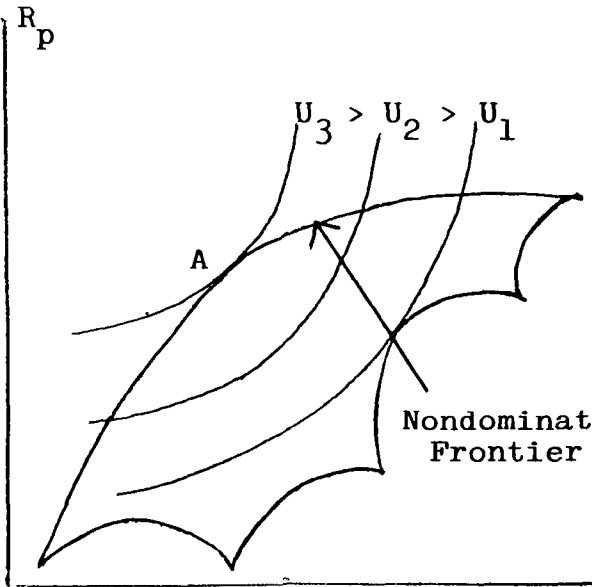


Figure 3

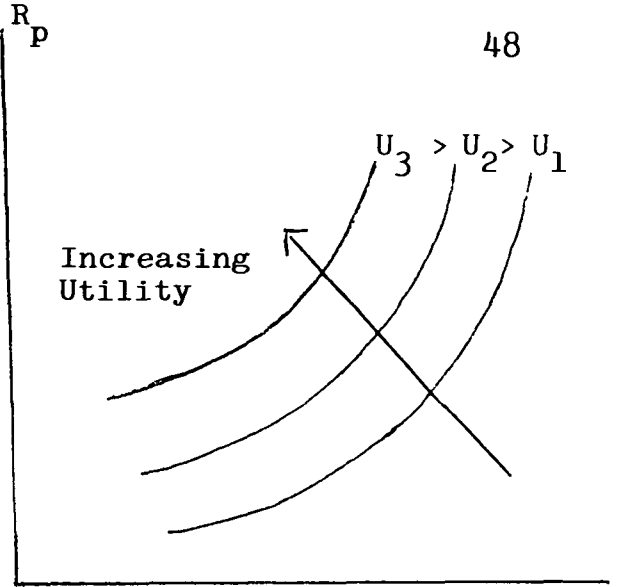


Figure 4

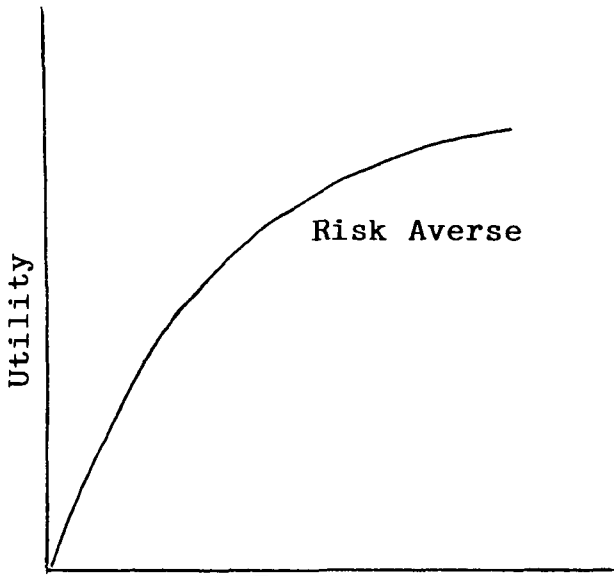


Figure - 5

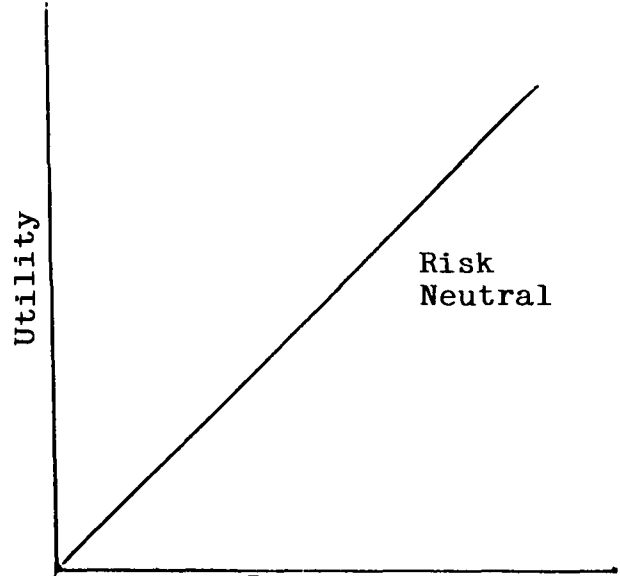


Figure - 6

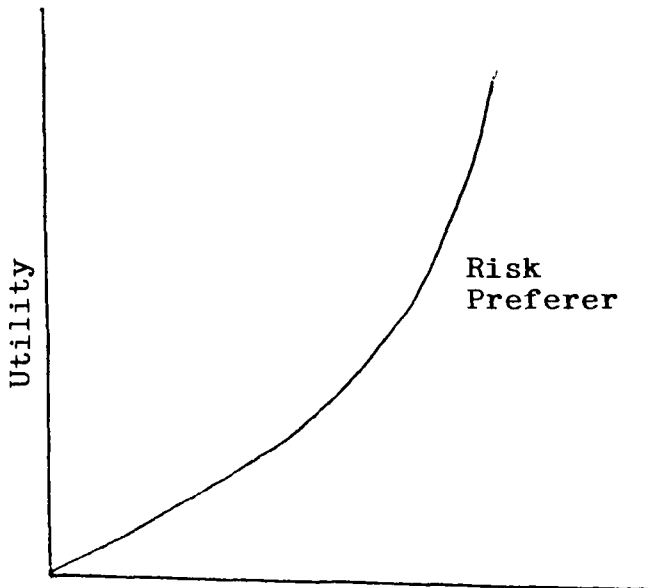


Figure - 7

Figures 3 & 4 shows Indifference Curves and Nondominated Frontier

Figures 5-7 - Three types of Utility Curves

If we have  $n$  criteria represented by  $n$  utility functions, then the simplest form of the overall utility function  $U(x)$  can be obtained by taking a simple additive model

$$\begin{aligned} U(x) &= U_1(x) + U_2(x) \dots\dots + U_n(x) \\ &= \sum_{i=1}^n U_i(x) \quad \dots \quad \dots \quad \dots \quad (23) \end{aligned}$$

However, in the additive model it is more usual to assign weights to the criteria. Then we have the weighted additive model as

$$\begin{aligned} U(x) &= w_1 U_1(x) + w_2 U_2(x) + \dots\dots + w_n U_n(x) \\ &= \sum_{i=1}^n w_i U_i(x) \quad \dots\dots\dots (24) \end{aligned}$$

Where  $w_i$  are the weights such that

$$w_i > 0 \text{ for all } i \text{ and } \sum_{i=1}^n w_i = 1$$

Note that (23) is only a special case of (24) when weights are equal for every  $U$ .

However, a constant  $w_i$  represents constant marginal rate of substitution between the criteria and it is more realistic to have weights that are dependent on the current solution point  $(x)$ . It is generally believed that as the achievement level of any criterion increases, its relative importance decreases. Thus a more realistic model would be:

Find  $x \in X$

which maximises

$$\begin{aligned}
 U(x) &= w_1(x) U_1(x) + w_2(x) U_2(x) + \dots + w_n(x) U_n(x) \\
 &= \sum_{i=1}^n w_i(x) U_i(x) \quad \dots\dots\dots (25)
 \end{aligned}$$

Usually the different criteria are measured in different units (i.e. they are noncommensurable). This makes the weights (i.e. the MRS) less significant.

The additive models that we have discussed above assume that the criteria are independent of each other. This is not usually the case, and the criteria implicitly depend on each other. In such cases the nonlinear and multiplicative models can be used.

The overall utility function can take a quadratic form as:

Find  $x \in X$  which maximises

$$U(x) = \sum_{i=1}^n w_i (U_i(x))^2 \quad \dots\dots\dots (26)$$

$$\text{or } U(x) = \sum_{i=1}^n \sum_{j=1}^n w_{ij} (U_i(x_i))(U_j(x_j)) \quad \dots \quad i \geq j$$

We can also have the multiplicative model (Nash, 1950)

Find  $x \in X$  which maximises

$$U(x) = \prod_{i=1}^n U_i(x) \quad \dots\dots\dots (27)$$

Theory and practical experience show that weighted additive model yields results that are a close approximation even to a very complicated non-linear form and at the same time it is easier to use and understand (Einhorn and Hogarth, 1975). It is to be noted that the cost-benefit and cost-effectiveness analyses are special cases of this approach to decision making and evaluation.

While the utility approach has the advantage that it can deal with cases of risk (probabilistic cases) and also seems to be easy to understand, it has some difficulties involved with assigning utilities to outcomes and also in assessing probabilities. Also the determination of weights, etc. and the particular form of utility function to use are not very easy problems.

### **(3) Surrogate Worth Trade Off Method**

While Goal Programming and Utility approach can deal with both continuous and discrete types of variables, Surrogate Worth Tradeoff (SWT) method can deal with continuous variables and differential functions. This method was developed by Haimés and his group of researchers (Haimés and Hall, 1974; Haimés et al., 1975). It is based on the assumption that in comparing systematically two objectives at a time, the D.M. reveals an implicit MUF. It makes use of a tradeoff function  $T_{ij}(x)$  between the  $i$ th and  $j$ th objectives, obtained by interacting with the D.M. of those tradeoffs which are revealed to

be optimal, a best compromise solution is chosen (Hall and Haimes, 1976). Following Goicoechea et al. (1982) we briefly discuss the essentials of this method.

Given the problem

$$\left. \begin{array}{l} \text{Max-satisfice } Z(x) = [Z_1(x), Z_2(x), \dots, Z_p(x)] \\ \text{subject to } g_k(x) \leq 0 \quad k = 1, 2, \dots, m \end{array} \right] \dots(28)$$

the trade off functions  $T_{ij}(x)$  are defined as follows (Haimes et al., 1975).

$$T_{ij}(x) = \frac{dZ_i(x)}{dZ_j(x)}, \quad i \neq j, \quad i, j, = 1, 2, \dots, p. \dots\dots\dots (29)$$

According to this method, first we try to maximise only one  $Z_i(x)$  and the remaining  $p-1$  objectives are expressed as constraints, i.e. we have

$$\begin{array}{l} \text{Max } Z_i(x) \\ \text{subject to } x \in X \quad \dots\dots\dots (30) \\ Z_j(x) \geq L_j; \quad j = 1, 2, \dots, p \text{ and } j \neq i. \end{array}$$

However, of these  $p-1$  objectives, all but the  $k$ th are fixed at certain levels. Thus,

$$Z_j(x) = L_j \quad j \neq i, k. \quad \dots\dots\dots (31)$$

Then using generalized Lagrangian multipliers  $\lambda_{ij}$  and  $\mu_k$  we have the form;

$$L(x, \lambda, \mu) = Z_i(x) + \sum_{\substack{j=1 \\ i \neq j}}^p \lambda_{ij} (Z_j(x) - L_j) + \sum_{k=1}^m \mu_k g_k(x)$$

$$\text{so that } \lambda_{ij} = \frac{-\partial L}{\partial L_j} \dots\dots\dots (32)$$

$\lambda_{ij}$  is related to  $T_{ij}$  such that

$$\lambda_{ij} = - T_{ij}$$

The method assumes that there are Surrogate Worth functions  $W_{ij}$  for each tradeoff function. The  $w_{ij}$ 's are ordinal in nature and their values are assigned by the D.M.

Through interaction with the D.M.  $MRS_{ij}$  are obtained and then we have

$$\begin{aligned} w_{ij} > 0 & \quad \text{if } MRS_{ij} > \lambda_{ij} : MRS = \text{marginal rate of substitution} \\ w_{ij} = 0 & \quad \text{if } MRS_{ij} = \lambda_{ij} \quad \dots\dots\dots (33) \\ w_{ij} < 0 & \quad \text{if } MRS_{ij} < \lambda_{ij} \end{aligned}$$

That solution will be considered to be the best for which all  $w_{ij}$ 's (for all  $i, j; i \neq j$ ) are equal to zero.

This method has been applied to problems with hierarchical objectives, by Haimes (1977), Olenik and Haimes (1979), Tarvainen and Haimes (1980), Haimes and Tarvainen (1980). Chankong and Haimes (1978) have discussed an interactive version of this method.

## **B. Discrete Methods (Outranking Methods)**

In Section A, we have discussed methods for problems with an infinite number of alternatives. However, we also have problems where the DM has to choose from a finite number of alternatives. The structure of discrete problems can be given by a payoff matrix. Since the various criteria of a multi-objective problem are heterogeneous, there remains considerable incomparability between them. The idea in the methods discussed in this section is to construct an outranking relation (fuzzy or non-fuzzy) and to exploit this relation in ranking of the alternatives. These will become more clear as we discuss the methods for dealing with such problems.

### **(1) Exclusionary Screening**

In this method, for each criterion, minimum acceptable levels are fixed. The alternatives which satisfy the acceptable levels for all criteria simultaneously constitute the acceptable set and the rest of the alternatives constitute the unacceptable set. The set of dominated alternatives are eliminated at the very beginning. Once the acceptable non-dominated alternatives are identified they have to be ranked using a suitable procedure.

### **(2) Conjunctive Ranking**

In this method, attempt is made to make a ranking of the members of the acceptable set. As a first step, the domi-

nated alternatives are eliminated. Then exclusionary screening is done on the nondominated sets, on the basis of all criteria except one. The acceptable set formed thus is next ranked on the basis of the criteria that had been excluded in exclusionary screening.

### **(3) Copeland's Reasonable Social Welfare Function**

This method makes paired comparison of alternatives. Of a pair of alternatives, that is considered to be best, which has the largest number of better criteria levels. The alternative which wins the most paired comparisons is considered as the most preferable. The method also allows for assigning unequal weights to the different criteria.

### **(4) Concordance Analysis**

The Concordance Analysis of Nijkamp and Delft (1977) is a method which helps to outrank the alternatives available. We present here a simplified approach to Concordance Analysis which planners can follow for multi-criteria evaluation of public policies. The following approach has been adopted from Mishra and Subudhi (1981).

Let there be  $m$  projects ( $m > 1$ ) and  $n$  effects of these projects ( $n > 1$ ), where these effects are the criteria on which the projects/alternatives are evaluated. This information can be represented by a Project Matrix,  $R$ , Where:

$$r_{ij} = [R]_{n \times m} \quad \begin{array}{l} i=1, \dots, n \\ j=1, \dots, m. \end{array}$$

If a project  $j$  does not have the effect  $i$  then  $r_{ij} = 0$ .

Some criteria prefer lower values to higher values (e.g. pollution, etc.) while some others prefer higher values to lower ones. To take this into account, the vector  $S$  is constructed where  $S_i = -1$  for the former type of criteria and  $S_i = 1$  for the latter type.

Next the Project Effect Matrix has to be normalized since the effects are in different units and scales and hence may be quite noncommensurable. So we have,

$$R^* = (r_{ij}^*)_{n \times m} \quad \dots \dots \dots (34)$$

$$\text{Where } r_{ij}^* = \frac{r_{ij}}{\left( \sum_{j=1}^m r_{ij}^2 \right)^{\frac{1}{2}}}$$

Mishra and Subudhi have used Euclidean norm. But any other norm can also be used.

To the DM, all the criteria may not assume the same values (importance) hence weights are assigned to the  $n$  criteria and we have a vector of weights

$$w_i = [w]_{1 \times n}$$

Since the weights of the different criteria should add up to unity so we construct a new vector  $w^*$  for which

$$w_i^* = \frac{w_i}{\sum_{k=1}^n w_k} \quad \dots\dots\dots (35)$$

The Concordance Analysis makes use of the two indices - Concordance Index and Discordance Index and on the basis of these two it is decided whether alternative  $i$  is preferred to alternative  $j$  or not. An alternative  $i$  is said to be preferred to another alternative  $j$  if the Concordance Index  $C_{ij}$  is at least equal to a certain fixed tolerance level  $T_c$  and the discordance index is less than or equal to  $T_d$  (tolerance level of discordance).

The Concordance index is computed as follows:

$$[C_{ij}^*]_{i \neq j} = [C^*]_{m \times m}$$

Where

$$C_{ij}^* = \sum_{k=1}^n w_k^* L_k$$

$$L_k = 0 \text{ if } S_k R_{ki}^* - S_k R_{kj}^* < 0$$

$$\text{otherwise } L_k = 1 \quad \dots\dots\dots (36)$$

We then have to compute discordance index. For this, a weighted Project Effect Matrix is constructed such that

$$[V_{ij}^*] = [V^*]_{n \times m}$$

$$V_{ij}^* = r_{ij}^* w_i^* \dots\dots\dots (37)$$

Now, crude discordance index

$$[d_{ij}] = [D]_{m \times m}$$

$d_{ij}$  is computed as follows

$$d_{ij} = \text{Max} (\text{Abs}(V_{ki}^* - V_{kj}^*) \cdot L_k)$$

$$L_k = 0 \text{ if } (S_k R_{ki}^* - S_k R_{kj}^*) \geq 0 \dots\dots (38)$$

otherwise  $L_k = 1$ .  $k = 1, 2, \dots, n$ .

Standardizing the crude discordance matrix we get  $D_{ij}$  matrix

$$[d_{ij}^*] = [D^*]_{m \times m}$$

$$[d_{ij}^*] = [D]_{m \times m}$$

$d_{ij}^*$  is given as \dots\dots (40)

$$d_{ij}^* = \frac{d_{ij}}{\Delta} \quad i \neq j$$

where  $\Delta = \text{Max}_k (\text{Abs}(V_{kj}^* - V_{ki}^*))$

$$\begin{aligned} k &= 1, 2, \dots, n. \\ i &= 1, 2, \dots, m. \\ j &= 1, 2, \dots, m. \end{aligned}$$

Once the concordance matrix and discordance matrix are computed and the Tolerance level  $T_c$  and  $T_d$  are fixed, the ordering on ranking of the projects can be done.

