MULTIOBJECTIVE DECISION SUPPORT IN DEVELOPMENT PLANNING

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ABSTRACT

Planning essentially involves decision making of some kind either by a single or a group of decision makers (planners). Quite often these decision making tasks are loaded with multiple conflicting objectives (goals, criteria etc). It becomes a formidable tasks for the planners to find a compromise solution in such circumstances. The techniques of multiple criteria decision making (MCDM) become useful in such choice making situations. Coupled with user friendly and interactive softwares MCDM tools offer sophisticated and practical approaches to support the decision making activities of development planners. This paper reviews some applications of MCDM in development planning. It then presents a collection of MCDM based decision support tools and propose their applications in development planning area. Problems and prospects of MCDM in development planning are also discussed.
1. INTRODUCTION

It is often said that "planning is a process of decision making". For example, Dror [1963] defines planning as "the process of preparing a set of decisions for action in the future, directed at achieving goals by preferable means". Although there is no generally accepted definition of planning but some common dimensions of planning emerge from the above definition, for example (i) planning involves decision making, (ii) planning has future implications, and (iii) planning is directed at achieving multiple goals which are often conflicting. While planning and decision making are closely related, a distinction exists between the two. Decision making is discrete in nature but planning is always a continuous process. Future goals, priorities, preferences change with time. Planning, therefore, has to be updated continually by a series of new decisions.

Development planning is concerned with planning at national level which has development implications of some kind. According to Waterston [1965] development planning involves conscious and continuing attempt by the government of a country to increase its rate of economic growth and social betterment and to alter the institutional arrangements which are considered to be obstacles to the achievement of this aim. While general theme of development planning is well understood, the process of carrying it out depends on the socio-political circumstances of a country. Avgerou [1993] summarizes three basic approaches of development planning: the classical "optimization" approach, the "rational" approach, and the "incremental" approach. In optimization approach well defined goals (objectives) are considered and it involves quantification of data and assumes the existence of all relevant information [Avgerou 1993]. In rational approach the concept of optimization is replaced by "satisfaction" of objectives and accepts incomplete information for analyses. The incremental approach, on the other hand, uses the concept of gradual and marginal changes and emphasize the role of political pressure groups rather than optimal problem solving [Avgerou 1993]. This approach uses more qualitative and judgemental type information than other two approaches. In practice a combination of these approaches is often used to suit the circumstance.
It is evident from above that development planning is always complicated by the presence of multiple objectives. In optimization and rational approaches the multiple objectives emerge from the very core of economic modelling. While in incremental approach the objectives of the pressure groups are confounded with the economic objectives. In a recent article Petry [1990] emphasizes the existence of social and environmental objectives in any development planning. The author also provides specific examples of rural development planning with multiple objectives and discusses how the techniques of multiple criteria decision making (MCDM) can help resolve difficult choice making situations.

MCDM is a natural tool for modelling and analyzing development planning problems. It can handle all the three approaches mentioned above. When all quantitative information are available for optimization and rational approaches, more mathematically elegant approaches of MCDM [Zeleny 1982, Steuer 1986] can be used effectively. On the other hand in incremental approach and where judgemental type information is mostly needed to evaluate alternatives and to clarify conflicts, the simple and easy to use interactive MCDM [Belton 1990] approaches can be used most effectively.

In this paper we highlight the need for multi-objective decision support systems (DSS) in development planning. DSS has been defined by Sprague and Watson [1989] as a computer based tool to support the decision making activities of semi-structured to highly unstructured problems. Main features of a DSS are that, it is

(i) interactive and extremely user friendly,
(ii) highly flexible in carrying out a decision support task, and
(iii) dedicated (or can be made dedicated) to support a specific decision making activity (e.g. development planning) by using its model base and data base facilities.

Because of the visible presence of multiple objectives in development planning we propose to use multi-objective based DSS. In the next several sections we emphasize the need for proper decision making process in development planning from the theoretical and practical perspectives. We then review some applications of MCDM in development planning and present some common multi-objective DSS and propose their applications in development
planning. Finally, pros and cons of using multi-objective approach to development planning are also reported.