An alternative  $i$  is said to be preferred to  $j$  if we have

$$C_{ij}^* \geq T_c \quad \dots\dots (41.a)$$

Again  $i$  is preferred to  $j$  if

$$d_{ij}^* \leq T_d \quad \dots\dots\dots (41.b)$$

Thus if both (41.a) and (41.b) are satisfied then we can say for sure that  $i > j$ . Hence if  $i$  is preferred to each of the alternatives in the set  $\pi^u = (j, k, \dots, m')$  in the sense that concordance condition is satisfied and also if from the point of view of discordance  $i$  is preferred to each of the alternatives in the set  $\pi^v = (j, k, \dots, n')$ , then from both concordance and discordance point of view

$$i \text{ is preferred to } \pi^u \cap \pi^v \quad \dots\dots\dots (42)$$

Sometimes instead of finding a single alternative as preferable to all other alternatives, we may come up with a set  $\pi^o$  of alternatives as being preferable to set  $\pi^u$  or  $\pi^v$ , etc. Here we have incomparability within the elements  $\pi^o$  itself. As a result, the method may lead to indecisive conclusions. In such cases, slight changes in tolerance levels  $T_c$  and  $T_d$  may help. However, it is seen that higher the value of  $T_c$ ,

the bigger the domain of indifference of one alternative with others, i.e., narrower the domain of preference of one alternative over others. Again, lower  $T_d$  would also expand the domain of indifference between the alternatives. Thus very high  $T_c$  together with very low  $T_d$  would lead to indecisiveness in arriving at a conclusion. Another way of dealing with incomparability within  $\pi^0$  would be to check how many times an alternative  $i$  has its concordance index higher than  $T_c$  with respect to  $\pi_j$  ( $j = 1, 2, \dots, l-1, i+1, \dots, m'$ ) and how many times  $i$  has its discordance index less than  $T_c$ . That alternative in  $\pi^0$  with the largest sum of the two frequencies can be selected. It may be necessary sometimes to revise the weights  $W_i$  or the  $r_{ij}$ 's also.

##### 5. Electre I (Elimination and Choice Translating Algorithm)

This method, developed by Benayoun, Roy and Sussman (1966), also is a method for problems with discrete and finite number of alternatives, and it helps to reduce the set of nondominated alternatives to a smaller size by ranking the alternatives therein. This method, like concordance analysis, also makes use of concordance index and discordance index. The method makes a partial ordering of nondominated alternatives but some incomparability still remains. The concordance index,  $C_{ij}$ , can be viewed as the satisfaction that is achieved by choosing  $i$  over  $j$ . It means the weighted relative frequency of criteria

where alternative  $i$  is preferred to alternative  $j$ . The discordance index measures the strength of criteria which is in greatest disagreement if  $i$  is chosen over  $j$  and it is in effect a measure of the dissatisfaction of choosing  $i$  over  $j$ .

### Concordance Index

If there are  $n$  criteria represented by a set  $I = 1, 2, \dots, n$  and if  $W_k : k = 1, 2, \dots, n$  represents the weights of the  $n$  criteria determined by the preference pattern of the D.M..

The set  $I$  is then partitioned into three subsets

$$\begin{aligned} I^+ &= I^+(i, j) = k \in I : i > j \\ I^= &= I^=(i, j) = k \in I : i = j \quad \dots\dots\dots (43) \\ I^- &= I^-(i, j) = k \in I : i < j \end{aligned}$$

and also

$$\begin{aligned} W^+ &= \sum_{k \in I^+} W_k \\ W^= &= \sum_{k \in I^=} W_k \quad \dots\dots\dots (44) \\ W^- &= \sum_{k \in I^-} W_k \end{aligned}$$

Then, we can define Concordance index as

$$C(i, j) = \frac{W^+ + \frac{1}{2}W^=}{W^+ + W^= + W^-} \quad \dots\dots\dots (45)$$

When each of the  $C_{ij}$ 's are obtained by using this formula, the Concordance matrix  $C$  can be constructed. The diagonal elements are not given any value since we cannot think of preference or deference of alternative  $i$  over itself.

The Concordance index  $C_{ij}$  has the following properties.

- (i)  $0 \leq C_{ij} \leq 1$ .
- (ii)  $C_{ij} = 1$  if  $i$  outranks  $j$  (i.e.  $i$  is preferred to  $j$ ).
- (iii) If a criterion  $f_k(x)$  is further subdivided into a number of criteria  $f_{k1}(x)$ ,  $f_{k2}(x)$ , ...,  $f_{kr}(x)$  with weights  $w_{k1}$ ,  $w_{k2}$ , ...,  $w_{kr}$  provided that  $w_k = w_{k1} + \dots + w_{kr}$  then the  $C_{ij}$ s retain their significance and do not lead to any inconsistency.

However, for a pair  $i, j$  of alternatives, even if  $C_{ij}$  is close to 1 (i.e.  $\neq 1$ ) we cannot infer that  $i$  outranks  $j$ .

### Discordance Index

The next task is to construct the discordance index. The discordance index is defined as

$$D_{ij} = \frac{\text{maximum interval where } i < j}{\text{total range of scale}} \quad \dots\dots\dots (46)$$

i.e., the largest normalized discord interval over all the criteria for which  $i < j$  is defined as the discordance index.

To do this normalization, an interval scale that is common to all  $n$  criteria is defined. The  $D_{ij}$ s also lie between 0 and 1, i.e.  $0 \leq D_{ij} < 1$ .

Again, the discordance indices can be used to make a discordance matrix  $D$  whose diagonal elements are assigned zero values or alternatively we may not give them any value since  $D_{ij}$  does not make sense.

### The Outranking Relation and the Kernel

Once the concordance and discordance matrices are computed, these will be used to define the outranking relation  $R$ . The outranking relation  $R$  is then used to define a composite graph  $G_c$ . Two numbers  $T_c$ , the concordance threshold and  $T_d$ , the discordance threshold, are taken such that both lie between 0 and 1 where  $T_c$  is nearer to 1 and  $T_d$  is nearer to 0. Alternative  $i$  will be said to outrank alternative  $j$  if two relations

$$(i) \quad C_{ij} \geq T_c \quad \dots\dots\dots (47)$$

and

$$(ii) \quad D_{ij} \leq T_d \quad \dots\dots\dots (48)$$

are simultaneously satisfied and only then an arc  $(i,j)$  will occur in the composite graph  $G_c$ .

After the outranking relation  $R$  is defined and the graph  $G_c$  has been constructed, the only remaining step is to deter-

mine the core or 'kernel' of this graph. The kernel  $K$ , which is a subset of  $M$  (the set of available alternatives) has the following properties.

- (1) The elements of  $K$  do not outrank each other. In symbols, for all  $i, j \in K$   $i \not\prec j$  and  $j \not\prec i$  where  $\prec$  means 'does not outrank'.
- (2) For each element  $b$  of  $M-K$ , there exists at least one element  $k$  of  $M$  such that  $kRb$ . Symbolically,

for all  $b \in M-K$  there exists  $k \in K$  such that  $kRb$

One of the ways of determining the set  $K$  is described below (Hwang and Yoon, 1981).

From the matrices  $C_{ij}$  and  $D_{ij}$ , the concordance and discordance boolean matrices  $C'_{ij}$  and  $D'_{ij}$  are formed as follows:

$$C'_{ij} = \begin{cases} 1, & \text{if } C_{ij} \geq T_c \\ 0, & \text{if } C_{ij} < T_c \end{cases}$$

and

..... (49)

$$D'_{ij} = \begin{cases} 0, & \text{if } d_{ij} > T_d \\ 1, & \text{if } d_{ij} \leq T_d \end{cases}$$

$C'_{ij}$  and  $D'_{ij}$  are characteristic functions  $\mu_{R_1}(i,j)$  and  $\mu_{R_2}(i,j)$  of the non-fuzzy outranking relations  $R_1$  and  $R_2$  (concordance and discordance conditions (47) and (48)). The elements of both  $C'_{ij}$  and  $D'_{ij}$  are either 0 or 1. The relation  $R_1(i,j)$  and  $R_2(i,j)$  are both satisfied if  $C'_{ij} = D'_{ij} = 1$ .

Where  $R_1(i,j)$  and  $R_2(i,j)$  denotes "i is preferred to j" based on concordance and discordance conditions respectively.

Next, the aggregate dominance matrix  $(e_{ij})$  is formed with its elements as  $e_{ij} = C'_{ij} \cdot D'_{ij}$ , so that each  $e_{ij}$  is either 0 or 1. If  $e_{ij} = 1$  then i outranks j because both (47) and (48) are fulfilled. After comparing every pair of alternatives, there will be found some alternatives that are not dominated by any other alternative belonging to M. Such alternatives are incomparable amongst themselves and constitute the kernel K.

#### (6) Electre II

Like Concordance Analysis and Electre I, Electre II is also concerned with true criteria, but unlike them it is concerned with devising fuzzy outranking relations for the same purpose. This method too was developed by Roy (1968, 1974, 1975) and Roy and Bertier (1971). While Electre I provides partial ordering of the nondominated set, Electre II offers a complete ordering.

As in the case of Electre I, both concordance and discordance conditions must be satisfied so that alternative i may outrank alternative j. In this method, multiple levels of concordance and discordance thresholds are specified and used to construct outranking relations, a strong relation  $R_s$  and

a weak relation  $R_w$  and they are used to construct two graphs.

### Concordance Index:

Here concordance index is defined as

$$C_{ij} = \frac{W^+ + W^-}{W^+ + W^- + W^0} \quad (i,j) \dots\dots\dots (50)$$

where  $W^+$ ,  $W^-$  and  $W^0$  are defined as in Electre I. The Concordance Test requires fulfilment of the following inequalities

$$(i) \quad C_{ij} \geq T_c \quad 0 \leq T_c \leq 1 \quad \dots\dots\dots (51)$$

and

$$(ii) \quad W^+ > W^-$$

where  $T_c$  specifies the minimum level of concordance.

### Discordance Condition:

Let  $X = (x_j: j=1,2, \dots\dots,m)$  be the set of available alternatives.  $\gamma_i$  is a positive bounded function which represents the worth of alternative  $x_j$  based on criterion  $i$ . Then  $X$  is mapped to  $E_i$  where  $E_i$  is an interval scale.

According to the discordance condition, alternative  $x$  will outrank alternative  $y$  if for  $(x, y)$

$$\frac{\gamma_i(y) - \gamma_i(x)}{\theta(i, \gamma_i(x))} < T_d \quad \dots\dots\dots (52)$$

$T_d < 1$  specifies the maximum allowable level of discordance.

The parameter  $\theta(i, \gamma_i(x))$  is a function of  $\gamma_i(x)$  and parameter  $S(k)$  such that  $\theta(i, \gamma_i(x)) = \max(\gamma_i(x), S(k))$ .

Having defined the concordance and discordance conditions it is possible to construct the two outranking relationships  $R_s$  and  $R_w$ . The use of  $R_s$  leads to stronger discrimination than the use of  $R_w$ .

Let  $p^*$ ,  $p^0$  and  $p^-$  be three specified levels of Tolerance values of concordance such that  $0 \leq p^- \leq p^0 \leq p^* \leq 1$ , and similarly, the specified Tolerance values for discordance are  $q^0$  and  $q^*$  such that  $0 < q^0 < q^* < 1$ .  $R_s$  is obtained if either I or II of the following or both are satisfied.

- |    |     |                   |        |     |                   |
|----|-----|-------------------|--------|-----|-------------------|
| I. | (1) | $C(i,j) \geq p^*$ | or II. | (1) | $C(i,j) \geq p^0$ |
|    | (2) | $D(i,j) \leq q^*$ |        | (2) | $D(i,j) \leq q^0$ |
|    | (3) | $w^+ \geq w^-$    |        | (3) | $w^+ \geq w^-$    |

If either I or II or both are satisfied then  $iR_s j$ .

$R_w$  is obtained if the following conditions hold.

- |     |                   |            |
|-----|-------------------|------------|
| (1) | $C(i,j) \geq p^-$ |            |
| (2) | $D(i,j) \leq q^*$ | ..... (54) |
| (3) | $w^+ \geq w^-$    |            |

If the above conditions are satisfied then  $iR_w j$ . The two relations  $R_s$  and  $R_w$  are reduced to two acyclic groups  $G_s$  and  $G_w$ . These graphs are then used for obtaining the ranking of the alternatives. The ranking procedure involves three

stages. A strong ranking, and a weak ranking are obtained. Then using these two a median ranking is obtained based on which we will get the final ranking of the alternatives.

Though the outranking methods are quite useful they have the disadvantage that they cannot be applied to continuous problems. Also, the assigning of weights  $w_i$  and the concordance and discordance thresholds are done subjectively. In many cases it is not possible to find a unique kernel of the graph. Derivation of quasi-kernel is used in such cases as has been discussed in Hansen et al. (1976).

### III. Interactive Methods

In many of the methods discussed in the previous sections the DM's involvement consisted only in prior articulation of preference by him. It is understood, however, that it is practically impossible for a DM to specify a priori the global preference structure because of the complexities of a multi-criteria evaluation problem. As the solution process advances, the DM gains more and more insight into the process. These methods are called 'Interactive' because each iteration in the methods consists of two stages:

- (1) A nondominated solution is identified.
- (2) The DM is asked to give his tradeoff information according to which modifications are made.

This process continues till a further improvement is no longer necessary or possible.

Some of the methods discussed in this section requires explicit tradeoff information from the DM, whereas others require only implicit tradeoff information. Such information are usually given by the DM in either of the following ways:

- (1) At the current solution point the DM examines the levels of the various criteria and indicates the amount of the criteria which has attained the most satisfactory achievement level so that it can now be conceded for improving the achievement levels of others.
- (2) The DM may be asked to choose the best compromise or nondominated action out of a set of 'good ones' presented to him. The choice is based on the effects of the alternatives over the criteria.

#### **A. Methods Involving Explicit Tradeoff Information**

##### **(1) The Method of Geoffrion et al. (Geoffrion, Dyer and Feinberg, 1972)**

In this method there are  $p$  objective functions reflecting the arguments of the DM's utility function. The method is based on a mathematical programming known as Frank Wolfe (1956) algorithm with the added feature of interaction with the DM.

It is assumed that the DM can specify an overall value function aggregating the individual  $p$  objective functions such that

$$Z = (Z_1(x), Z_2(x), \dots, Z_p(x)) \quad \dots \quad (55)$$

and the problem reduces to a single objective maximisation problem

$$\text{Max. } U(Z(x)) \quad \dots \quad (56)$$

subject to  $x \in X$

However, the method does not require the utility function,  $U(Z(x))$  to be explicitly defined. It requires only such local information as are needed to perform the computations. The method makes use of large step gradient method for solving the above problem. For convergence to occur, the following conditions must be satisfied.

- (1)  $X$  must be convex and compact.
- (2)  $U(Z(x))$  must be convex and continuously differentiable.
- (3)  $\frac{\partial U}{\partial Z_i (i=1, \dots, p)}$  is positive in the neighbourhood of the  $k$ th solution  $x^k (k=1, \dots)$ , (i.e. the marginal utility with respect to any criterion as reference, say  $Z_i(x)$ , should be positive). This method solves problem (56) by using linear approximations of  $U(Z(x))$  at each iteration. First of all, using Taylor series expansion, a temporary optimal solution  $Y$  is obtained for the problem (56) that uses the same constraints but whose objective function is a linear approximation  $\hat{U}(Z(x))$  of  $U(Z(x))$  at a feasible point  $x^k$ . We have,

$$\hat{U}(Z(x)) = U(Zx^k) + \nabla_x U(Z(x^k))^t (y-x^k) \quad \dots\dots\dots (57)$$

Substituting (57) in (56) we get,

$$\begin{aligned} \text{Max } & U(X(x^k)) + \nabla_x U(Z(x^k))^t (y-x^k) \\ \text{subject to } & y \in X \quad \dots\dots\dots (58) \end{aligned}$$

Since  $U(Z(x^k))$  and  $\nabla_x U(Z(x^k))x^k$  are constants, hence the problem reduces to the directional subproblem.

$$\text{Max } \nabla_x U(Z(x^k))^t \cdot y; \quad y \in X \quad \dots\dots\dots (59)$$

Let  $y^k$  be the solution to (59). The method then seeks to move in the direction  $d^k = (y^k - x^k)$  in which the value of  $U(Z(x))$  should increase. How far we should move in the indicated direction is determined by the solving of the distance subproblem.

$$\text{Max } U(Z(x^k + T^k d^k)) \quad \dots\dots\dots (60)$$

$$\text{subject to } 0 \leq T^k \leq 1$$

Once  $T^k$  is defined we get the next feasible point  $x^{k+1}$  such that

$$x^{k+1} = x^k + T^k d^k \quad \dots\dots\dots (61)$$

This process is repeated until no further improvement can be achieved.

As  $U(Z(x))$  is not explicitly known, solution of both sub-problems requires information from the DM. To tackle this, an equivalent expression for (59) is obtained as follows:

$$\begin{aligned} \nabla_x U(Z(x^k))^t y &= \left[ \frac{\partial U}{\partial Z_1}, \dots, \frac{\partial U}{\partial Z_p} \right]_{Z(x^k)} \begin{bmatrix} \frac{\partial Z_1}{\partial x_1}, \dots, \frac{\partial Z_1}{\partial x_n} \\ \dots, \\ \dots, \\ \dots, \\ \frac{\partial Z_p}{\partial x_1}, \dots, \frac{\partial Z_p}{\partial x_n} \end{bmatrix}_{x^k} \cdot y \\ &= \sum_{i=1}^p \left[ \frac{\partial U}{\partial Z_i} \right] \nabla_x \cdot Z_i(x^k)^t y \dots \dots \dots (62) \end{aligned}$$

Any arbitrary reference function, say  $Z_2$  is chosen and (62) is divided by  $\partial U(x^k)/\partial Z_2(x^k)$

We have now, the problem as:

$$\text{Max } \sum_{i=1}^p w_i(x^k) \nabla_x Z_i(x^k)^t y \dots \dots \dots (63)$$

subject to  $y \in X$

$$\text{Where, } w_i(x^k) = \frac{\partial U(x^k)/\partial Z_i(x^k)}{\partial U(x^k)/\partial Z_2(x^k)} = \frac{\partial Z_2(x^k)}{\partial Z_i(x^k)}$$

which represents the MRS of the DM between the  $i$ th objective and the arbitrary reference objective,  $Z_2$ .

Once  $w_i$  is determined, (63) can be solved using linear programming. The next step is to find a solution to the distance subproblem (60). Again, since  $U(Z(x))$  is not known,

the solution can be realised by presenting  $Z(x^k + T^k d^k)$  to the DM for various values of  $T^k$  such that  $0 \leq T^k \leq 1$ . The most appropriate step size ( $T^k$ ) is defined by the vector of objectives,  $Z$ , that the DM finds to be most satisfactory. Once  $T^k$  is determined, the next feasible point can be determined and so the algorithm continues. However, if the DM considers the current solution ( $x^k$ ) to be most satisfactory then the best solution is  $x^k$  i.e.  $T^k = 0$  and so the algorithm terminates.

This method is suitable for both linear and nonlinear MCDM problems. It is simple computationally, and its convergence is rapid. However, it requires a great deal of interaction with the DM. It also demands two types of statements from the DM:- (i) indifference tradeoffs, and (ii) for each feasible point considered, the DM's preference selection among several vectors of objective functions. Obviously, the articulation of the DM's explicit trade off information is difficult.