2. DECISION MAKING AND DEVELOPMENT PLANNING

Application of development planning as a tool for achieving economic development became widespread in the post-second world war period when a large number of countries achieved independence. Over the years the concept of economic development has changed. As a result the objectives and tools of development planning has gone through evolutionary changes. Academia has played a significant role in this by developing appropriate planning models to assist the planners to take accurate decisions in development planning. It is now widely recognized that the concepts of development, development planning and decision making are interlinked. Decision making is, in fact, the hardest part of the planning process. The planners invariably face conflicting objectives in decision making for development planning. For example, the objectives of increase in output and employment may not be compatible. Rapid increase in output may require the introduction of capital intensive technology which may not help increase employment. Similarly the objectives of equity and growth cannot be achieved simultaneously. Fortunately the planning models which have been developed over the years "enable the planners to reach decisions on how to achieve specified goals. They highlight the strategic choices open to the policymaker in the knowledge that not all desirable goals are achievable simultaneously. Only with an understanding of the interrelationship between different paths of the economic system, is it possible for meaningful and constant policy decisions to be reached" [Thirlwall 1989, pp 181-182].

Development planning is further complicated by the influential "actors" who primarily want to impose their preferences and priorities in the process of decision making. A collective approach, therefore, has to be made to increase the feasibility of implementation of development planning. A new breed of support tools called group decision support systems (GDSS) are increasingly becoming popular for group deliberations and decision making [Bostrom et al 1992]. The multi-objective DSSs presented later fall in the category of GDSS which can be used effectively for group deliberations and judgements in development planning.
Some examples of planning decisions which require careful examination and scrutiny from any rational planner are listed below:

(i) *Specification of objectives*: The decision makers specify a number of objectives and "then identify the most appropriate measures to achieve those objectives with certain constraints." [Thirlwall 1989, pp 182].

(ii) *Specification of instrument variables*: "These are the variables that the planners intend to influence in some way in order to achieve the objectives specified within the constraints laid down." [Thirlwall 1989, pp183].

(iii) Choice of techniques - capital versus labour intensive.

(iv) Strategy of growth - balanced versus unbalanced growth.

(v) Investment criteria.

(vi) Negotiation and coordination between different authorities and target groups of planning.

3. **OVERVIEW OF MCDM IN DEVELOPMENT PLANNING**

MCDM is a relatively new field of research emerging as a separate discipline only in the early sixties. Bulk of the activities, however, have occurred in seventies and eighties and since then hundreds of papers have appeared in the literature and many books have been published, for example Zeleny [1982], Steuer [1986], Ringuest [1992], Vincke [1992], and Bogetoft and Pruzan [1991], among many others. Literature suggests many frameworks of classifying MCDM. But primarily there are two types of MCDM problems, *continuous* and *discrete*, and many operational techniques to structure and solve them.

3.1 **Continuous MCDM Problems**

The continuous type problems are characterised by a large number of implicit alternatives embedded in the functional form of the constraints. The objectives are defined in explicit functional form of decision variables. Mathematically these problems are represented as follows:
Max \{f_1(x), f_2(x), \ldots, f_L(x)\}

Subject to: \(x \in X\) \hspace{1cm} (1)

where \(x = (x_1, x_2, \ldots, x_n)\) denotes \(n\)-dimentional vector of decision variables, the feasible set \(X\) is a subset of \(n\)-dimensional real vector space \(\mathbb{R}^n\) and characterised by a set of constraints, and \(f_i(\cdot)\) represents \(L\) conflicting objectives. Because of its explicit consideration of objective functions continuous MCDM problems are also widely known as multiple objective decision making (MODM), or design problem [Belton 1990]. It is noted that MODM problems are similar to classical mathematical programming type optimization problems.

A wide variety of solution approaches are available in the literature for MODM problems. All these approaches need interactions of some kind from the planners to arrive at a compromise (and satisfactory) solution. The timing and type of interactions are, however, important. Some interactions are performed before the solution process even starts. In this type explicit preference function of the planners are solicited. In other the preference information of the planners are needed during the solution process. In this type the planners are required to provide on line preference information, but no explicit preference function is needed. The third type of approach requires preference information after a large set of candidate solutions have been generated. In this the planners are simply required to choose the most satisfactory solution from the set.

3.2 Discrete MCDM Problems

The discrete type problems are characterised by a set of distinct alternatives evaluated on a number of attributes. Formally these problems can be represented as follows:

Select: \\{Alternative A_1, Alternative A_2, \ldots, Alternative A_m\}\n
Subject to: \\{Attribute T_1, Attribute T_2, \ldots, Attribute T_n\}\hspace{1cm} (2)

The "selection" is normally based on maximizing a multiattribute value or utility function. In the literature the discrete MCDM is also widely known as multi-attribute decision making (MADM), multi-attribute value theory (MAVT), or multi attribute utility theory (MAUT)
when uncertainty is considered explicitly. The classical book by Keeney and Raiffa [1976] covers MAVT and MAUT problems in greater detail.

A wide variety of approaches are also available to structure and solve MADM problems. The value or utility theory approach develops a multi-attribute value or utility function of the planners and then selects the alternative which maximizes this function. Literature suggests different schools of thought to develop this function. On one hand a rigorous approach is suggested to test various conditions (preference independence etc) and develop a comprehensive multiattribute value or utility function [Keeney and Raiffa 1976]. On the other hand a simple linear weighted sum approach is suggested to develop the multi-attribute value or utility function [Edwards 1977, Belton 1985]. Key to this simple approach is the interactive sensitivity analyses with the planners to clarify uncertain and fuzzy ideas until a requisite model is developed [Phillips 1982]. From the applied point of view this simple approach deserves attention. Many variations of this simple approach are available in the literature which are being applied widely to tackle real world problems.

A class of approaches exist where no value function of any kind is developed to solve MADM problems. The planners simply need to provide importance weights of the attributes and some other related information to arrive at a compromise solution. Outranking methods [Vincke 1992, pp 57-78] and the analytic hierarchy process (AHP) [Golden et al 1990] are the notable ones which fall in this category.

3.3 Applications

MCDM has been applied to a wide variety of problems from buying a computer to high level strategic and development planning problems for the betterment of a society. In this section we review some applications of MCDM in development planning area. Our definition of development planning is rather broad. We have included all applications with explicit development implications. For example, a decision support system for an irrigation project would be included in our review if it is one of many specific projects initiated by the government for the betterment of the community [Rama Rao 1990, Petry 1990]. Our primary

### 3.3.1 MADM Based Applications

Corner & Kirkwood [1991] primarily reviewed MADM applications which have been solved using multi-attribute expected utility approach. The authors identified 84 published applications out of which 24 fall in our category of development planning. Most of these applications have dealt with specific development projects. The authors have mentioned that due to proprietary restrictions many MADM applications are not reported in the literature. Among the non-utility theory approach analytic hierarchy process has been applied to a wide variety of problems including development planning [Golden et al 1990]. The simple linear weighted sum approach of MADM have been mainly applied in group environment using a process called "decision conference" (DC). DC is a 2/3 day process where planners can get together in a face to face environment to analyze a development planning problem and to obtain a commitment to action for the implementation of the plans [Quaddus et al 1992]. Hundreds of decision conferences have been conducted in various facilities around the globe. But due to proprietary nature of the problems DC based applications have not been published in the literature.

### 3.3.2 MODM Based Applications

White [1990] reviewed 504 MODM based applications. We identified 230 applications which match our definition of development planning. These applications explicitly consider, via the objective functions or constraints, (i) the society/community in general, and (ii) the national or regional economic development. We also did a CD-ROM search on different databases (e.g. ABI/INFORM, SOCIOFILE, LISA etc) using various combinations of keywords. This produced 100 more references not in White [1990]. But only 25 of them matched our definition of development planning. Altogether we produced a list of 255 applications of MODM in development planning area. Table 1 shows the applications in summary form.
TABLE 1
Summary of Dev Planning Applications of MODM