Details of this method are available in Geoffrion et al. (1972), Hwang and Masud (1979). Goicoechea et al. (1982) have given a flow chart to explain the method and have also given illustrative examples.

## (2) Interactive Goal Programming

Dyer (1972) has modified the simple Goal Programming problem by converting it into a vector maximisation problem

which can then be solved by the Interactive method of Geoffrion et al. (1972). We shall here discuss only, how a Goal Programming model is converted into a simple vector maximum problem. Let the problem be:

$$\text{Find } x \in X \quad \dots\dots (64)$$

$$\text{subject to } f_i(x) \geq a_i^*; i = 1, 2, \dots, n$$

$d_i^+$  and  $d_i^-$  are the over and under achievements from the aspiration point  $a_i^*$  (as already discussed in Goal Programming model).

The weighted additive model of the above problem will be

$$W = w_1(d_1^- + d_1^+) + \dots + w_n(d_n^- + d_n^+)$$

$$\text{such that } f_i(x) + d_i^- - d_i^+ = a_i^* \quad \dots\dots (65)$$

$$d_i^+ \cdot d_i^- = 0, w_i, d_i^+, d_i^- \geq 0$$

This problem is converted to the vectormaximum problem as:

$$\text{Max } \sum_{i=1}^n w_i U_i(x)$$

subject to satisfaction of the constraints  $U_i(x)$  are the maximisation type objectives obtained by applying suitable transformation over the problem (65).

$$\text{Since } \text{Min} \sum_{i=1}^n w_i d_i^- \Leftrightarrow \text{Max} \sum_{i=1}^n w_i (f_i(x) - d_i^+)$$

where  $\Leftrightarrow$  : "implies and is implied by"

Hence, the problem (65) can be restated as

$$\text{Max} \sum_{i=1}^n w_i (f_i(x) - d_i^+) \quad \dots\dots\dots (66)$$

$$\text{subject to } f_i(x) + d_i^- - d_i^+ = a_i^*$$

$$d_i^+ \cdot d_i^- = 0, w_i, d_i^+, d_i^- \geq 0$$

$$x \in X$$

which is a vector maximum problem to which the method of Geoffrion et al. (1972) can be applied for solving.

### (3) The Method of Zionts and Wallenius

This method is applicable when the objective functions are all linear. If they are not, then the nonlinear objective functions and constraints are first linearized. The feasible solution space  $X$  should be convex. Moreover, concavity of the objective functions and convexity of the constraint set are assumed. Thus the method assumes the feasibility of linear approximations of the nonlinear objective functions and constraints and also that the overall utility function is a linear function of the objective functions.

The best compromise solution will be an extreme point solution of the linearized constraint set. It is based on interactively generating nondominated actions.

First of all, from a set of arbitrarily chosen positive weights, a linear composite objective function is formed. Optimisation of this objective function gives a nondominated extreme point solution.

Thus, we have a problem

$$\begin{aligned} & \text{Max} \quad \sum_{i=1}^n w_i F_i(x) \\ & \text{subject to} \quad f_j(x) \leq b_j \\ & x \geq 0; \quad w_i > 0 \quad \forall_i; \quad \sum_{i=1}^n w_i = 1 \quad \dots\dots\dots (67) \end{aligned}$$

weights  $w_i$  are arbitrarily chosen by the DM.

If this extreme point is not the best compromise solution, then the DM is presented with adjacent nondominated points for consideration. Then a set of nonbasic variables which would lead to nondominated solution is brought to the basis. To make it a little more clear, an efficient nonbasic variable is one which, on being introduced into the basis cannot increase the value of an objective without decreasing that of others.

The DM is presented with the tradeoffs for each nonbasic variable and he determines whether they are desirable, undesirable or neither.

If  $d_{ir}$  is the decrease in the objective  $F_i(x)$  by introducing the nonbasic variable  $x_i$  in the basis, then the tests

for  $x_r$  to be an efficient nonbasic variable are as follows. For each nonbasic variable  $x_r$  the following LP problem is stated as follows:

$$\text{Min } F_r = \sum_{i=1}^n \lambda_i d_{ir}$$

$$\text{subject to } \sum_{i=1}^n \lambda_i = 1$$

$$\sum_{i=1}^n \lambda_i d_{ij} \geq 0; \quad j \in N; \quad j \neq r$$

$$\lambda_i > 0, \quad i = 1, 2, \dots, n$$

$N$  = set of nonbasic variables that have not been declared dominated.

**Test 1:** If  $F_r < 0$ , then the nonbasic variables  $x$  leads to a nondominated solution and it is an efficient variable.

**Test 2:** If  $F_r \geq 0$ , then  $x_r$  does not lead to a nondominated solution.

The next step involves interaction with the DM. For each of the efficient basic variables (i.e. those satisfying Test 1) the DM is asked whether the tradeoff  $d_{1r}$  of objective  $F_1(x)$ , tradeoff  $d_{2r}$  of objective  $F_2(x)$ , .... etc. are desirable, undesirable or neither. For responses indicating yes, no, and indifference, the corresponding constraints are satisfied:

$$\sum_{i=1}^n \lambda_i d_{ir} \leq -\xi \quad \dots\dots (69)$$

$$\sum_{i=1}^n \lambda_i d_{ir} \geq \xi \quad \dots\dots (70)$$

$$\sum_{i=1}^n \lambda_i d_{ir} = 0 \quad \dots\dots (71)$$

Where  $\xi$  is an arbitrarily chosen small positive number.

In the final step (69), (70), (71) are solved for  $\lambda_i$ . The resulting  $\lambda_i$ 's give the new weights consistent with the DM's preferences, to be assigned to the criteria  $F_i(x)$ . Then the entire process is repeated. At each iteration, (69), (70), (71) constraints are used, plus the new ones added to the side conditions in the current iteration. The process continues till a compromise solution is reached, i.e., the process terminates when  $N$  is empty or when all the  $x_j$ 's represent an undesirable tradeoff according to the DM.

This method has the advantage that it guarantees convergence in a finite number of iterations. Since the number of extreme points is finite and at least one point is eliminated at each iteration, therefore, convergence occurs eventually. Also the DM's involvement is less. But there is the restriction that all the objectives and constraints should be amenable to linear transformation, if not already linear.

#### (4) Frisch's Social Preference Function

Ragnar Frisch (1971) has given a method for formalising the preference structure of the DM into a model. In all the interactive models the DM's involvement at each iteration is significant. This method gives a process for using the preference structure of the DM in constructing a preference function. This function represents the preferences of the DM and is not to be confused with a general Welfare Function. This method proceeds through pairwise comparison of alternatives. Some important points about the method are:

- (1) The method uses the free form equation (which later on may be transformed by the expert into the reduced form if required).
- (2) The DM (who is being interviewed) should give his preferences irrespective of the possibility to realise them.
- (3) The variables that are to be included in the model are those which affect the justice consideration in the economy. Some variables which according to the expert's opinion influence justice consideration may also be included though it would be better to indirectly take care of them. Variation of minor importance will be left out for computational reasons. Even 'parameters of action' for the Government will be excluded unless they directly reflect an act of consumption.

For each pair of alternatives incorporated in the two packages - 'the package to the left' and the 'package to the right' - a dichotomic run of package questions are carried out. At each step in the run of questions, the DM is asked to give his preference for either package, until he comes to a point where he is indifferent between the two packages. This is the point of interest for the analyst. In this way, the preference pattern for each pair of alternatives is taken and the preference function that is constructed can take any mathematical form like quadratic, quasi-linear, linear, scale constant form, independence form, general scale function form, etc.

There are however some difficulties with this method. For instance, it is difficult to say who is the true representative of the society. Society consists of classes and the interests of one class often conflict with the interests of the others and the valuations and ideologies behind the arguments given by each class in support of their priorities and interests are also conflicting. Hence, it is difficult to construct a single Social Preference Function. While it is easier to form 'class preference functions' but then the problem will be to combine them into a single function. What weights will be assigned to the different 'class preference functions' is also difficult to decide. Further, it is always possible that the decision-maker is inconsistent in articula-

his preference pattern. If such inconsistencies are present in the preference pattern obtained by the analyst, the preference pattern violates the axiom of transitivity. In fact, such inconsistencies are due fundamentally to the fuzzy nature of preferences, as T.L. Saaty has observed. Mishra (1987) has suggested statistical treatment to deal with such inconsistencies. Narsimhan (1980) suggested geometric averaging method for inducing transitivity in such cases.

## B. Methods Involving Implicit Tradeoff Information

### (1) Step Method (Stem)

This method was proposed by Benayoun, de Montgolfier, Tergny and Larichev (1971). The method can be conceptually applied to both linear and nonlinear programming problems and discrete as well as continuous problems. The method proceeds through alternate stages of decision and computation. As the method proceeds, the DM becomes more and more aware of the problem and learns to recognise a good solution. The step involved in this method are as follows:

**Step 1:** The first step consists in preparing the pay off table by solving  $p$  linear Programming problems stated as:

$$\text{Maximise } Z_k(x) = \sum_{j=1}^n C_{jk} x_j \quad \dots\dots\dots (72)$$

subject to  $x \in X$

$$k = 1, 2, \dots, p$$

Let  $x^k$  be the solution to the above problem which gives the maximum value of  $Z_k$  (the  $k$ th objective) denoted by  $Z_{kk}^*$ . The values taken by the other objectives at the optimal solution of  $Z_k$  i.e.  $Z_{jk}^*$ . With these the payoff matrix  $Z_{ij}^*$  is constructed as

$$Z_{ij}^* = \begin{bmatrix} Z_{11}^* & Z_{12}^* & \dots & Z_{1p}^* \\ Z_{21}^* & Z_{22}^* & \dots & Z_{2p}^* \\ \dots & \dots & \dots & \dots \\ Z_{p1}^* & Z_{p2}^* & \dots & Z_{pp}^* \end{bmatrix} \quad \dots\dots (73)$$

The minimum value of each column  $Z_1^*$ ,  $Z_2^*$  .....  $Z_p^*$  of the objectives  $Z_k(x)$ ,  $k = 1, \dots, p$  obtained from the payoff matrix  $Z_{ij}^*$ , define a point  $g^*$ .

The ideal vector is given by the diagonal elements of the table (73) which gives the ideal point in  $p$  dimensional criterion space. Due to the conflicting nature of the various objectives, the ideal point does not lie in the feasible criterion space. Let us denote this ideal point as

$$g^{**} = (Z_1^{**}, Z_2^{**}, \dots, Z_p^{**}) = (Z_{11}^*, Z_{22}^*, \dots, Z_{pp}^*)$$

This vector however serves as a standard for evaluating the nondominated solutions.



The optimal solution to this problem is represented as  $x^r$ .

The  $w_k$ 's are normalised weights and their values are dependent on the variation of the objective from its value at the ideal point  $g^{**}$ . The greater the variation, the greater the emphasis on that objective and vice versa. However, these weights bear no resemblance to the DM's preferences or values but are only arbitrary.

**Step 3:** This stage consists of decision making. The solution vector  $x^r$  is presented to the DM who compares it  $(Z_1^r, Z_2^r, \dots, Z_p^r)$  with the ideal vector  $g^{**} = (Z_1^{**}, Z_2^{**}, \dots, Z_p^{**})$ . The DM must now indicate which objectives in this solution  $x^r$  can be decreased so as to increase the levels of unsatisfactory objectives. Not only this, he has to specify the amount by which the satisfactory objectives can be decreased. If  $H_s$  is the set of objectives at a satisfactory level, and  $H_u$  is the set of unsatisfactory objectives, then we have

$$x^{r+1} = \begin{cases} x^r \\ Z_i(x) \geq Z_i(x^r) - \nu Z_p & \text{for } Z_i(x^r) \in H_s \\ Z_j(x) \geq Z_j(x^r) & \text{for } Z_j(x^r) \in H_u \end{cases} \dots\dots (76)$$

$Z_i$  is the amount of the satisfactory objectives that the DM is willing to give up. The weights  $w_i$  associated with  $Z_i \in H_s$  are set = 0 and the weights  $w_j$  of  $Z_j \in H_u$  is calculated as in (75).

This procedure is repeated, conceding an objective at every iteration. It stops after a compromise solution is reached. If no compromise solution can be found then the DM has to see whether he can relax any aspiration level. If he cannot then it means that the problem has no satisfactory solution.

## (2) Method of Displaced Ideal

This method, developed by Zeleny (1974b, 1976) is also an interactive method suitable for MOLP. The method helps in generating efficient solutions and in measuring the nearness of these to an ideal point by using a suitable norm. In most cases a large number of nondominated points are generated and so it has to be reduced by using  $L_p$  metric as a norm. As a result of discarding a subset of the set of efficient points, the ideal point is displaced. The method involves the following steps:

**Step 1:** A set of nondominated solutions is generated by using any of the MOLP algorithms. This set is denoted by  $N_e$ .

**Step 2:** Now the ideal point is obtained by solving

$$Z_k(x) = \sum_{j=1}^n C_{jk} x_j \quad \dots\dots\dots (77)$$

subject to  $x \in X$ ;  $k = 1, 2, \dots, p$

which gives the ideal point  $g^{**} = (Z_1^{**}, Z_2^{**}, \dots, Z_p^{**})$  as in STEM.

**Step 3:** Next, a compromise set  $N_c \subset N_e$  is found such that the elements of  $N_c$  are closest to  $g^{**}$  by some suitable norm.

**Step 4:** If the set  $N_c$  is manageably small so that one or few solutions can be singled out, then the process is stopped. Otherwise a new ideal point  $g^{***}$  is defined so as to reduce the size of  $N_c$ . We have said that the closeness of elements of  $N_c$  to  $g^{**}$  is measured by a norm. Use of  $L_p$  metric which provides a wide range of geometric measures for measuring closeness, can be made to obtain  $N_c$  which consists of only those  $x^i$ 's for which

$$L_p(x^i) = \left[ \sum_{j=1}^k (d_j(x^i))^p \right]^{1/p}; 1 \leq p \leq \infty \quad \dots (78)$$

is reasonably small.

Here  $d_j(x^i)$  is a norm measuring the distance of the solution  $x^i$  from  $g^{**}$ .

### (3) Interactive MOLP (Method of Steuer)

Steuer (1977) has discussed an interactive method. Here the interval criterion weights are used, and the gradient cone technique is used to generate a smaller set  $N_c$  than is usually generated by other MOLP methods which generate an unmanageably large set of nondominated extreme points. But in case of a number of real world problems the set  $N_c$  generated by this method is also not very manageable. If there

are  $p$  number of criteria then the method presents  $(2p + 1)$  nondominated extreme points to the DM. If these are not satisfactory, then in the next iteration, another  $(2p + 1)$  nondominated extreme points are presented to him for his consideration. The process continues till a compromise solution, or a small number of compromise solutions, is reached.

#### (4) Compromise Programming

This interactive method also, developed by Zeleny (1973, 1974) is a method for Multiple linear objectives problem. Duckstein and Opricovic (1980) have used a variant of it in the analysis of discrete problems. In this method also, like in Displaced Ideal, a solution is found which is nearest to an ideal point by some measure of distance. This set of solutions is called the compromise set or compromise solution. Usually, the  $L_p$  metric is used as the norm for measuring the distance.

For the problem

$$\text{Max } Z_i(x) \quad \dots\dots\dots (79)$$

subject to  $x \in X$

$$i = 1, 2, \dots, n.$$

The ideal solution is defined as the vector

$$Z^{**} = (Z_1^{**}, Z_2^{**}, \dots, Z_n^{**})$$

and

$$Z_1^* = \min_{x \in X} Z_i \quad i = 1, 2, \dots, n.$$

The operational definition of a compromise solution for any given  $n$  is

$$\text{Min} \left[ L_p(x) = \left( \sum_{i=1}^n \alpha_i^p \left( \frac{Z_i^{**} - Z_i(x)}{Z_i^{**} - Z_i^*} \right)^p \right)^{1/p} \right] \dots (80)$$

$$= L_p(x^{**})$$

subject to  $x \in X$

where  $(\alpha_1, \alpha_2, \dots, \alpha_n)$  are the given weights.

Solving of (80) always generates a nondominated point for  $1 \leq p \leq \infty$ . For  $p = \infty$  there will be at least one nondominated solution  $x_p^{**}$  (Yu, 1971). Usually the method generates a small set  $N_e$ . If  $N_c$  is small and manageable enough for the DM to arrive at a final solution the process stops, otherwise it is necessary to redefine the ideal point. In a discrete problem, a payoff table can be used to define  $Z_i^*$  and  $Z_i^{**}$ . Hence, the method can be suitably applied to discrete as well as continuous problems. Moreover, the DM's involvement is also not much.

Another method requiring implicit tradeoff information is Goal Programming Step Method (GPSTEM (Fichefet 1976) - a goal version of STEM). The Sequential Multi-Objective Problem Solving Method (SEMOPS) of Monarchi, Kisiel and Duckstein (1973) which also involves implicit tradeoff information from the DM is a three step procedure involving set up, iteration

and termination. It cyclically uses a surrogate objective function based on goals.

In all the interactive methods an understanding of the process is gradually achieved by the DM at the successive iterations and each iteration results in generation of solution. The process of repeated evaluation continues till a compromise solution is reached. Hence, these procedures are dynamic and are suitable for evolutive situations. Methodologies of this class do not, however, guarantee a global optimum, and hence when these methods are used for evaluation, one cannot be definite or unfallibly sure about choosing the best alternative project/policy.

One of the shortcomings of the interactive methods is that as the methods proceed the DM gains more insight into the given problem, but once a particular tradeoff information has been conveyed at a particular step, it cannot be changed at a later stage when the DM feels like doing so. If such a change was possible the methods would be more relevant for practical purpose. Another practical difficulty is that more often than not the DMs do not like to face the questioning of the analyst. In this context we may say that methods which require lesser involvement of the DM are generally more popular.

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#### IV. Evaluation Under Risk and Uncertainty

Economic behaviour is generally characterized by elements of stochasticity and fuzziness. A majority of the methods discussed so far assume complete information (about the policy means and their outcomes). We know that this is not realistic. A rich literature on stochastic economic behaviour has been developed over the past few decades. Decision making and hence evaluation also has to take risk and uncertainty into account. Some methods like the Utility-Function Approach can deal with probabilistic cases. It is true that the methods become more complex because each criterion has a discrete or continuous set of outcomes for each action and the outcomes have some associated probability density function. For example, to take a single criterion case where criterion is  $g(x)$  and  $g^{rj}$  is the  $j$ th outcome of  $g(x)$  for  $r$ th alternative  $x^r$  with probability  $p^{rj}$  ( $\sum_j p^{rj} = 1$ ). The expected value of outcome for  $x^r$  is

$$E(g^{rj}) = \sum_j p^{rj} \cdot g^{rj}, \text{ for discrete random outcomes}$$

and

$$E(g^{rj}) = \int f(g(x^r)) d(g(x^r)) \text{ for continuous random outcomes.}$$

where  $f(g(x^r))$  is probability density function

$$d(g(x^r)) \text{ is the differential of } g(x^r) \quad \dots\dots\dots (81)$$

(81) can be used when all  $g^{rj}$  are quantifiable.

If they are not quantifiable then a quantifiable  $u^{rj}$  is associated with each  $g^{rj}$  and we have

$$U(g(x^r)) = E(u^{rj}) = \sum_j p^{rj} \cdot u^{rj} \text{ for discrete cases.}$$

and

$$U(g(x^r)) = E(u^{rj}) = \int (u^{rj}) d(u^{rj}) \text{ for continuous cases.}$$

..... (82)

Stochastic Programming methods have been developed to deal with DM problems because it is necessary to deal with:

- (1) The variations that arise in the estimation of the parameters associated with the probability distributions governing the random variables.
- (2) Variations in data at points of time as the decision process is carried on.
- (3) The uncertainty present in the type of probability distribution that is associated with the available data.

Some of the stochastic programming approaches developed in the literature (Sengupta and Fox, 1975) are:

- (1) Stochastic sensitivity analysis.
- (2) Decision - theoretic programming models.
- (3) Risk programming in Linear Programming models including:
  - i) Two Stage Programming (TSP).
  - ii) Stochastic Linear Programming (SLP).
  - iii) Transition Probability Programming (TPP).
  - iv) Chance Constrained Programming (CCP).

Some of the methods are:

- (1) Probabilistic Tradeoff Development (PROTRADE) Method.
- (2) The  $\alpha$ -Model.

However, most of the literature developed for stochastic behaviour deal with single objective decision problems. We shall not discuss these methods in details. However, we visualise that they can be applied/converted into multicriteria decision methods. Kahneman and Tversky (1984) have given an analysis of decision making under presence of risk.

We also visualise that unlike the models assuming certainty, the probability models of decision-making and evaluation may be such in which coefficients (in the objective functions/constraints) and constants (in the constraints) might be (among themselves) correlated. Such a situation is more likely to be faced by the analyst when functional relationships are econometrically estimated. To give an example, when we estimate an econometric model  $Y = XA + e$ , in all practical cases  $\hat{a}_i$  and  $\hat{a}_j$  ( $\hat{a}_i, \hat{a}_j \in \hat{A}$ ) have a nonzero covariance  $= \hat{\sigma}^2 (X'X)^{-1}_{ij} \neq 0$ . In multiequation models, coefficients across the equations too may be found to be correlated. By assuming that they are not correlated in population we cannot wish away their real and empirical presence at the sample (prediction) level, and hence they have bearings on evaluation (Mishra, 1987).

Optimisation in case of intercorrelated constants of side conditions has been attempted by Mishra (1985). While

minimising over/under production when final demand vector is stochastic and intercorrelated he introduced stochastic programming in the input-output framework. However, he has used only one objective function.

#### V. Fuzzy Set Theoretic Approach to Evaluation

While literature has developed in the area of stochastic economic behaviour and decision making under elements of stochasticity, very little systematic attempt has been made to investigate decision-making and evaluation in fuzzy economic situations. In the most non-technical way a fuzzy relation is expressed when the decision-maker expresses himself in statements like "a is more or less same as b" (corresponding crisp statement would be:  $a=b$ ), "a is rather better than b" (corresponding crisp statement would be:  $a > b$ ). Fuzzy relations, in general, are not transitive. If  $a \cong b \cong c \cong d \cong e$ , it does not follow that  $a \cong e$ , where  $\cong$  is fuzzy equivalence or fuzzy indifference. Fuzziness is due to dialectical nature of the change while crispness is due to arithmomorphism, as Georgescu-Roegen would put it (N. Georgescu-Roegen, 1971). Thus fuzziness and stochasticity are qualitatively different.

The theory of fuzzy set was first developed by Zadeh (1965). Later it was further refined and developed by Kaufman (1976), Kandel and Lee (1979) and Dubois and Prade (1980). Chen, Lee and Yu (1983) have investigated certain properties of a fuzzy utility function. Here the utility function is

expressed as a mapping from an n-dimensional commodity space to fuzzy subsets of utility space; then the fuzzy utility is maximised under budget constraints.

They have concluded that, with diminishing marginal utility of every iso-membership grade surface of a fuzzy utility relation, the optimum consumption equilibrium is obtained as a fuzzy set on the budget line in commodity space, provided that the fuzzy utility indicator is convex and normalized. It is found that as the membership grade of the equilibrium decreases, the utility level from the consumption equilibrium increases. Moreover, when the utility function is fuzzy, multiple consumption equilibrium are identified due to which the demand function also becomes fuzzy.

Leung Yu has given a discussion on fuzzy elements in decision process with conflicting objectives. In many of the methods that we have discussed so far, the algorithm proceeds by first defining an ideal point and then identifying a solution that is nearest to it. However, it is not realistic to have a point-value for the ideal. It is more likely for DMs to state objectives as, e.g. the profit accruing from the project must be very high, the pollution caused by the industry should be minimal and such other approximations implying fuzziness. Hence the ideal is more appropriately defined by a fuzzy intervals of a particular criterion (Zeleny (1976)).

Hence the compromise solution associated with the fuzzy ideal is also likely to be fuzzy. The constraints of the problem are also often fuzzy rather than crisp. Even the tradeoff information from the DM and other evaluation rules are usually better stated qualitatively (i.e. in linguistic terms) and hence it is necessary to make a mathematical translation of it and the translation can be best done in terms of fuzzy sets. Though, having fuzzy ideals and compromise solutions is perturbing to some DMs but actually it is more powerful in resolving multicriteria conflicts. There is, however, difficulty in deciding which point in the fuzzy ideal set should be chosen. Leung Yu has suggested two zero-in procedures for Fuzzy Ideal, which are defuzzification mechanisms for deriving point values of ideal point in the fuzzy ideal region, so that the associated compromise solution will be a point value also. After a compromise solution associated with the most compatible element of the fuzzy ideal is identified, should any conflicts arise, then it is possible to zero in on the next most compatible element of the fuzzy ideal and identify the relevant solution and so on. Hence resolution of conflict is made more flexible and effective.

Fuzzy set theory has been used to derive crisp equivalents of such decision making problems very elegantly (Bellman and Zadeh, 1970; Tanaka et al., 1974; Negoita and Ralescu, 1975; Yager, 1977, 1978, 1979, 1980; Zimmerman, 1978; Narasimhan, 1980).

Given the fuzzy model of the problem

(a) Determine  $x \in X$ .

$$\text{subject to } g_i(x) \succeq p_i; \forall_i \quad \dots \quad (83)$$

$$f_j(x) \preceq b_j \leq b_j; \forall_j \quad \text{and } x \succeq 0$$

with fuzzy constraints, where the symbol  $\succeq$  and  $\preceq$  are fuzzy relations corresponding to  $\geq$  and  $\leq$  crisp relations respectively.

Or

(b) Find  $x \in X$

$$\text{subject to } G_i(x) \succeq p_i; \quad i = 1, 2, \dots, k.$$

$$f_j(x) \leq b_j; \quad j = 1, 2, \dots, m. \quad \dots \quad (84)$$

$$x \succeq 0$$

with crisp constraints.

the crisp modelling consists of the following stages:

- (1) For the fuzzy goals (including fuzzy constraints), fuzzy sets  $A_i$  are identified, with membership function  $\mu_{A_i}(x)$  defined in  $X$ .
- (2) The fuzzy sets are aggregated by a suitable operator and for the fuzzy sets thus obtained, a membership function is specified which serves as the overall value function. The membership functions are normalised to take values in the interval  $(0, 1)$ . This provides a common measure for various goals (often noncommensurable).

Another significance about fuzzy set approach is the similar treatment of objectives and constraints.

The overall value function  $V(\mu)$  that incorporates all the objectives can be formed by using the interaction operator, the algebraic product operator, the union operator, the algebraic sum operator or  $\gamma$  compensatory operator. When the criteria are equally important and therefore conflicting, the intersection operator  $\mathbf{\Lambda}$  (corresponding to  $\mathbf{\cap}$  intersection operator in crisp set theory) can be used.

$$\begin{aligned}\mu_{A1} \mathbf{\Lambda} \mu_{A2}(a_j) &= \min [\mu_{A1}(a_j) \cdot \mu_{A2}(a_j)]; \forall a_j \\ &= \mu_{A1}(a_j) \mathbf{\Lambda} \mu_{A2}(a_j) \quad \dots \quad (85)\end{aligned}$$

The algebraic product implicitly takes care of compensation (tradeoffs) between criteria

$$\mu_k \prod_{i=1}^k \mu_{A_i}(a_j) = \prod_{i=1}^k \mu_{A_i}(a_j); \forall a_j \quad \dots \dots (86)$$

Models using union operator  $\mathbf{V}$  and algebraic sum operators are compensatory in nature.  $\mathbf{V}$  corresponds to  $\mathbf{U}$ , union operator, in crisp set theory.

The union operator is defined as

$$\begin{aligned} \mu_{A1} \mathbf{V} \mu_{A2}(a_j) &= \max \left[ \mu_{A1}(a_j), \mu_{A2}(a_j) \right]; \forall a_j \quad \dots\dots (87) \\ &= \mu_{A1}(a_j) \mathbf{V} \mu_{A2}(a_j). \end{aligned}$$

and it achieves the full satisfaction of a single goal.

The algebraic sum operator is defined as:

$$\begin{aligned} \mu_{A1(+)}\mu_{A2}(a_j) &= \mu_{A1}(a_j) + \mu_{A2}(a_j) - \mu_{A1}(a_j) \cdot \mu_{A2}(a_j); \forall a_j \\ &\dots\dots (88) \end{aligned}$$

Fuzzy outranking methods have also been developed. For instance, the Electre II and III methods are concerned with devising fuzzy outranking relations. A detailed review of decision-making techniques in fuzzy situation is given by Singh, D. (1983).

## VI. Group Decision Making and Evaluation

In many cases the decision making is done by not one person but a group of decision makers. Hence it is necessary for the methods to be able to incorporate the preference pattern of not one person but the group. Some models that have been developed allow for explicit interpersonal comparison of preference, for example, (1) The Delegation Process for parameter assessment, (2) Parameter assessment through Nash-Harsanyi bargaining model. Some methods that are relatively popular in Group Decision Making are:

- (1) Krysztofowicz's Group Utility Model.
- (2) The Nominal Group Technique.
- (3) The Delphi Technique.
- (4) Iterative Open Planning Process (IOPP).

As we have seen from our discussion in this chapter, many methods have been developed in the field of Multi Criteria Evaluation. However much still remains to be done. Multicriteria Decision-making and evaluation methods as a branch of knowledge is still young in its development and much research is being done to overcome the shortcomings of the methods already developed and to make them more suitable for real world situation taking into consideration the institutional framework, the dynamic nature of the economy and realistic economic models with fuzzy specifications and uncertain and risky outcomes.

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**C H A P T E R - I I I**  
**CONCEALED VALUATIONS IN THE EVALUATION**  
**METHODS AND PRACTICES**

## CONCEALED VALUATIONS IN THE EVALUATION METHODS AND PRACTICES

Our study on the methods of multicriteria evaluation of public policies will not be complete unless we discuss at length about the concealed valuations that underlie the evaluation methods and in turn permeate into the practice of evaluation. The main objective of this chapter is to reveal these concealed valuations in the evaluation methods elaborated in the previous chapter.

It looks rather overstretched to make such an allegation against the methods of evaluation and decision-making which are founded on well-reasoned mathematical foundations and scientific premises. Most of them are operations research methods and may find their applications wherever the analyst seeks for an optimum point in a feasible region. The field of their application need not necessarily be the social sciences in general and economics/economic planning in particular.

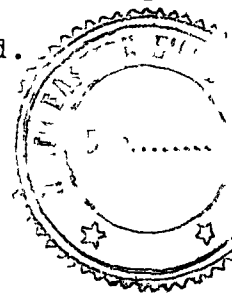
We do not find ourselves competent enough to comment on these methods when they are applied elsewhere. But when they are applied in economics/economic planning, it would be hard to deny that they become value-loaded. One may go further. It would be rather hard to deny that every piece of work in social sciences is value-loaded, as G. Myrdal has very successfully shown through his critical studies on objectivity in social research.

To present an etymological argument we would say that the word "evaluation" refers to the act and process of ascertaining or setting the amount or value of something. It also refers to judging or assessing the worth of something; more appropriate meaning of the term in the present context. Judgment, assessment and worth imply certain criteria, the choice of which, in turn, is dependent on certain norms. Hence 'evaluation' can neither be value-free nor can it be ideology-neutral.

There are at least seven points where valuation enters into the evaluation methods and permeates into the practice. These points are in:

- (i) Choosing the method of evaluation and decision-making,
- (ii) Choosing of objective functions, the terms and concepts that define them, the way they are measured,
- (iii) Setting of target levels, if any,
- (iv) Determining the direction of movement to a preferred point,
- (v) Choosing the metric, or the measure of distance between desired and achieved levels of aspiration function.
- (vi) Choosing the weights assigned to different objectives or aspiration functions,
- (vii) Choosing the decision-variables, the terms and concepts that define them and the way they are measured.

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One illustration should suffice justification. In development planning one often chooses objectives like increase in per capita income, reduction in inequalities in income distribution, generation of more employment opportunities, minimal environmental disruption, etc. Now the questions are: why increase in per capita income is opted for, while very respectable men held that a camel can pass through the eye of a needle but a rich man cannot pass through the gates of heaven? Buddha spoke of Nirvana not by increasing per capita income but by decreasing the desires! Further, why increase in overall per capita income? Why not of a specific class? Great men suffer greatly and insignificant ones suffer insignificantly, said Nietzsche. Then how does it matter if per capita income on an average decreases but for a particular class - the chosen ones of Nietzsche - there is an increase in per capita income? Environmental disruption and exhaustion of non-renewable resources are potential threat to the well-being of the future generation. But why to bother for those who are not yet born, at the cost of those who are there to enjoy life? These questions cannot be answered without holding on to some value judgement.

Now, let us come to the definitions of concepts like per capita income, inequality in income distribution, employment, etc. In defining income (national income), should we include the contribution of the housewives, though they

are not paid in an employee's sense? Should the income generated through the employment of crime control branch of police be included into the national income? Should expenditure on preparation for war be deducted from national income? A.K. Sen (On Economic Inequality, 1971) has shown how the methods of measuring inequalities in income distribution are value-loaded and his arguments need not be repeated here. A.K. Sen in his "Poverty and Famines: An Essay on Entitlement and Deprivation" (1981) has shown how valuation determines the meanings of famines, poverty and shortage. Gordon Tullock in his "The Economics of Wealth and Poverty" (1986) thoroughly discusses the valuation in policies regarding alleviation of poverty. To turn to "employment", it would be worthwhile to ask for the justification of preferential treatment to some on the extra-economic considerations like caste, tribe, sex, physical handicap, etc. Do such considerations satisfy efficiency criterion? or is efficiency criterion bogus? We are here not to criticise one set of values and applaud another. We want simply to note that all such considerations are value-loaded.

In Cost-benefit analysis we are often to choose a particular rate of discount to convert future net benefits into their present value. The time preference function is based on valuation - the relative importance that we give to the net benefits in future with respect to the net benefit at present. In practice, the present rate of interest is often

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used as the rate of discount. But the rate of interest depends on so many factors like profit rate on investment, supply of savings, etc. The choice of interest rate to represent discount rate, therefore, hinges on many premises involving justification of the current profit rate and supply of savings which depend, in turn, on existing income distribution. If the existing distribution of income is not justifiable, the rate of interest would not be justifiable and hence the rate of discount too.

In multicriteria evaluation methods we often choose a particular metric, say  $L_p$  metric defined as:

$$\begin{aligned}
 L_p &= \left[ \sum_{k=1}^m (\text{Abs}(Z_k^* - Z_k(x)))^p \right]^{1/p} \\
 &= \left[ \sum_{k=1}^m (\text{Abs}(Z_k^* - Z_k(x)))^{p-1} (\text{Abs}(Z_k^* - Z_k(x))) \right]^{1/p} \\
 &= \left[ \sum_{k=1}^m \alpha_k^{p-1} (\text{Abs}(Z_k^* - Z_k(x))) \right]^{1/p}; \quad 1 \leq p \leq \infty
 \end{aligned}$$

Where  $\alpha_k^{p-1}$  is the weight assigned to the distance between  $Z_k^*$  and  $Z_k(x)$

$$\alpha_k^{p-1} = (\text{Abs}(Z_k^* - Z_k(x)))^{p-1} = w_k, \text{ or weight.}$$

If  $p = 1$ , equal weight is assigned to all objectives. If  $p = 2$ , weight is assigned to objective  $k$  proportionate to the deviation of  $Z_k(x)$  from  $Z_k^*$  and so on. Thus choice of

p decides the weight given to deviations. Further, in this method of defining the metric equal weight is assigned to the deviation when  $Z_k^* > Z_k(x)$  and when  $Z_k^* < Z_k(x)$ . That is, the distance metric is symmetric around  $Z_k^*$ . This in itself is a case of valuation. In some cases symmetric distances may be acceptable, in some other cases lower side deviations may be more damaging than upper side deviations.

So far the case of choosing the decision variables is concerned, one may argue that the same objectives may be attained if we choose market mechanism rather than a non-market mechanism for distribution, allocation and production, and also the other way round. The society may be organized, argues K. Boulding, on the principles of exchange, threat or integration (Boulding, K.; Grants Economics: The Economy of Love and Fear, 1981). Choosing either of the three systems, or a mix of them, will determine our choice of policy instruments or decision variables. Choosing either of the three systems is largely a question of valuation.

When we carry out evaluation of public projects/policies, the question of social welfare comes in explicitly or implicitly. An economist would naturally invoke the concept of Pareto optimality and related issues in dealing with the desirability of public policies. But as Baumol (Economic Theory and Operations Research, 4th Ed. 1980, p.503) observes:

"Pareto optimality analysis sidesteps the issue of income distribution. Economists tried various approaches, none of them fully satisfactory, to the problem of income distribution. But the marginal optimality rules, which generally rests on Paretian foundation, themselves have little benefitted from this discussion. They remain either silent or prejudiced in favour of the status quo on the issue of income distribution and are, therefore, necessarily incomplete or unsatisfactory even on matters for which distribution is not the primary issue. Ultimately, the Paretian approach can be considered the welfare economists' instrument par excellence for the circumvention of the issue."

Discussing on the criteria for welfare judgements  
Baumol further comments (*ibid.*, pp. 526-27).

"... I believe that the discussion of welfare criteria was relatively sterile and was largely foredoomed to failure. Any attempt to construct a rigorous and universally applicable criterion for distinguishing what policy change is an economic improvement must founder on the problem of interpersonal comparisons. Where a policy change affects some person favourably and others adversely, as is usually the case, there is no a priori way of weighing the net result. Of course, we can and must make interpersonal comparisons .... However, these judgements must be rough and ready and can only be handled case by case. No abstract and general formula can be invented which handles all such problems satisfactorily."