<table>
<thead>
<tr>
<th>Dev Planning Area</th>
<th>Frequency</th>
<th>Dev Planning Area</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>12</td>
<td>Transport</td>
<td>12</td>
</tr>
<tr>
<td>Water Resource</td>
<td>42</td>
<td>Regional/Community</td>
<td>26</td>
</tr>
<tr>
<td>Energy</td>
<td>17</td>
<td>Forest Mgmt</td>
<td>30</td>
</tr>
<tr>
<td>Environment</td>
<td>22</td>
<td>Land Use</td>
<td>11</td>
</tr>
<tr>
<td>Health Care</td>
<td>20</td>
<td>Education</td>
<td>10</td>
</tr>
<tr>
<td>Economy</td>
<td>23</td>
<td>Allocation</td>
<td>3</td>
</tr>
<tr>
<td>Location</td>
<td>13</td>
<td>Others (media, Ins.)</td>
<td>15</td>
</tr>
</tbody>
</table>

It is observed that MODM has been applied to a wide variety of development planning problems. In reviewing the applications goal programming [Steuer 1986] has been identified as the single most widely used technique of MODM. In a recent article Korhonen et al [1992] observed that since 1980's there has been a research shift in MCDM towards providing multi-objective decision support to decision makers and planners. This has not been reflected in our review of the applications. We hypothesize that there is a general lack of understanding of the abilities of the multi-objective based DSS (MO-DSS) in development planning. MO-DSS can capture the decision and choice behaviour of the planners. It becomes a learning process for the planners regarding the problem situation. Dyer et al [1992] has recently reported that one needs simple, understandable, and usable approach to solve MCDM problems and such approach must be developed around decision support systems using the features of easy-to-use spreadsheets. We, therefore, advocate the use of MO-DSS for development planning. There are a number of MO-DSS tools available commercially and academically. In the next section we review a number of them and propose their usage in development planning.

4. COMMON MULTI OBJECTIVE DSS TOOLS

The multi-objective DSS (MO-DSS) tools presented in this section can be applicable for both single and group planning situation in a face-to-face environment. We shall only provide the brief overview highlighting the salient features. The details are available from the cited references. It is noted that every MO-DSS has its pros and cons. For successful applications in developing planning a number of factors, e.g. the problem situation, availability
of data, target groups, the planners and various other bureaucratic and socio-political situations, must be considered carefully.

4.1 MADM Based DSS

4.1.1 Linear Value Model Based DSS

One of the most widely used MO-DSS in this category is called HIVIEW [Barclay 1987]. Based on Edward's [1977] simple multi-attribute rating technique (SMART) HIVIEW was developed at the London school of economics. It is based on linear additive value model and has excellent graphic features. HIVIEW is excellent in model structuring and highly flexible in its use. One of the important features of HIVIEW is its ability to do various sensitivity analyses which will definitely help the planners to investigate various "what-if" type queries. HIVIEW also provides inside view of different pairs of alternatives which becomes a learning process for the planners.

EQUITY is another MO-DSS which is developed at the London school of economics [Barclay 1988]. It is also based on linear additive value model and quite simple to use. EQUITY is a dedicated software for equitable allocation of resources in a number of areas (eg projects) based on multiple attributes. The package provides a graphical display of efficient allocations and by interactions with the planners finds the most satisfactory allocation patterns.

Visual Interactive Sensitivity Analysis (VISA) [Belton & Vickers 1989] is also an MO-DSS which is based on linear additive value model. It is useful for both a single or a group of planners. As the name implies the most important feature of the software is its graphic based sensitivity analysis (both static and dynamic) which helps to clarify various fuzzy and uncertain issues of the development planning problem. It is simple to use and extremely user friendly.

PREFCALC [Lagreze et al 1984] is also based on multi-attribute additive value function. But the value function of individual attribute here could be non-linear. The method is also based on initial preference judgments on some reference alternatives. Various value functions are then suggested which can be adjusted by the planners to match their choice behaviour. The software is not highly user friendly and it is not very flexible either. But methodologically it is elegant than other approaches.
4.1.2 Analytic Hierarchy Based DSS

The most widely used package in this category is called EXPERT CHOICE [Expert Choice Inc 1992]. It is based on the theory of analytic hierarchy process (AHP) [Golden et al 1990]. Although it has some similarity with the additive value model, in theory it is quite different. The software is excellent in problem structuring in a hierarchical fashion. It has various options in judgments elicitation e.g. verbal, numeric and graphic. One of the main features of the software is its various modes of sensitivity analysis e.g. gradient, dynamic and performance. The package has been widely used to analyze thousands of planning problems both in individual and group situation.