Now, the hot debate on interpersonal comparison was due to non-commensurability. The switching over to multicriteria evaluation from cost benefit analysis is also due to non-commensurability. Requirements for weights to make these non-commensurable measurements comparable are there in both

the cases and with the same difficulties.

Baumol (ibid., pp. 531-535) discusses the Arrow's Democratic Group decision issue also. About the axiom of "Independence of irrelevant alternatives" he observes that one may suspect that the popularity among mathematical economists of the axiom of "independence of irrelevant alternatives" stems as much from its spectacular consequences as from its attractiveness as a political tenet. This again shows that evaluation and decision-making cannot be value-neutral or ideology-neutral.

Majumdar (1987, p. 91) has put it very clearly that evaluation cannot be ideology-neutral.

"The objectives of the society and the place of any individual in the society, the conflict between the social choice and individual values and such questions are no easy matter to decide. On these issues there are different viewpoints, and each viewpoint has a support of an elaborate system of philosophy. These philosophies are often conflicting among themselves. Social evaluation based on the philosophy of Nietzsche will applaud what the social evaluation based on the philosophy of Bentham or that of Rousseau will condemn. The result is that one cannot help but take sides and face criticism. The choice of criteria for social evaluation will depend on the ideology defining the relations of the individual with the society and the state, the objectives of the social organization and the polity and the related issues. That is to say that the choice of criteria of evaluation is not ideology-neutral."

Having argued at a general level to show that evaluation cannot be value-neutral and that it is not overstretched

to make the allegation against the method of evaluation and decision-making, we now turn to the evaluation methods one by one and show as to how they can conceal valuation at different stages.

### I. The Cost-Benefit Analysis

The Cost-benefit analysis can be represented by the simple formulae (2) through (6) in chapter I. In these formulae, the social rate of discount appears as one of the concepts which is very much dependent on valuation. In deciding the social rate of discount, the following questions are important.

- (a) Is it democratic to judge the value of costs and benefits that would accrue to the future generations, without allowing the future generation to vote? By invoking Arrow's axioms, it can be shown that even if a single person in future generation will have a different ranking of alternatives than does the present generation have, the general consensus cannot be achieved.

But such possibilities cannot be brushed aside. This question has a tremendous scope for philosophical controversies and nothing can be settled without holding a particular ideological position.

(b) Should discount rate be positive? By taking the side of the future generation, one may argue that instead of converting the net benefits of the grandsons into the net present value of benefits to the grandfathers, one should convert the net benefit of the grandfathers into the values of benefits to the grandsons. Further, the gones should be bygones and a great suffering of the grandfathers is commensurate with the small benefit to the grandsons. After all we survive by the future generation; we save for them, we suffer for them and we bequeath to them. This argument would make the discount rate negative.

(c) Should costs and benefits be discounted at the same rate? If we assume the axiom of diminishing marginal utility (or any such thing that is based on the Weber-Fechner Law), costs should be discounted at a lower rate than the benefits are discounted. Of course, this issue becomes unimportant when net benefit is computed. But while computing net benefits, one may argue that differential weights should be assigned to costs and benefits and thus

$$PVNB = \sum_{t=0}^T \frac{\alpha_t B_t - \gamma_t C_t}{(1+i)^t}$$

where  $\alpha_t$  and  $\gamma_t$  are differential weights given to

benefits and costs, would be the correct formula for computing PVNB. However, to determine  $\alpha_t$  and  $\gamma_t$  we shall have to use value judgement.

- (d) Should the prevailing rate of interest be used as the discount rate? Factors that decide the rate of interest may not be suitable for justifying the social discount rate, because fundamentally the discount rate and the rate of interest are conceptually two different things.

These are some of the questions that involve value judgement in deciding a particular rate of social discount to be used in converting the future benefits and costs in the present value.

Now we turn to accounting of costs and benefits. Benefits are many in number and measured in different, usually non-commensurable, units. Costs also are of many types and usually non-commensurable. Some of the costs and benefits are not tangible, some others are not even identifiable, until the projects are already executed. The analyst, therefore, accounts for a subset of costs and benefits from the larger set of costs and benefits. The choice of an appropriate subset involves value judgement. Sometimes an important type of cost or benefit may not be included in the subset due to the bias of the decision-maker or the analyst or both. At other times,

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as Myrdal would warn us, ignorance and knowledge both may be opportunistic in highlighting what we want to highlight and ignoring what we want to ignore. Such highlighting or ignoring may be subconsciously done or may be purposefully directed.

In cost-benefit analysis different types of costs and benefits are measured in different units. Then each of them is assigned a weight, reflecting the social price/value of that particular cost or benefit. The choice of weights is the most tricky problem. Market prices may not be available for each of them, and when such prices are available, they may not reflect the true social prices. It is suggested, therefore that shadow prices may be used. The computation of shadow prices is made by solving the dual of the original optimand model. But shadow prices depend on the structure of constraints. These constraints may not always be technological. Some of them may be there on account of value judgement. What the policy makers think to be relatively a scarce resource that needs conservation or minimal use decides the shadow prices. A few decades back, forest resources were considered as free gift of nature and environmental pollution was not a matter of concern. Now policy makers have become concerned about planned preservation and conservation. This change in attitude reflects upon the structure of constraints and thus on the shadow prices. Thus, shadow prices are not immune to value judgement.

Some economists have argued for using international prices of commodities. These prices, however, need not reflect the true social worth of the commodities in the society where the project/policy is being evaluated for execution. At best, these prices may reflect the worth of commodities which enter into the international exchange, and that also when there are no taxation, bounty, restriction or efforts of promotion of international trade by any country.

In the cost-benefit analysis it is tacitly assumed that costs and benefits accrue, as if, to the same person. However, the costs of the project may be paid by a different group of people than those to whom benefits accrue. If interpersonal comparisons are not allowed, the problem becomes very difficult to resolve. But if such comparisons are allowed then also the question of assigning weights would arise. This problem can be solved only if we are prepared to apply value judgement.

## **II. Multicriteria Evaluation Methods**

Many of the characteristics of being involved in value judgement that have been mentioned in case of Cost benefit analysis are attributable to the multicriteria evaluation methods also. However, we do not want to repeat them here. We present below only the additional points to be noted.

Let us first of all take up the methods of generating non-dominated solutions. These methods work with a number

of objective functions corresponding to the objectives of the policy maker. From the viewpoint of an economy, the very fact that a fixed number of alternatives is considered for a given evaluation exercise implies the valuation that full information is available to the decision-maker and the chosen alternatives are the only significant alternatives. Also, most of the methods proceed with the valuation that the different objectives are quantifiable in the degree of their attainment. In some cases weights are assigned to different objectives. The very assigning of weights to the different objectives reflects such valuations or importance given to various objectives or aspiration functions.

Next we come to methods with prior articulation of preferences by the decision maker. In these methods, as we have already seen, the decision maker is expected to state his preferences for the different objectives at the very outset. The valuation underlying this requirement is a straight one. It assumes that the decision maker has full information at the very outset and has full insight into the entire problem. This is a tall expectation. In small decision making problems at the micro level this may be possible to some extent but for an economy with all its complexities this is not possible, not to mention the underdeveloped economies where so much of an information gap exists. Goal Programming, which is one of such methods, also requires the decision maker

to set targets for the different objectives at the very start of the process. It would be interesting to observe that since the decision maker is made to specify aspiration levels in terms of goals and because he has very little information about the system and as such even about how much the constraints will allow for, the solution arrived at may not always be a nondominated solution. For example, if the intersection of the lines representing the constant goals, is itself a dominated point, then the final solution obtained may also be dominated. This happens when all the deviations in a solution are zero indicating that all targets have been fully attained.

In the general formula used for Goal Programming, where we try to minimise the sum of the absolute values of the differences between target values and actually achieved values, the emphasis is on the sum of the deviations over the different objectives. This is due to the valuation that the overall effect of an alternative (policy/project) depends on the overall value of the deviations. But this, as we can see is not the case. For example, we may have an alternative for which, for all the objectives there are slight deviations and the sum of the absolute value of the deviations amounts to, say, D.

For another alternative, it may be that all the target levels are exactly achieved except for the  $i$ th objective,

where the deviation is very great and itself equal to D. Now in each case the sum of the absolute value of the deviations is equal to D and if this is the minimum achievable deviation then by this method both the alternatives are equally acceptable. This would be considering the objectives (criteria) as fully compensatory in nature and not at all competitive. In reality however the criteria are both competitive and compensatory. As such the valuation that both the alternatives have the same effect on the welfare of the economy is not tenable. What is required at this stage is that the decision maker should exercise his preference for either of the alternatives subjectively. The methods that generate a set of nondominated solutions at least allow for this choice. However, it is really the interactive methods that do not avoid such possibilities by being too optimistic about the information possessed by the decision makers at the very beginning, and they are therefore more realistic.

We shall now turn our attention to the Utility Approach. Here even the formation of the utility function assumes that the decision maker is fully aware of the alternatives and the utility derived from each. Also, the fact that additive form of utility function is used and even the axioms for the analysis assumes that the utility from the different objectives is independent.

When the MUF assumes the multiplicative form

$$1 + k\mu(x) = \left[ \prod_{i=1}^n 1 + k\lambda_i \mu_i(x_i) \right]$$

it implies that the decision maker is either risk averse for all objectives or risk seeker for all objectives. On the other hand, when the MUF takes the additive form

$$\mu(x) = \sum_{i=1}^n \lambda_i \mu_i(x_i)$$

it implies that the scaling constants  $\lambda_i$ ,  $i=1, \dots, n$ .

$$\text{satisfies the norm } \sum_{i=1}^n \lambda_i = 1$$

In Utility Approach use is made of weights. The weights actually represent the marginal rate of substitution between any two criteria. Hence if constant weights are applied to the model as

$$\mu = \sum_{i=1}^n w_i \mu_i(x)$$

then the importance assigned to a particular objective remains the same whatever its achievement level. This cannot be true since the weight of an objective should decrease with the increase in its achievement level. Since the MRS between two criteria always depends on the current solution point therefore the weights,  $w_i$ , should also depend on the current solution point. Hence we have,

$$\mu = \sum_{i=1}^n w_i(x) \mu_i(x)$$

Cost Benefit and Cost Effectiveness Analyses are special cases of this Approach and are based on the same principle.

In the Surrogate Worth Tradeoff Method the tradeoffs between the criteria continues till all the surrogate worth functions (i.e.,  $w_{ij}; V_{i,j}, i \neq j$ ) are simultaneously equal to zero. We know that whenever  $w_{ij} = 0$  we have  $MRS_{ij} = \lambda_{ij}$ . Actually this is the point at which a best compromise solution is reached because at this point marginal loss equals marginal gain for all objectives taken two at a time. Since the decision maker wants to reach the point of a best compromise solution, hence at this point (where all  $w_{ij} = 0$ ) he finds that he cannot increase his gain by any further tradeoffs. So at this point he is satisfied. However it is possible for a number of solutions to have surrogate worth functions all equal to zero. All these solutions together will therefore form the indifference band, since the decision maker will be indifferent between these solutions.

The methods like Exclusionary Screening, Conjunctive Ranking are based on ordinal value functions. In the Conjunctive Ranking Method the ultimate ordering is done on the basis of only one criterion and therefore the method escapes the important concept of tradeoffs between different criteria which the decision maker should carry out in order to choose from the set of nondominated solution.

Regarding the methods that are based on using an outranking relation to order the set of nondominated alternatives we can say that the nontransitivity assumptions which state that  $a_1Ra_2$  and  $a_2Ra_3$  need not necessarily imply that  $a_1Ra_3$  because the reasons (criteria) on which  $a_1Ra_2$  and those on which  $a_2Ra_3$  may be so distinct that they cannot be compared. This is quite a realistic assumption that goes against the full rationality assumption made generally.

The outranking methods give each criterion its importance because the project effect matrix shows pairwise comparison of the alternatives on the basis of each criterion, separately. This gives a clear picture of the problem. Moreover, it gives emphasis not only on the criteria for which  $i$  is preferred to  $j$  but the very fixing of acceptable levels for Discordance Index also implies that it is not biased against even one criterion if for it  $i$  is sufficiently inferior to  $j$ . However, the choice of tolerance levels involves value judgement.

Thus, we can say that the outranking methods are based on the following assumptions that indirectly depend on valuation of a particular type.

- (1) There should be sufficient majority among the criteria to consider that an alternative  $i$  is not worse than another alternative  $j$ . That is, there should

be enough reason to argue that  $i$  is at least as good as  $j$ .

- (2) No criterion in disagreement with this majority should be in too much superiority of  $j$  over  $i$ . That is, the conditions that favour the proposition ' $i$  is not at least as good as  $j$ ' should not be too strong.

The Concordance Analysis, Electre I and Electre II methods are all based on these valuations though they are slightly different from the operational point of view.

In Concordance Analysis, we see from the formula for calculating the  $C_{ij}^*$ 's that  $i > j$  and  $i = j$  for  $S_i = +1$  are given equal weightage i.e. for both cases  $L_k = 1$  and only  $i < j$  is taken on the other side that is  $L_k = 0$ . Therefore in this formula indifference between alternatives  $i$  and  $j$  or preference of alternative  $i$  over alternative  $j$  is given the same treatment, whereas in Electre I method, also discussed in Chapter II we find from equation (45) that  $W^-$  (i.e. when  $i$  is indifferent to  $j$ ) is given half the weightage of  $W^+$  (where  $i$  is preferred to  $j$ ). This seems to be more reasonable so as not to bias the analysis towards alternative  $i$ 's favour.

The Electre II method is a little more sophisticated in that it allows for both strong and weak preference relationships. Sometimes even if an alternative does not satisfy the strong preference conditions, it may still be worthwhile to implement it if it satisfies the weak preference conditions.

From the discordance formula

$$\frac{\gamma_i(y) - \gamma_i(x)}{\theta(i, \gamma_i(x))} < q \quad : (x,y) \in X \times X$$

we find that  $\theta(i, \gamma_i(x))$  introduces a dynamic element. If this is not desired then the method also allows a static discordance measure. For this a fixed  $\theta(i, \gamma_i(x))$  for each criterion  $i$  will be taken. If the same  $\theta(i, \gamma_i(x))$  is chosen for all criteria then this discordance measure becomes identical to that of Electre I.

Again the parameter  $S(k)$  which is related to the  $k$  type scale used for criterion  $i$ , and of which  $\theta(i, \gamma_i(x))$  is a function, in effect allows the decision maker to vary the importance of the difference of the levels of the  $i$ th criterion, that is, the importance of  $\gamma_i(x) - \gamma_i(y)$  for any criterion  $i$ . If  $S(k)$  is large the number of pairs of alternatives  $(x,y) \in X \times X$  that do not satisfy the discordance test could be decreased and the decision maker may tend to ignore the impact of a criterion  $i$  that would yield a large value of  $\gamma_i(y) - \gamma_i(x)$ . If  $S(k)$  takes a small value the opposite would be the case. Thus the decision maker can reflect his preferences and opinions not only through the tolerance levels but also through  $S(k)$ .

Though these methods that involve prior articulation

of preferences by the decision maker allow explicitly for incorporating the decision maker's preferences into the methods, yet the valuation that the decision maker is one who has complete information about the working of the entire economy is quite unrealistic. Of course in developed countries the statistical material available is now much more complete and reliable. But not so in the underdeveloped countries where it is difficult to get reliable statistics even for simple concepts. Moreover, in these countries mere knowledge of economic conditions (which itself is quite difficult to attain) also would not be enough because in these countries even the non-economic factors play an important role unlike in the developed countries where such factors are less important in the analysis since they are either already adjusted to or will soon become adjusted to once the economic impulses are let through.

Under such conditions it is not possible for the decision maker to state his preferences for the different alternatives in a precise and consistent manner. For it is only as the method proceeds that the decision maker gains more and more insight into the problem and then he is in a position to state his preferences rationally and in a consistent manner.

It is this principle on which the interactive methods are based. Because as the method proceeds, the decision maker can state his preferences, (usually in the form of tradeoffs),

more rationally. Some of the interactive methods like Compromise Programming, Method of Displaced Ideal, etc. try to minimise the distance of the solution from an ideal point. To measure the distance, often the  $L_p$  metric is made use of. In Chapter II we have seen that even Goal Programming makes use of the  $L_p$  metric.

We have noted earlier that the deviations are weighted proportionately to their magnitude, i.e. the larger the magnitude of the deviation the larger the weight. As  $p$  becomes larger in size, the largest deviation get more and more weight.

And when  $p = \infty$  we have

$$L_{\infty} = \max_k (Z_k^* - Z_k(x))$$

We see that the parameter  $p$  clearly reflects the importance to the maximal deviation that the decision maker wants to assign.

The  $\alpha_k$ 's reflects the importance that the decision maker attaches to each objective.

Hence in Compromise Programming the decision maker expresses his preferences through the values of both  $\alpha_k$  and  $p$ .

From the very categorisation of these methods under the name 'Interactive Methods' we know that these methods proceed through interaction with the decision maker. However,

even these methods do not allow the decision maker to change his previous information supplied, at a later stage when he has gained more understanding of the situation when he may feel that he would like to change the information he has supplied at a previous stage. So even though these methods are 'interactive' they still assume that the decision maker even at the start of the process has enough understanding to state his preferences quite rationally. It is due to this that these methods are not as realistic as the name implies.

Coming to the Fuzzy Set Theoretic Approach, this approach recognises the fact that the goals specified by the decision maker may not always be so rigid, that is, he may make statements like - the achievement level should be approximately greater than  $p_i$  or the achievement level should be in the vicinity of  $p_i$ , and the like. The Fuzzy Set Approach allows for including such fuzzy goals also.

In the conventional approach, the criteria in a given problem help to establish a total preorder over the alternatives. In the Fuzzy Set Approach, the membership functions also does the same thing. The membership functions are derived from the performance functions (criteria) by a suitable normalisation to the linear closed interval  $[0, 1]$ . Due to this normalisation, a common measure is obtained for the various commensurable or noncommensurable goals.

We have seen in the conventional multicriteria evaluation methods weights are often assigned to the objectives which are in noncommensurable units and therefore they cannot truly reflect the MRS between objectives. The Fuzzy Set Theory Approach takes care of this also implicitly. Here weights are assigned to the membership functions of the fuzzy sets that identify the fuzzy goals. Since the membership functions are unidimensional therefore the implied tradeoffs by assigning weights to membership functions is made more significant than by assigning the weights directly to the objectives.

The use of Lagrangian multipliers in many methods showed the implicit similarity between goals and constraints. In the fuzzy formulation, however, this similarity is made explicit by treating goals and constraints equivalently.

This approach also recognises the fact that the objectives are sometimes highly competitive in nature and often they are also compensatory. Dealing with both types of objectives is possible through this approach which can be done by choosing the right kind of operators for aggregation. For instance, modelling  $V(\mu)$  with intersection operator would ensure minimum degree of satisfaction of each criterion and this is known as the competitive model. In the model based on algebraic product operator however, their compensatory nature is implicit. The union operator on the other hand, is fully compensatory in nature. Since the criteria cannot be

fully competitive or fully compensatory, the superiority of the algebraic product operator can be acknowledged. The use of the  $\gamma$ -compensatory operator used by Zimmermann and Zysno (1980) in fact allows for varying degrees of compensation between the criteria in a given problem.

We make another interesting observation about the Fuzzy Set Theoretic Approach. We have seen that in Goal Programming, the solution obtained may sometimes be a dominated solution, especially if the ideal point itself is a dominated one. But the Fuzzy Mathematical Programming (FMP) and the Fuzzy Linear Programming (FLP) models always result in a non-dominated solution. Even if the ideal point (say  $Z^*$ ) is a dominated point, the maximisation of  $V(\mu)$  always ensures a nondominated solution, whichever aggregating operator we use, because maximum of  $V(\mu)$  always lies on the efficient frontier. In such a case, the solution may be  $Z'$  for which all levels are higher than the aspired levels. This is not possible in Goal Programming where the constraints are rigid and cannot be violated.

The Group Utility Models are more value-oriented than goal-oriented. Arrow's Impossibility Theorem shows that it is possible to construct Social Welfare Function only if we allow for interpersonal comparison of utility. The Group Utility Models therefore explicitly introduces interpersonal comparison of utility. Here, since the utilities of each indivi-

dual in the group are taken to be independent of that of the others, the methods implicitly hold the valuation that there is absence of any interaction within the group of decision makers. This ignores the very dynamics of group decision making.

### III. Concluding Remarks

In the previous sections we have attempted to bring out into the open some of the valuations that were implicit in the evaluation methods. Valuations enter in the choice of alternatives, the gathering of data, choice of approach, definition of concepts, the formulae for measurement and numerous other stages. Once again we stress on the importance of bringing out these valuations explicitly because by remaining unaware of them by leaving them implicitly assumed is only to leave space for uncontrolled biases and influences from the valuations sphere. Once the valuations are made explicit their validity can be judged on the basis of their logical consistency, feasibility, relevance and significance in the society we are dealing with, i.e., the institutional setup and also the nature of the problem to be applied to, the level at which the methods will be applied (i.e., micro level or macro level) etc. If they are found not to be logically consistent among themselves or not realistic, taking into consideration the special characteristics of the context, then they should be done away with or at least modified and made realistic.

To acknowledge the importance of the possible consequences of valuation in evaluation methods we sum up the main points of this chapter, here, though at the cost of some repetition.

- (i) The choice of the method of evaluation is not value free, because different methods of evaluation have different scope for different types of valuations to entertain.
- (ii) The assumption that the policy maker represents the society and fully knows the social preference is value loaded and rests on a particular type of political philosophy. Every policy maker cannot be the "Philosopher King" of Plato, and even if one is like that, he must go along with the philosophical tenets of Plato, which may at times be objectionable.
- (iii) How many and which objectives/criteria/aspirations functions to account for in evaluation? The choice may be opportunistic, biased and favouring certain values, or classes. Each objective does not serve all classes in the society equally well.
- (iv) Target levels, if any, set for different objectives involve some value judgement.
- (v) Weights assigned to different objectives are necessarily value loaded.
- (vi) Time preferences are necessarily value loaded.

- (vii) That what is desired, need not be desirable. Desires of different classes may be conflicting among themselves, but the "desirables" must be value loaded. Also, it may not be possible to know about the "desirables" by studying the "desires".
- (viii) The choice of metric to measure the gap between 'desired' and 'achievable' is not free from value judgements.
- (ix) To think of different objectives competing or complementing is to involve in value judgements. The choice of an evaluation method depends on this consideration.
- (x) Methods that use Tolerance Levels (e.g. concordance analysis, Electre) may be prone to certain value judgements in choosing the tolerance levels. By suitable choice of tolerance, an equivalent project (otherwise) may be declared preferred or deferred.

We confess, however, that all these points are not exhaustive and there could be many more points where valuation may enter, though we could not recognise those points.

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C H A P T E R - I V  
MULTICRITERIA EVALUATION METHODS: APPLICABILITY  
TO ECONOMIC POLICIES AT MICRO LEVEL

**MULTICRITERIA EVALUATION METHODS: APPLICABILITY  
TO ECONOMIC POLICIES AT MICRO LEVEL**

**1. Two Levels of Decision-Making and Evaluation**

In Chapters II and III we have discussed the various methods that are available for multicriteria evaluation of public policies and also the implications underlying these methods. Now, we want to point out that evaluation of public policies/projects can be done at two levels -

- 1) Micro level evaluation, and
- 2) Macro or national level evaluation.

Whether the evaluation is to be done from the micro or the macro stand point, the methods available for carrying out such evaluation are the same. But the picture at the micro level is different from that at the macro or national level. As a result, not only the objective functions and constraints and the variables to be dealt with would be different at the two levels, but there would be many other factors that are peculiar to evaluation at each level. It is important to understand all these peculiarities because without a full understanding of the situation it is difficult to capture the reality in a number of equations for using any method of multicriteria evaluation. Hence, in this chapter and the next we try to explore critically the important features which we come across in applying the methods of multicriteria evaluation

of public policies at the micro level and the macro level. These features also help to understand why evaluation is done at both levels, whether one type of evaluation is more important than the other and such other questions. In this chapter we shall discuss the features of evaluation at micro level and in Chapter V we shall talk of macro level evaluation.

## **2. Micro and Macro Level: Specificities**

But let us first of all define clearly what we mean by 'micro level' and 'macro level'. The term 'micro' is derived from the Greek word 'mikros' meaning 'small' and the term 'macro' from the Greek word 'makros' meaning 'large'. According to K.E. Boulding (1950),

"Microeconomics is the study of particular firms, particular households, individual prices, wages, incomes, individual industries, particular commodities."

and

"Macroeconomics deals not with individual quantities as such but with aggregates of these quantities; not with individual incomes but with the national income; not with individual prices but with the price levels; not with individual outputs but with the national output."

The above definitions give an idea about the scope of decision/policy making at the two levels.

## **3. Evaluation at Micro-Level: Justification**

Next, we shall try to justify why micro level evaluation is necessary at all. Such a justification must be made

from both theoretical and practical angles. Micro level evaluation is required for an indepth understanding of policy implications. It tells us how the outcome of different projects affect different individuals and different classes of the society. Only such a study can tell us (i.e. explain) the conditions of efficiency of consumption and production and point out the factors responsible for any departure from the efficiency or economic optimum. Only on the basis of this it may be possible to suggest policies to correct such discrepancies and promote thereby the efficiency, and also the welfare of the people. Hence the 'actual operation' of the economy cannot be understood without taking such a micro level study. Describing the usefulness and indispensability of a micro level study, A.P. Lerner (1968) says that it

"facilitates the understanding of what would be a hopelessly complicated confusion of billions of facts by constructing simplified models of behaviour which are sufficiently similar to the actual phenomena to be of help in understanding them. These models at the same time enable the economists to explain the degree to which the actual phenomena depart from certain ideal constructions that would most completely achieve individual and social objectives. They thus help not only to describe the actual economic situation but to suggest policies that would most successfully and most efficiently bring about desired results and to predict the outcomes of such policies and other events."

Modern economies are so complex that it is difficult for the Decision Maker while framing economic policies to

gather all relevant information required for the optimum allocation of resources in order to maximise the achievement of multiple objectives set out for a plan, or to give directives to the thousands of individual units within the economy, each one with its own problems, so as to ensure efficiency in the use of resources. Also, the economy is not static but dynamic. Hence, by the time the effects of the government policies trickle down to those for whom they were meant, many interactions take place within the system. Hence, it is often seen that there is a discrepancy between ex-ante and ex-post magnitudes of the levels of different objectives that are set by the Decision Makers. If the individual units do not benefit from the policies then we can hardly say that the plan has been successful. For attaining social or national welfare it is necessary to ensure welfare of each micro unit. It is because of this that it becomes necessary to carry out micro level evaluation. As an example we can say that when government levies a commodity tax it is micro level study that can determine the distribution of its incidence between buyers and sellers and without this knowledge it is difficult to know about the impacts of the tax system.

#### **4. Odds Against Evaluation at Micro Level**

At the micro level money expenditure will reflect costs and money receipts (revenue) will represent benefit. So, at the micro level both input and output of a project must be

valued at market price. It is true that the market prices may not reflect the real cost to the society, but that is not of concern to the individual unit.

Thus, one of the most important differences between evaluation at micro and macro levels is due to the treatment of external effects. Many effects of a particular project - both positive and negative - on account of their being external are not reflected as the input or output of the project - e.g. air or water pollution resulting from the setting up of a project will not be reflected in the profit or loss account of that project at the micro level. Of course, when we are evaluating from a national point of view then such externalities should be taken into account. Hence we find that many projects cannot be considered to be at profit, even though they have beneficial external effects, so long as these beneficial spill-overs remain unpriced. On the other hand, and more significantly, we find that, many profitable projects produce harmful external effects to such an extent that on a more comprehensive pricing criterion, they would be considered as uneconomic. This amounts to saying that though such projects will be considered profitable from micro point of view, yet, from the macro or national standpoint they will not be recommended. Moreover at the micro level it is also not necessary to consider the forward and backward linkage effects of a project/policy.

This is one of the biggest drawbacks of micro level evaluation of public policies. By not considering the problem

in its entirety, such piecemeal evaluation is often misleading from the point of view of the economy as a whole. For, the harmful external effects will affect not only others but usually also the procedures of these spillovers. This means that though they remain unpriced, the entire community is affected by such external diseconomies, or, for that matter, also external economies. This limitation can be done away with, to quite some extent, if the 'stated objectives' (i.e. the multicriteria) in policy evaluation, even at the micro level, be not too limited as to ignore the many side effects of it. For, ultimately, an appraisal of a policy will depend not only on the 'stated objectives', but the overall effects.

It is said that the choice of criteria of evaluation of public policies depends on whether the basis of evaluation is economic or social. In economic evaluation, the utilitarian element is dominant, whereas social justice in the democratic framework forms the basis of a social evaluation. But recently, economics has broadened itself not to be limited to the market mechanism. Kenneth Boulding, the leader proponent of Grants Economics maintains that the 'exchange system', the 'threat system' and the 'integrative system' constitutes the three major modes of organizing social life. Hence in the broader economic framework, the social basis of evaluation is not beyond economics. However, social justice can be better ensured while taking the picture of the economy as a whole and hence it is done better from a macro angle.

## 5. Hierarchical Nature and Integrability at Micro Level: A Further Justification of Evaluation at Micro Level

The odds against decision-making and evaluation at the micro-level cannot, however, be fatal to justification if we consider integrability and hierarchical nature of objectives at the micro-level as plus points. There is more integration in the smaller units such that there can usually be no conflict within a single objective though there will be the possibilities of conflicts among the various objectives even at the micro-level. As H.A. Simon (1959) has shown, as firms grow larger in size conflicts arise and the objectives of the organisation are structurally changed. It is true that at the micro level also we sometimes deal with aggregates, but they are of a different nature, i.e. at micro level we may be evaluating policy regarding a particular industry. Now, since an industry is an aggregate of various firms producing the same product, therefore any policy favouring that particular industry will be to the interest of all firms within that industry. Hence, there cannot arise any conflict within a single criterion. In macro level evaluation, however, we deal with aggregates which cut across various products and industries and therefore relate to different classes of the society. The interests of different sectors of the economy usually conflict, and so do the interests of different classes of the society. Thus there may be conflict within an objective at the macro level. This problem is however not met in evaluating at micro level.

At the micro level, the hierarchical nature of objectives become more prominent. Very often the criteria are found to be clustered in such a way that they have a natural hierarchical structure. The analysts who are evaluating a project/policy can take advantage of this feature which the objectives exhibit. Let us see what is meant by hierarchical nature of objectives.

In a multi-criteria evaluation it is found that at least some of the criteria are qualitative rather than quantitative. By quantitative criteria we mean that the decision maker is able to present his preferences for different alternatives on the basis of these criteria on a cardinal scale. On the other hand, a criterion is said to be qualitative, if the decision maker can only present his preferences (on the basis of that criterion) on an ordinal scale.

Often most of the goals, apart from being 'non-compulsive', are also 'non-basic', in the sense that they are implied by a combination of some other goals. To construct a hierarchy of objectives, it is necessary to subdivide an objective into various lower level objectives which are a 'means' to attain the 'end' which is the higher level objective such that at the lowest level of the hierarchy we have several concrete criteria even if the 'end' is a qualitative or 'abstract' criterion.

Roubens (1982) and Korhonen (1984) have given a detailed solution procedure for aggregating evaluation information from concrete criteria into the more abstract (higher level) criteria. Korhonen (1985) has also developed an interactive approach by which the alternatives are evaluated using the criteria at the basic level. Since the criteria at the basic level are more quantitative in nature, therefore the decision maker can give a cardinal scale to describe his preferences, or, he can rank alternatives or make only pairwise comparisons. To describe the interdependence between criteria these information are used to compute a 'correlation matrix'. This correlation matrix and the hierarchy of criteria are used for aggregating lower level criteria to the next upper level. This process continues till the highest level criteria are reached.

At the micro level, the objectives are easier to be arranged into such a hierarchy than at the macro level where there is inherent conflict within the objectives themselves. Most of the complexities of the macro level evaluation are not met at the micro level and the decision maker at this level usually has a better understanding of the problem he is faced with, as against the decision maker at the macro level. Hence this technique of making use of the hierarchical nature of objectives can come to a great advantage in evaluating projects/policies from a micro point of view. The technique is useful because it makes clearer the meaning and the

intended aim of an objective. Moreover, the more the objectives can be subdivided into lower level subobjectives, the easier will it be to identify some scales for the attributes which are amenable to objective measurement. And it is needless to say that the greater the objectivity the better will be the applicability of the methods designed for multicriteria evaluation. However it is necessary to ensure that the subobjectives incorporate all facets of the higher level objectives and give a comprehensive picture of the problem.

In the preceding paragraphs we have seen that for various complexities involved in macro level evaluation it is often necessary to undertake micro level evaluation, for an indepth understanding. But again in evaluating projects/policies at micro level, many factors are ignored as not being of concern to it which we consider to be its disadvantage also. However, one cannot say whether micro level evaluation or macro level evaluation is more important. In fact both types of evaluation are complementary to each other. Macro level evaluation (national profitability analysis) will be useful for a single project because it has to function in the network of the entire economy and hence has to meet the criteria set up at the national level. This is so because the government agencies at the national level will have to accord approval and/or extend financial assistance to the individual public projects. For this, even if a project is found profitable on

evaluation from the micro angle, yet it may not get the approval of the decision maker from macro angle unless it also fulfils the criteria set for the national plans. Similarly, micro level evaluation proves useful to macro level evaluation too. Each unit of the macro level policies will in reality have to function like private firms in many respects; they have to make their purchases and sales at market prices. If a project is chosen on the national level criteria which turns out to be unprofitable from the micro angle, it will be necessary to subsidize the project and this has to be provided for in the budget. In case it is felt (on the basis of national level criteria) that subsidy is not the best policy then the government will have to protect the project by imposing duty on the competing projects. But how much subsidy or protection is needed by the project for it to be commercially viable also, can be known only if prior evaluation is done at the micro level. Thus it becomes easier for the decision maker to frame policies, once an indepth study has been done through evaluation at micro level. However, it may not be possible to incorporate all the information obtained by carrying out micro level evaluation for the thousands of individual units, for the macro level evaluation. This would not only involve huge costs of evaluation but would also make the decision process at national level extremely complicated.

## **6. Various Methods of Evaluation: Suitability at Micro Level**

In Chapter II we had discussed some methods for carrying

out multicriteria evaluation and in Chapter III we have also discussed the implications underlying the methodological procedures so that we know the limitations and advantages of applying each method. Now the choice of a multicriteria evaluation method for applying to a particular problem itself depends on multicriteria (!) These criteria are obtained from the characteristic features of the multicriteria evaluation problem at hand. In this chapter we have discussed the general characteristic features of an evaluation problem at micro level. On the basis of these characteristic features we will now see which methods are, in general, more suitable at this level. Of course, even within the broad category of a micro level problem, different multicriteria evaluation problem may present different characteristics which may justify the use of different methods for each case. We will, however, consider the category of micro level evaluation in general and try to explore the suitability of the different methods at this level.

For micro level multicriteria evaluation problems, much of the complexities of a macro level problem are absent, as we have already seen. Hence the criteria for selecting a method should be that the method must suit the needs of the problem and at the same time should not be too time consuming and expensive (we must not forget that good evaluation requires highly trained personnel, time and money). In other words, the benefits from the evaluation should be greater than the costs involved.

If the problem is such that it can be tackled reasonably well by a single decision maker then methods like Goal Programming can be usefully applied. Goal Programming method allows the decision maker to have enough flexibility needed to deal with cases with conflicting multiple goals. Also Goal Programming method does not require the prior generation of nondominated set and usually requires only one solution step, i.e. the computational burden is less. However, sometimes the solution arrived at may be a dominated solution. In this case, the targets have to be readjusted and the model solved again.

The Surrogate Worth Tradeoff method can also be used. Of course, in using this methods it is advisable that the tradeoff function relationships should be used which will greatly reduce the computational requirement. Otherwise the computational burden of this method will be great. This method can be usefully applied to hierarchical decision making also. This is another reason why it is suitable to micro level problems.

If the main criteria of a micro level evaluation problem is to ensure 'commercial profitability', then it is useful to apply methods that take into consideration risk and uncertainty also. The Von Neumann Morgenstern Expected Utility approach, the Multi-Attribute Utility Theory (MAUT), the approach by Wilhelm (1975) and by Fandel and Wilhelm (1976) have been built to deal with multicriteria decision making under

uncertainty. These methods also can be applied at the micro level.

At the micro level it may be possible for the decision maker to reasonably articulate his preferences for different criteria even at the beginning of the problem. Moreover it has been found that most decision makers do not like to be involved with too much questioning of the analyst. Assuming that at the micro level, commercial profitability is more important than justice and such other considerations the decision maker are even more uninterested and unwilling to answer questions because they feel it is too time consuming and also too opaque for their understanding i.e., they feel that the costs are more than the benefits.

Hence they prefer to rely on the simple trial and error methods. For such reasons it is suggested that methods with prior articulation of preferences is more suitable in most cases.

Of course the various characteristics of a particular micro level evaluation problem will help to choose the best method for the problem at hand. The above discussed considerations can help only as providing general guidelines for choosing the right method at this level.