Another MO-DSS based on AHP is called CRITERIUM [Sygenex 1989]. It is also excellent for problem structuring. It has excellent facilities to report and document the decisions. It is simpler but not as user friendly as the EXPERT CHOICE. It can also be used for both single or group situation.

4.1.3 Outranking Based DSS

Outranking method was first proposed by Roy [1973]. It is quite different from the value theory approach. It is based on two indices: concordance index (CI) and discordance index (DI). CI measures the strength of alternative A being better than alternative B. While DI measures the opposite. When CI is greater than a threshold value and DI is less than another threshold value, alternative A is preferred to alternative B. Outranking method is very transparent and easy to use.

PROMETHEE [Brans et al 1986] is an MO-DSS based on outranking method. However it uses a kind of preference function to find the equivalent of CI and DI. Various forms of preference function are suggested by the computer and the planners may choose or improve them. The software provides a complete ranking of the alternatives and displays it graphically.
4.1.4 Visual Display Based DSS

A recent trend in multiple criteria based DSS is the holistic display of MCDM problem graphically. It is recognised that humans are better at processing graphical rather than numerical information and displays [Kasanen et al 1991]. There seems to be growing interests in using the modern computing technology to develop easy-to-use graphic displays of MCDM problems. Unlike value theory or analytic hierarchy based DSS, visual display based DSS does not use any form of aggregation of MCDM problems. The planners can directly compare various alternatives in multiple dimensions of the attributes and choose the one which is most attractive in the overall sense.

**GRADS** [Klimberg 1992] is one such DSS based on visual display. In its present version **GRADS** can handle upto 12 attribute dimensions. In simple sense **GRADS** uses the principles of higher dimension scatterplot. It uses any two attributes, selected by the user, as the basic axes and plots the alternatives as points in this two dimensions. Other attributes of the alternatives are then displayed as star/polygon. The user can move from one point (alternative) to another point and investigate the shape of the star/polygon for visual decision making. **GRADS** (or any visual display based DSS) is not intended for "optimal" decision making. It merely supports the human choice behaviour by graphical display. It will be highly useful for the planners who find it difficult to aggregate the multiple criteria in any form.

4.2 MODM Based DSS

Unlike MADM, there is not much MODM based DSS available or reported in the literature. Though the review of applications (section 3.3.2) reveal many computer applications of MODM, it is our belief that very few of them would satisfy the requirements of DSS [Sprague & Wanton 1989].

Recently Korhonen & Wallenius [1990] reported an MO-DSS called **VIG** (Visual Interactive Goal Programming). It is based on goal programming and has interactive graphic features which help the planners to investigate various solutions. **MOLP-PC** is another MO-DSS which has been applied to a number of planning problems [Quaddus 1993]. It has a
model base of fourteen MODM methodologies. MOLP-PC is highly user friendly but it does not yet have graphic facilities for better interaction with the planners.

5. CONCLUSION

MCDM techniques are well recognized to analyze planning problems of various kinds [Bogetoft et al 1991, Massam 1988, Petry 1990]. This paper shows MCDM applications in development planning area. In particular we concentrate on DSS based on multiple objectives and propose their applications in development planning.

One must take into account a number of analytical, technical, behavioural and socio-political factors to apply MO-DSS in development planning problems. The pros and cons of mathematically elegant methods have to be judged with the practicality of simple and easy to use methods. World renowned researchers in MCDM area admit that in the years ahead simple, easy-to-use DSS type methodology would be needed to solve realworld problems [Dyer et al 1992]. Petry [1990] mentions that "when problems are too complex, human decision making by intuition (holistic synthetic thinking) is much faster and not so much worse than a heuristic analytical process". We hypothesize that human intuition will be enriched by the application of simple, transparent MCDM models which are DSS type. These models would give important insights into the planning problem. We therefore propose to use simple rather than complex MO-DSS for development planning problems.

6. REFERENCES