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**C H A P T E R - V**  
**MULTICRITERIA EVALUATION METHODS:**  
**APPLICABILITY AT MACRO LEVEL**

**MULTICRITERIA EVALUATION METHODS:  
APPLICABILITY AT MACRO LEVEL**

**1. Justification of Evaluation at Macro Level**

While applying the methods for Multi-Criteria Evaluation of public policies at macro level, the picture becomes much more complex. Many factors that we could keep outside our purview while discussing evaluation at micro level will now have to be considered. Moreover, many other factors which we had considered at micro level is found to assume quite a different nature from a macro point of view.

One may ask the question - Is it necessary to conduct an evaluation of public policies at macro level once it is done at the micro level? If each of the projects/policies are evaluated from micro standpoint and only the 'best' are implemented for each micro unit, then, will not the economy as a whole reach its best achievable state too? A little reflection into this matter will reveal that the case is not so simple. The behaviour of the economic system is such that the macro economy is not merely a simple aggregation of the individual micro units that constitute it. What is true of parts of the economy is not necessarily true for the entire economy. It is so because the various variables and concepts are interdependent and they act and react with each other in such a way as to make the whole (the macro economy) much more complex

than a simple aggregation of its parts (individual micro units). And it is due to this that we come across so many 'macro economic paradoxes'. "It is these paradoxes more than any other factor, which justify the separate study of the system as whole, not merely as an inventory or list of particular items, but as a complex of aggregates" (K.E. Boulding (1952)). Some examples could help to make this idea more explicit. The most common one would be the 'paradox of thrift'. Though savings is a virtue from the point of view of an individual at normal times as well as in conditions of depression and unemployment, yet for the economy as a whole, if it is passing through a depression and unemployment caused by deficiency of aggregate effective demand, then an increase in savings by all individuals will lead to a further fall in aggregate effective demand, then an increase in savings by all individuals will lead to a further fall in aggregate effective demand and thereby worsen the situation of depression and unemployment. The result would be that the individuals in the economy would be worse off rather than better off if they save more and this is contradictory to the conclusion that would have been drawn if only a micro level consideration was made. This helps to throw light on the fact that for policy makers and evaluators of such policies, whose duty it is to make programmes to increase the welfare of the society, an understanding of the economic system in its entirety becomes very important.

Of course, another factor which makes it impracticable for policy makers to take the economy to that state where each individual micro unit is at its best position is due to the fact that they have to work under budget constraints. Moreover, the resources available in the economy also are not unlimited. So their use in one sector naturally reduces their availability in another sector. This is our familiar concept of trade-offs again, which we have discussed in our study of micro level evaluation.

The necessity of tradeoffs is not only due to the constrained budget but also due to the conflicting nature of the objectives set up for the plans and also conflict among their inherent subobjectives. To carry this idea further we will revisit the concept of hierarchical nature of objectives (already discussed in Chapter IV).

## **2. Parallelism in Objectives at Macro Level**

Any policy maker who is responsible enough to seriously think about the many objectives set up for a plan, comes up with some sort of hierarchy of objectives. We have seen in Chapter IV that at the micro level such hierarchical specification of objectives is an important step in forming a clear idea about what is really wanted to be achieved.

But at the macro level, the objectives laid down are characterised by their parallel nature, i.e., of the various

objectives aimed at, it is difficult to find some objectives which are a 'means' to attain some other objectives. This is because the different objectives are usually noncommensurable and often conflicting, though sometimes complementary. However, sometimes the conflicting nature of objectives are not so apparent at the first sight. So here again, the formalising of each objective into lower level subobjectives may help to bring out clearly why and where two higher level objectives conflict with each other. This can be explained by some suitable examples - If, of the multiple objectives set out for a plan, one is to accelerate the rate of growth of the economy and another is to reduce inequalities in the distribution of national income, then a means to attain the second objective will be to tilt the distribution of national income in favour of the less affluent sections of the society so as to reduce the differences between them and the affluent ones. On the other hand, one of the subobjectives of the first objective may be to increase capital formation in the economy which will lead to increased growth of national income. Now, since the marginal propensity to save is higher for the richer people than for the poor, tilting the distribution of national income against the poor will help perhaps to increase capital formation in the near future. But this, as we see will be against the interests of the second objective.

Again, for steady and rapid development of a strategic

industry it may be thought wiser to develop it in areas which are already developed so that there will be ready availability of infrastructure and market. However, if side by side, the objective of reducing regional imbalances is pursued, then developing of the industry in backward areas will be recommended. Now, these two subobjectives again are conflicting.

Hence, we find that, in both the above examples, the conflict between the first and second objectives which was not explicit at a first glance becomes quite clear once specification was done to lower level objectives. Once the area of conflict has been located, it will be easier to do something about it than without a specific knowledge about it. For instance, the higher level objectives may be sought to be attained by defining the subobjectives in a different manner. Therefore, at the macro level too, formalizing the objectives help, because the Decision Maker has to consider not just two but multiple objectives and the interdependence between them is very great which makes matters more complex.

But this formalising into lower level objectives cannot be taken to great depths because (a) very soon conflicts start posing themselves, (b) if all of these diverse objectives were broken up into a big number of subobjectives, then the number of relevant attributes to account for them would be huge and this would necessitate aggregating them up again into higher level objectives, by some subjective procedure.

In this process, many of the details may be missed out which may create loopholes in the planning process so that the results will diverge from what was intended. This is another reason why, for objectives of very high importance, apart from evaluation at macro level, it is advisable that evaluation be also done at micro levels so as to ensure that the intended results are achieved. However, it should be mentioned that some methods have been developed by which qualitative information is transformed into a quantitative form and there the information at the basic level of the hierarchy is aggregated to higher levels (e.g. Saaty, 1980; Korhonen, 1985). Thus even at the macro level if a hierarchy of objectives can be developed for certain problems then these methods may be used quite usefully.

But in macro level evaluation problems, for which the objectives are more parallel than hierarchical, subjectivity will be of a higher degree. This creates some difficulty because often the Decision Maker is not an expert in the techniques of multicriteria evaluation, so he has to be helped and advised by his analyst. The subjective preferences and tradeoffs, however, are more difficult to convey to another person than the objectively measurable attributes. If the Decision Maker were himself an analyst, however, there would be no need to convince anyone about the correctness of his action.

### 3. The Issue of Externalities

In applying the multi-criteria evaluation methods at macro level, another thing of great importance to be discussed is the problem of externalities, which we had briefly touched upon in Chapters II and IV. From the micro angle, effects that are external to the micro unit is not of consideration to it, but for the whole economy, such effects are no longer irrelevant.

It is true that within a general equilibrium system, there is interdependence among the various sectors of the economy, so that changes in the variables in one sector essentially effect other sectors too. But the interdependence caused by externalities are of a slightly different nature because they influence the welfare of others not through the price mechanism, but directly. Hence in spite of the interdependencies any general equilibrium system will fulfil Pareto optimality conditions in the absence of externalities. But in the presence of externalities the solutions attained may not be Pareto optimal. E.J. Mishan (1972) has with the help of an example showed, how, by removing the harmful external effects it may be possible to increase the welfare of the consumers of the external effect, without correspondingly making anyone worse off (i.e. Pareto non-optimal situation). Hence, to achieve best result from the application of the methods of multicriteria evaluation, externalities must also be taken

into account. And for this, the decision maker must have enough insight into the nature in which the economy functions. The methods for multi criteria evaluation themselves do not have any procedure for dealing with externalities inbuilt in them, so these must be explicitly introduced into the models as either objective functions or constraints. In methods where the objective functions are combined into a single objective function, the externalities should be introduced as attributes in the overall objective function and proper care should be taken in assigning weights.

An externality may be either 'technological' or 'pecuniary'. A 'technological' externality is that which affects the production function of the producer or utility function of the consumer. A 'pecuniary' externality does not change the technological possibilities but is reflected in changed prices. 'Pecuniary' externalities are only transfer payments from one section of society to another and therefore, including both technological and pecuniary externalities would involve the error of double counting. However, if distributional weights are assigned in the social welfare function then pecuniary effects (causing transfer payments) must also be considered.

A project has important implications for its link industries. Hence at the national/macro level we have to consider all the forward and backward linkage effects of a certain project.

#### 4. A Consideration of Social Justice

Another matter of importance to be considered for evaluating public policies at macro level is that of social justice. This question does not enter into evaluation from micro angle. But while planning for the entire economy the decision/policy maker has to assume a paternalistic attitude and it becomes his responsibility to ensure that his decisions/policies lead not only to rapid growth of the economy but growth with justice. Not only this, any evaluation of public policies has, therefore, to be based on both economic and justice considerations.

Now, this, as one will understand, is a subjective aim, since the concepts of justice is of a philosophical nature. We know that society consists of different classes and the interests of the different classes are often conflicting. The ideologies that justify the interests of one class is different from that of the other and they are often incompatible. Any project/policy which leads to the betterment of one class may be detrimental to the interests of another class in the sense that they may feel they are worse off whether in absolute terms or relatively. Hence we come across a peculiar feature of conflict within a single objective at the macro level. This problem is not met at the micro level.

To tackle this problem, if in the social welfare function different weights are to be assigned to different classes,

then this process will have to be based on some concepts of justice and equity that comply with the Decision Maker's convictions. Hence the evaluation may be from the standpoint that justice will be ensured only if there is 'greatest happiness of the greatest number of people'. This is the utilitarian concept of justice. Alternatively, it may be the conviction of the Decision Maker that the decisions should be to the greatest benefit of the least advantaged under conditions of fair equality of opportunity. Again, the Decision Maker may be Idealistic in his views and believe that each man is an end in himself and that sacrificing one man's interest for the sake of that of the majority would be unjust. Hence, we find that the problem becomes much more involved when seen from the macro point of view and as such even the construction of a social welfare function becomes difficult. Arrow (1951) has also shown how, in passing from individual preferences to a social welfare function based on majority principle, contradictions arise.

It is held by many economists (Kaldor and Hicks, mainly) that a social state  $x$  would be said to be better than another state  $y$  if those who are better off under state  $x$  can make compensations to the losers and still be better off. It is true that such a definition means that in state  $x$  the aggregate production in the economy will be higher than in state  $y$ . But then this leaves aside the problem of distribution, since,

under it, those who gain should only 'be able' to make the compensations even though the compensations are not actually made. Hence the compensation principle is only arbitrary since policy makers would definitely want to take the economy to that state which is better not only from the point of view of aggregate production but from all other considerations including distributional aspects. This would mean that if  $x'$  is the social state under which the compensations are actually made in transition from  $y$  to  $x$ , then it is really the state  $x'$  and not  $x$ , that is better than  $y$ . All this must be considered carefully by the decision makers of macro level policies and it is needless to say that these need not be done by decision makers at micro level.

Apart from the above discussed features of macro level evaluation of public policies, another difference between micro and macro level evaluation is the nature of variables to be dealt with under each, and this difference is quite obvious. Since market prices (which are used for evaluation at micro level) do not reflect the true gains and costs to society, hence, at macro level both inputs and outputs are valued at 'social prices'.

The difference between market and social prices is due to taxes and duties, exchange rates and wage rates. Market price includes taxes but from the national point of view, tax is not a cost; it is only a transfer payment from individuals

to the government. Again market prices of imported goods are based on official exchange rates. However, in developing countries, the official exchange rates, usually, do not conform to the intrinsic value of foreign exchange. Also, the market and social wage rates are not always the same. In countries with vast unemployment and disguised unemployment, the market wage rate is usually not same as the social wage rate. And the market price being based on market wage rates do not, therefore, reflect real cost to the economy.

In our above discussion we have seen that for many reasons it is necessary for macro level evaluation to be done. However, it cannot be said that micro level evaluation is unnecessary either. Both, in fact, complement each other. But since the process of evaluation is time consuming and expensive it is suggested that together with macro level evaluation, some important programmes/policies, from the point of view of national evaluation criteria, be evaluated also from micro angle. However, not all the macro level policies/projects are considered important enough to warrant a detailed and expensive probing.

##### **5. Suitability of Evaluation Methods at Macro Level**

Our next task is to see which of the methods developed in the literature are more suitable to macro level evaluation problems.

We have seen that at this level (macro) the multi-criteria evaluation problems are characterised by their complexity (i.e. they are much more complex than the problems faced at micro level). Because of the complexity and the multifaceted nature of any decision problem at this level, a single decision maker may not suffice to take decisions on a problem with such varied aspects. And so, more usually the decisions are taken by a group of decision makers.

To be more suitable to reality, therefore, Group Decision Making models are more preferable. The Iterative Open Planning Process (IOPP), the Delphi Technique, Nominal Group Technique, are some methods to deal with complex problems and group decision making. The Nominal Group Technique has the advantage that it involves less time. Again, because the group comes into face to face contact it provides better understanding of each other's position (preference) so as to arrive at a concrete decision. The group decision making models can to some extent be used to tackle the problem of conflicting interests of the different classes of society. If each member of the group represents a different class of society then methods like Delegation Process for Parameter Assessment can be used to determine the relative weights of each decision maker (who in turn represent the different classes). However, unfortunately not much applications of the group decision making techniques have been made to real world situations to show the adequacy of these models.

Again, due to the complexity of the problems it is difficult for the decision maker to make prior articulation of preferences because at the very outset it is difficult to get an insight into the entire problem. Hence it is advisable to use methods which allow for progressive articulation of preferences (i.e. Interactive Methods). As the solution process advances the decision maker becomes more and more aware of the problem. He is therefore able to indicate his trade off information at successive steps more rationally. It is to be accepted that a person's value structures change over time and more significantly, they change as a result of learning and experience. Also in a macro decision making problem there are so many subjective factors involved in the decision making (e.g. that of justice, equity etc.) that it is thought wiser to reach a satisficing rather than an optimising solution. Dorfman (1960), for instance, has emphasized the role of satisficing rather than maximising in economic problems. It is true that the interactive procedures are more time consuming because they require the decision maker's involvement at every stage. Also as we have already seen (in Chapter IV) that he does not like to face too many questions from the analyst because he is usually not an expert in such mathematical techniques and their implications. But it must be remembered that at the macro or national level decision making, the decision maker is faced with immense responsibility for the welfare of the multitudes of his countrymen depend on his

decisions. Hence it is worthwhile, even if the procedures are time consuming, so long as the results obtained suit the requirements of his economy from various aspects. Realising these needs some interactive group decision making processes have been formulated.

Since the economy is characterised by its dynamic nature, methods like dynamic multiobjective goal programming,  $\epsilon$ -constraints, compromise programming and weighting methods which can be reduced to single objective dynamic programming problems are recommended as being suitable.

However, as we can understand, the choice of the exact method can be determined only with reference to the specific nature of the macro economic evaluation problem at hand.

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**C H A P T E R - V I**  
**PROPOSED IMPROVEMENTS WITH REFERENCE**  
**TO UNDERDEVELOPED ECONOMIES**

## **PROPOSED IMPROVEMENTS WITH REFERENCE TO UNDERDEVELOPED ECONOMIES**

As we have seen, a considerable number of methods have been developed for multicriteria evaluation. However, most of these methods have been developed by economists in the developed countries keeping in mind the setup of those countries. Would the same methods be adequate for underdeveloped countries too? Or would it be unwise to use such tools, which have been forged in the developed economies, to solve policy decision problems in an underdeveloped economy as ours?

### **1. Characteristic Features of Underdeveloped Economies**

Often the incorrect view is held that the difference between developed and underdeveloped countries is only 'dimensional' and not 'qualitative' in nature. It is also wrongly assumed that there is merely a 'time lag' between developed and underdeveloped countries. Actually, however, the very institutional setup of the underdeveloped countries is different from that of the developed countries. For such institutional differences, is it necessary to have a different framework for methods of evaluating public policies in underdeveloped countries?

There is a general tendency among economists to generate general propositions which they expect to be true for every time, place and economy, though there is no empirical

justification for this. When such theories are confined to the use in developed countries, there is not much harm done. But when models and concepts designed to fit the conditions of social reality of the developed world are applied to underdeveloped economies where the same conditions do not exist, such models and concepts do not fit in with reality and projections based on such models can have serious consequences. A major source of bias could enter into policy evaluation in underdeveloped countries by treating their internal problems and giving solutions to such problems from the point of view of developed western societies.

Due to institutional differences we observe two main characteristics of underdeveloped countries with respect to evaluation. The first is that the type of data on the basis of which evaluation will be done is very scanty. We are not, however, dealing with this problem in our study. The second characteristic is that many other factors mainly non-economic in nature need to be accommodated even in the methods of evaluation so as to meet the requirements of such economies in general.

We understand that any model is an abstraction but it should definitely be an abstraction of reality and should not be built in vacuum. Only then it will be able to help in making projections or finding solutions to evaluation problems of the particular kind of institutional setup. If this is so,

then it is no use starting with a model suited to developed economies and when any distortions arise, by attributing them to the residual influences, which are characteristic features of the underdeveloped economies, that we have not taken into account. To make evaluation useful we must from the very beginning make provisions for inclusion of these other factors into the methods, i.e., we must change the very framework of the methods for applying them to underdeveloped countries.

Of course this is difficult to do in the absence of plenty of empirical work. Hence, meanwhile it is also worthwhile to perform the negative task of demonstrating the inadequacy of the existing methods. But we should have the more ambitious purpose of replacing the framework of these model with a more realistic model for underdeveloped countries. Hence our first step is to find out how the underdeveloped economies actually function. Failure to do this would lead to distortions in evaluation and hence failure of planning.

In this chapter we shall discuss the aspects of the methods of multicriteria evaluation already available that do not fit into the conditions of the underdeveloped economies and then we shall make some suggestions for improvements in the methods for making them applicable for evaluation of public policies in underdeveloped countries.

## 2. Multicriteria Evaluation: A General Framework

Multi criteria evaluation processes necessarily involve the following:

- (1) A set of decision variables from which the choice of the right alternative is to be made by assigning different set of values to the decision variables.
- (2) A set of criterion variables (or impact variables) corresponding to the set of decision variables i.e., corresponding to the levels that the decision variables assume, the impact variables will assume certain levels.
- (3) Some functional relationship which maps the set of decision variables to the impact variables.
- (4) A vector of weights to be assigned to the impact variables (or criterion variables).

Let  $X$  be a vector of decision variables with  $n$  elements, and  $Y$  a set of impact variables with  $m$  elements. If the decision variables are fixed at certain levels say  $X_1^*, X_2^*, \dots, X_n^*$ , then corresponding to these fixed levels, the different impact (or criterion) variables  $Y_1, Y_2, \dots, Y_m$ , will also assume certain values depending upon the function that maps the  $X$ 's to the  $Y$ 's.

Hence we have,

$$Y_1 = f_1(X_1^*, X_2^*, \dots, X_n^*)$$

$$Y_2 = f_2(X_1^*, X_2^*, \dots, X_n^*)$$

$$\begin{array}{ccc} \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{array}$$

$$Y_m = f_m(X_1^*, X_2^*, \dots, X_n^*)$$

For another set of values for the  $X_j$ 's the  $Y_i$ s will take different values. The overall effect of an alternative (i.e., one set of values of decision variables) will be calculated by taking weighted aggregative impact over all the impact variables, for which we will have a vector  $W$  of weights consisting of  $m$  elements such that the overall impact of the alternative represented by  $(X_1^*, X_2^*, \dots, X_n^*)$  is given by

$$W_{1 \times m} \times Y_{m \times 1}$$

or

$$\sum_{i=1}^m W_i Y_i$$

Once we have described the general structure of the majority of multi-criteria methods we will now discuss their applicability in underdeveloped economies.

### 3. Non-Economic Factors in Evaluation

Let us first consider the vector of decision variables. In a developed economy, the decision variables (which compose

the alternative policies) consist of only economic factors. But in underdeveloped economies, the decision variables would include many non-economic factors also. In the developed countries an analysis of problems in 'economic' terms, i.e., in terms of markets and prices, investment, output, savings and consumption, unemployment, underemployment and such concepts that abstract from culture, institutions and attitudes of the people may lead to reasonably valid inferences, but in underdeveloped economies this procedure does not work at all. Here any realistic approach would be to include also the non-economic factors that do not adjust smoothly to economic changes but rather set up obstacles against them. There is therefore a greater need to coordinate the planning in the 'non-economic' and 'economic' fields.

The social matrix in the developed countries is generally permissive of economic development. Even if it is not then also it gets readjusted easily and does not place much obstacle in the path of economic progress. It is because of this that an analysis in purely 'economic' terms, abstracting from the social matrix can produce valid and useful results. In these countries the non-economic and the economic factors have become integrated in such a way that the non-economic factors have got adjusted to the system and even if any change takes place in the economic factors, the social and other factors readjust themselves to the new situation and vice versa.

It is as if the matrix consisting of economic and non-economic factors is indecomposable. In such a case even by changing the economic factors alone it is possible to effect the desired changes in the society.

In the underdeveloped countries not only is the social matrix not easily adjusted to economic conditions and changes in economic conditions but it also places obstacles to any effort to economic development that is made. In these countries the economic, social, political and other factors have not been integrated. When economic factors are changed, the impulses of such a change do not run through the other factors also to bring about the desired change in the overall economy. Rather each of these sectors seem to work on their own and reach their own equilibria. Due to this lack of integration, by changing some economic factors through policies it is not possible to bring changes in the right directions and so development cannot be ensured. However, the economic factors are also not totally independent of the non-economic factors so that the non-economic factors exercise their influences by presenting obstacles to economic development. The difficulty therefore is that such influences cannot be known since the complex relationship between economic and non-economic factors cannot be predicted. The many social evils prevailing in these economies like caste structure together with other factors like illiteracy, poverty, inequalities in the distribution

of income and wealth, often result in diverging the economy from the path that it is desired or intended to follow. Since there are many such non-economic factors that are non-conducive to economic growth, the situation calls for induced changes in the social and institutional structure, since they do not change spontaneously to changes in the 'economic' sphere and also because it is necessary to change any factors that are impediments to economic growth. There are many non-economic factors that are not only peculiar to these countries but are greatly responsible for their underdevelopment and for the particular difficulties faced by them in their efforts to develop. Many economists have felt that radical egalitarian reforms are necessary for steady and rapid development of underdeveloped economies. Since the aim of planning is not just to increase the per capita income or National Income (which is a very partial measure of development of an economy) therefore to bring about overall development in the economy we think that it is necessary to include in the set of decision variables, not only economic factors but also some of the most important non-economic factors which are thought to be major obstacles to economic growth.

This is therefore the first important difference between developed and underdeveloped countries. As the economy gets more and more developed with the better integration of all sectors it is possible to bring about desired changes by

changing lesser and lesser factors because their impacts will spread smoothly and predictably over the entire structure. The number of decision variable to be taken will also decrease with development. But in underdeveloped countries it would be wrong to use just a few 'economic' decision variables for economic policies since their impulses will not run through the entire structure to effect desired changes.

Moreover it would be very superficial to first establish a method based on purely 'economic' factors i.e., abstracting from non-economic factors and then reserving the possibility for later adding the considerations for non-economic factors. In underdeveloped economies it is difficult to demarcate between 'economic' and 'non-economic' factors.

Our first suggestion for improving the framework of the methods of multi-criteria evaluation to suit conditions of underdeveloped countries is that the set of decision variables should include both economic and non-economic factors. We realise that this will make the evaluation process more cumbersome, but considering the fact that any 'simplification' of this complex situation would in fact be 'distortion' of reality, we think that it is worthwhile to go through this cumbersome process. At least we will be free from the 'opportunistic' bias that is so much prevalent in studies on underdeveloped countries which arises due to the attitude to escape the complexities by going in for simplification.

#### 4. Heterogeneous Structure of Preferences

Next let us come to the weight vector,  $W$ . We know that due to the conflicting nature of the criteria it is difficult to find any policy (alternative) that optimises with respect to all criteria simultaneously. This is because higher level of achievement of one criterion is usually followed by a lower level of achievement of some other criterion. Hence one alternative may have a higher level of achievement of one criterion and lower level of achievement of some other criterion as compared to another alternative. This creates difficulty in comparing the two alternatives. It becomes necessary therefore to attach weights to the different criteria. These weights are assigned by the decision maker and they represent the needs and preferences of the society.

In developed countries, again, due to the involvement of different sections of society and due to greater equality in distribution of National Income there is much greater coordination between the preferences of the different classes of society. Hence it is not very difficult to give suitable weights to the criteria which will more or less approximate the overall preferences of the society. Therefore in such countries, the vector of weights will have some significance in the evaluation process. With development of the economy, the weights assigned to the different criteria become more or less unique and they become consistent.

But in underdeveloped countries the picture is different. In these countries there exist several classes in the society. Because of inequality in the distribution of income and wealth the economic standard of the different classes are different. Also the social structure of the different classes are different. As such, the needs and requirements of the different classes also cannot be the same. And so, the preference pattern of the different classes for the criteria also will be different. This means that there cannot be any uniqueness of weights in these countries as in developed ones. A set of vectors of weights will also not be consistent.

Not only this, the preferences and requirements of the different classes often conflict with each other. For achieving a criterion preferred by one class it may be necessary to sacrifice the level of achievement of another criterion preferred possibly by another class.

What we suggest, therefore, is that there should be more than one weight vector for such economies, each representing the preference pattern of a major class of society. But for this it is necessary to create another weight vector, this one for assigning weights to the different classes whose preferences are being taken into account.

##### **5. Uncertain Relations Between Decision and Criterion Variables**

Now, let us consider the functional relationship ' $f_i$ '

which maps the decision variables to the impact variables (or criterion variables)

In the developed countries it is possible to predict more or less, the levels of the impact variables corresponding to the levels that the decision variables may assume. In the underdeveloped economies it becomes more difficult to relate observed outcomes and effects directly to policies. Policies exist in the operational world and not in the laboratory where randomness, coincidences, etc. can be controlled. Hence there may be numerous plausible explanations for the same effects. Due to the unpredictable manner in which the non-economic factors influence the working of the economy it is more likely that the outcomes (impacts) will be random in underdeveloped countries. Moreover it is difficult to generalise evaluation results in practice. The same program which has worked successfully under one set of circumstances and institutional setup or at one point of time may not work in other settings or at a different point of time. At one point of time, i.e., when evaluation is being done, a set of decision variables may yield certain values for the impact variables. But during actual implementation of policies (which will be at a different point of time) it may not lead to the same levels of impact variables as was predicted. In underdeveloped countries therefore it is more likely that ' $f_i$ ' will be multi-valued functions. Hence for a set of decision variables we cannot

assign a single value to the impact variables. We can at the most say that the value of each impact variable, for a set of decision variable, will lie within a certain range and then use probabilistic models to arrive at a solution.

#### **6. Costs of Uncertainty: Lower Achievements**

But under probabilistic conditions if we want to optimise the achievement of one criterion we will have to sacrifice much more of an alternative criterion than we would have to do if the impacts were deterministically predictable. Hence to ensure achievement of target levels under probabilistic conditions with a high level of confidence one should be willing to pay the cost for it. However, the lesser the standard deviation the lesser the cost. In underdeveloped economies the standard deviations of the levels of impact variables are quite high and this is one of the main reasons why development is much more expensive in these economies. This also explains to some extent why there is so much underutilisation of resources.

We, therefore, suggest that probabilistic models are more suited to underdeveloped economies and such models and methods of multicriteria evaluation and decision making should be developed. In Chapter II we have seen that probabilistic models have hardly been developed for multicriteria evaluation.

It goes without saying that the set of impact variables,  $Y$ , should include non-economic factors also. The objective of planning is not only to improve economic conditions but also social conditions in these countries. Hence some of the criteria will be non-economic in nature.

### 7. A Summary of Proposed Improvements

Symbolically we may present the structure of our proposed improvements as follows:

Let,

$$[Y_1 | Y_2] = [F_1 | F_2] [(X_1 | X_2)]$$

Where  $Y_1$  stands for economic criteria  
 $Y_2$  stands for non-economic criteria  
 $X_1$  stands for economic type of decision variables  
 $X_2$  stands for non-economic type of decision variables  
 $F_1$  stands for the set of functional relationships of  $(X_1 | X_2)$  with  $Y_1$ ;  $F_1$  are multivalued functions  
 $F_2$  stands for the set of functional relationships of  $(X_1 | X_2)$  with  $Y_2$ ;  $F_2$  are multivalued functions  
The symbol "|" stands for partition.

The problem of Evaluation is to find the ordered set

$$S = [(Y^1, X^1), (Y^2, X^2), \dots, (Y^k, X^k)] \quad \text{such that}$$

$(Y^i, X^i)$  is not dominated by  $(Y^j, X^j)$  where  $j > i$ ,

$$Y^i = [Y_1^i | Y_2^i], \quad X^i = [X_1^i | X_2^i] \text{ for all } i$$

or to find out the ordered set

$$V = \left[ \underline{w}(Y^1, X^1), \dots, \underline{w}(Y^k, X^k) \right] \text{ such that}$$

$\underline{w}(Y^i, X^i)$  is not dominated by  $\underline{w}(Y^j, X^j)$  for any  $j > i$ , and  $\underline{w}$  is a vector of weights, obtained from a compromise solution of weights assigned to the different objectives by the different classes in the society.

The problem of decision making is to choose  $(Y^i, X^i)$  from  $S$  or  $V$  for implementation.

For developed economies  $Y_2, X_2$  may be null sets, and  $F_2$  may be irrelevant.  $F_1$  may be single valued. But for underdeveloped economies  $Y_2$  and  $X_2$  are not null,  $F_2$  are relevant and  $F_1$  and  $F_2$  are multivalued.

With this kind of framework for multicriteria methods, they will be more suitable for application to underdeveloped countries. There is no doubt that such modifications will make the evaluation process more complicated. But if evaluation is to be really useful then it must be based on reality even if it is difficult to do. Hence we think that such modifications are worthwhile in underdeveloped countries.

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CHAPTER - VII  
CONCLUSION

## CONCLUSION

Over the previous Chapters we have discussed about the methods available for conducting multicriteria evaluation, from various angles. We shall now take a look back and state where we stand now.

### 1. Need for a Problem-Oriented Approach

We have seen that though Multi-Criteria Evaluation is still a young field of study, yet it has already created its position as an important line of study specially due to its need from the application point of view. A good number of methods have already been constructed for this purpose. However, we find that much more still remains to be done. For example, more methods need to be developed for Group Decision Making problems, evaluation under probabilistic conditions, evaluation under fuzzy conditions, etc. Moreover, we have also seen that it is difficult to pick out any method which would be suitable for evaluation of public policies under all circumstances. Nearly all the methods suffer from drawbacks of some kind or the other. The key to successful evaluation would, therefore, lie in the proper understanding of the evaluation problem at hand so that, the method which will suit the given conditions may be chosen. Again, it is through a problem-oriented approach that it is possible to develop new methods to suit such particular needs. An indiscriminate use of these methods to any problem or situation

in the evaluation of public policies may be harmful for the healthy development of the economy. One must be cautious in the choice and application of any method to a particular problem. Fortunately, more and more current research is being based on such a problem-oriented approach and we hope that not in the very distant future this field of study will reach sufficient maturity.

## **2. The Valuations Underlying the Methods**

By now we are also aware of the fact that there are many hidden valuations in these methods at various stages. Hence, it is not enough to have an indepth understanding only of the problem at hand. It is equally important to understand fully the implications of the methods of evaluation that we use. In the ultimate analysis, evaluation is done on the basis of some valuations. Since it is not possible to do away with such valuations, the next best position would be to bring out these valuations explicitly into the open. This in turn will make the evaluation process much more objective also. Without such a clear understanding of the valuations underlying the methods there may remain much room for biases. Evaluation, when it is done without such explicit statement of the valuations, is really like drawing inferences with a set of premises missing. The methods of multi-criteria evaluation have been formulated to make the evaluation process as objective as possible. Hence it becomes imperative

to be able to have a proper insight into the problem and the use of any particular method.

We have discussed some such concealed valuations which can be discerned in the methods of evaluation already developed. But considering the entire gamut of possibilities of such valuations in the methods, our discussion has been rather scanty. Our plea is that it is important to think on this line too in order to improve the evaluation practices. Our task, therefore, has only been the humble task of pointing out a problem, to set more able minds thinking on this line. Evaluation is not a mechanical process - it should not be so.

### **3. Need and Applicability of Evaluation at the Micro and Macro Levels**

We have seen that the need to make decisions arises at both macro and micro levels. Hence public policies may need evaluation at both levels. We cannot say whether micro level or macro level evaluation is more important or whether evaluation at one level will suffice for implementing plans/programs. Rather the two types of evaluation should complement each other to a certain extent.

We have, in very general terms, discussed the distinguishing features of evaluation at the two levels. It is important to understand these features so that from the available methods the right ones can be chosen to suit the requirements. This will also create the background for developing

new methods to suit the requirements at the two levels. But even within the same level, the choice of the right method will again depend on the nature of the particular problem. Hence a proper understanding of the features of evaluating at micro or macro level, though a necessary condition, is not, however, a sufficient condition. There are advantages of and odds against evaluation at each level (i.e., micro or macro). Hence the methods should be such as to make use of these 'advantages' and at the same time to take care of the 'odds'. It is important that evaluation should be effective and at the same time should not be too time-consuming or cumbersome. Here again our discussion about the applicability and suitability of the methods at the two levels has been very general. For taking care of any particular evaluation problem it would be useful to keep in mind these general features also together with the specific characteristics of the problem.

At the micro level, for example, the objectives can be patterned easily into a hierarchical structure. Such a possibility may be exploited for evaluation at the micro level as it makes evaluation more clear cut and objective. Again at the macro level it is possible to vary the targets and constraints more than at the micro level. Hence this could be usefully incorporated in the methods for evaluation at macro level. In fact, at the macro level the Fuzzy Set Theoretic Approach becomes more appropriate.

The valuations underlying evaluation at the two stages are also different. Justice considerations, effects on environment and such factors need not be taken into account at micro level whereas they are important factors for evaluating at the macro level. Such and other consideration also should be taken into account.

#### **4. The Situation in Underdeveloped Economies**

Some suggestions for improvements in the evaluation methods have been proposed in Chapter VI to suit the requirements of underdeveloped economies. The methods which have already been developed do not properly take care of the complex situation in underdeveloped economies. During evaluation process we come across two difficulties in these countries. Firstly, data are very scarcely available and what are available are not very reliable. Though we have not given any suggestions to tackle this problem, the problem as such cannot be overlooked. The unpredictability of the levels that the impact variables will assume corresponding to the levels of the decision variables is partly due to the influence of non-economic factors and also partly due to inavailability of adequate and reliable data, the role of other factors taken apart. For evaluation to be successful this problem must be solved.

The second difficulty in these countries is due to the non-integration of the system. We find that there is no

proper integration among economic and non-economic factors. The non-economic factors often pose obstacles in the path of economic development and often make the economy diverge from the intended path. Even the attainment of economic goals is not possible through economic decision variables alone, not to speak of the necessity of introducing non-economic decision variables for attaining non-economic goals. It goes without saying that it is not enough to seek only economic objectives. The situation in these economies calls for induced social changes. The social conditions are some of the major factors impeding development of these countries. Moreover, the social factors do not adjust and readjust themselves very easily and fast to changes in economic variables.

There is non-integration also among the different classes of society due to which it is difficult to obtain a consistent and unique preference or weight structure for the impact (or criterion) variables.

To take care of such factors (which are peculiar features of underdeveloped countries) in the evaluation methods we have given a general framework on which we think evaluation of public policies in underdeveloped countries should be based. It would not be very wise to indiscriminately use the methods forged in the developed economies for evaluation purposes in underdeveloped countries, because they do not always reflect the reality in these countries.

## 5. How Far We Have Gone

In our work we have discussed the methods of multi-criteria evaluation of public policies and their applicability only from a theoretical stand point. Ours has been a humble attempt at bringing together the different methods of multi-criteria evaluation (an also single criterion evaluation methods which are only a special case) so as to give just a little more exposure to this very important field of study which is evolving. Though we have tried to carry out an in-depth study of these methods from various angles we realise that our study has been very much general and not supported by empirical application. As such we understand that our work suffers from such drawbacks as are characteristic of such a purely theoretical study. While evaluating any particular problem the analyst is likely to come across many features that are peculiar to that problem. We have, therefore, repeatedly pointed out that the choice of the right method should be based on the particular requirements of that problem. Our suggestions and conclusions too are as such only general. The framework we have given for developing methods for under-developed countries is also given at a very broad and general level. No doubt, suggestions for improvements in these methods can be made from various aspects. Our work is only a small stepping stone starting from which many more improvements can be made in different directions in the field of multi-criteria evaluation methodology.

Away from the issues of concealed valuations and applicability at different levels and in different situations, we may note that, to the best of our knowledge, evaluation methods have not been developed appreciably to take account of dynamic decision-making problems and the problems where optimal control with multiple objectives is needed. In optimal control theory much advancement has been made (Takayama, 1974), but most of the methods in this field deal with a single objective function. However, in practice we require optimal control for attaining multiple objectives and, therefore, methods of decision-making and evaluation in the multi-objective optimal control theoretic framework. This is a field of study which will definitely be enriched in the near future.

Applicability of optimal control theoretic models in less-developed economies, especially with partial control of the state in the democratic set up, in itself requires evaluation. Nevertheless, development of such methods must not be contingent upon such considerations, though, if possible, the methods should be flexible enough to incorporate various feature of less-developed economies.

We realise that useful work can be done by doing more and more empirical work in this line and by carrying out research and applying them to particular problems to test for their applicability specially in the context of under-

developed economies. The general framework given by us can be used as a general guideline on which specific modifications can be made to suit special requirements.

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