An Integrated Model of Sustainable Development Planning Using Multicriteria Decision Conferencing

M A Quaddus, Graduate School of Business, Curtin University of Technology
M A B Siddique, Department of Economics, The University of Western Australia

Abstract: Development planning is multi-dimentional in nature. On the one hand it addresses economic growth, on the other it deals with economic development of the whole nation. Sustainable development, on the other hand, emphasizes the need for integration of economics and environment as well as promotion of intra and intergenerational equity. In this paper we offer a decision conferencing approach to sustainable development planning based on a multi-criteria model. The integrated model is presented and partially applied to a sustainable development planning exercise in a third world country. Sample results are presented and detailed sensitivity analyses show which environmental variables are of major concerns.

1. INTRODUCTION

Development planing is concerned with planning at the 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 (Avegrou 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 emphasizes the role of political pressure groups rather than optimal problem solving (Avegrou 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 (criteria). 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. It is also evident that development planning is typically undertaken by the highest level planning *group* of a nation and interests of the group members play significance roles in shaping the final outcome of the development plans.

Besides multiple criteria and accommodation of group diversities, *sustainability* is another important dimension of development planning. Siddique (1997) emphasizes that "the fundamental idea behind sustainable development is that the needs of the present generations must not be met at the expense of the future generations". Milne (1996) did a comprehensive review of sustainability and points that "sustainability is about integrating *social*, *economic* and *ecological* values". However, the author mentions that there is less agreement in the literature on how sustainability might be operationalized. The author also develops a relationship between sustainability and decision-making. Kelly (1998) takes a systems approach to identify information infrastructure to assess the courses of action for sustainable development projects. The author posits that systems approach identifies the key linkages among the sustainable indicators and thus helps in better implementation of the development projects. Minns (1994) discusses the use of mathematical modelling tools for R&D investment decisions within a sustainable development climate. The author develops a concept called "technology impact profiling" which includes various sustainable development indicators. Lesser and Zerbe (1995) discuss how benefit-cost analysis tool can contribute in sustainable planning. The

authors make the point that "values" to be used in benefit-cost analysis have to be found based on preferences. Systematic thinking and the need for value trade-off in sustainable planning are highlighted by McDaniels (1994). The author reports an application in Canadian utility planning.

Above discussions highlight three important issues of sustainable development planning. These are: (i) consideration of *multiple criteria*, (ii) accommodation of *group diversities*, and (iii) the inclusion of group *preferences*. In this paper we thus propose a model of sustainable development planning which addresses all the three issues identified. We propose to use the "Decision Conferencing" (Quaddus et al 1992) process to accommodate the group diversities. We also propose to use a multiple criteria tool called Analytical Hierarchy Process (AHP) (Saaty 1980) within the decision conferencing process, which will address the preference issues of the group. In the next several sections we first describe the "Decision Conferencing" process. Next, the integrated model for sustainable development is proposed followed by a partial application in the context of a third world country. Finally, conclusions are presented.

2. DECISION CONFERENCING

Decision conferencing is a kind of group decision support process for solving strategic decision problems in which the owners of the problem get together for discussions that are facilitated by an analyst, a facilitator and information technologies (Quaddus et al 1992). It is characterized by on-line development of a decision model to address the problem at hand. Typically, a multi-criteria model is developed by the group that is facilitated by the facilitator. The model is then analysed and extensive sensitivity analyses are performed to clarify various doubts, uncertainties, issues etc. The primary goal of the decision conferencing is shared understanding and commitment to action.

While every decision conference is different, there are some generic steps which are performed for every decision conference. These are: (i) structuring the problem, (ii) assessing the parameters of the model, (iii) running sensitivity analyses, and (iv) planning implementation (Quaddus et al 1992). It is noted that development of an appropriate (requisite) model is the key to the success of decision conferencing. Once the model is validated it is used extensively for subsequent analyses, decision making and implementation planning. In this paper we, therefore, highlight the model development and use for sustainable development planning.

3. INTEGRATED MODEL OF SUSTAINABLE DEVELOPMENT PLANNING

As mentioned earlier there is general agreement in the literature on the concept of sustainable development. Literature concentrates on various issues of sustainable planning but lacks in prescribing a methodology. In line with Milne (1996), Kelly (1998), McDaniels (1994) (among many others) we view sustainable development planning as the process of decision making. Although various modelling approaches can be adopted (Minns 1994) for sustainable planning, we take a simple easy to understand modelling approach based on the theory of hierarchical decision making as proposed by Saaty (1980) and popularly known as "Analytical Hierarchy Process (AHP)". Basically, a hierarchy is a structure of "objectives (criteria)" which comprises different levels whose detail increases from top to bottom. The first level of the hierarchy always describes the overall "purpose" of the problem and is usually perceived in a very abstract form. As we move down the hierarchy, we try to define the immediate upper level in more meaningful and tangible terms.

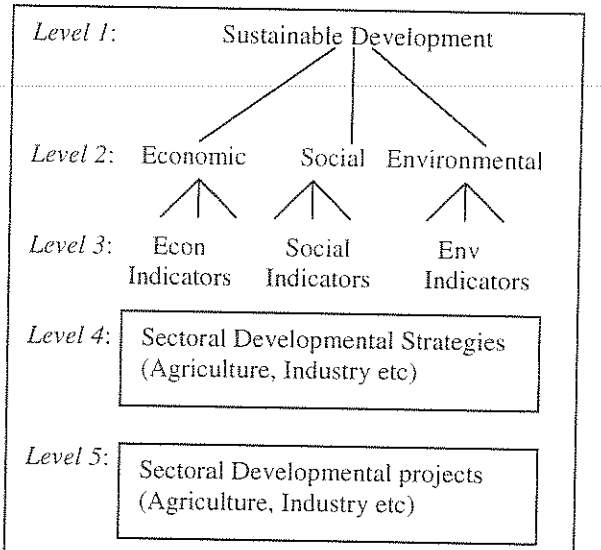

Figure 1: An Integrated Model of Sustainable Development

The bottom most level of the hierarchy contains the actions which if taken will improve the overall objective of the first level. AHP attempts to find the priority weights of the

elements at the bottom most level by doing pairwise comparisons. It is assumed that in order to achieve the overall objective the courses of action of the bottom most level must be followed with the priority weights (Saaty 1980).

Figure 1 presents an integrated hierarchical model of sustainable development planning. It has been developed based on the issues discussed in various literature. However, it has been kept flexible to accommodate specific problem situation.

Overall objective of our model is "sustainable development" (Figure 1). This overall objective is then defined in more tangible objectives as "economic", "social", and "environmental", which are three primary dimensions of sustainable development (Kelly 1998, Milne 1996). Note that integration of these three objectives is of prime importance in sustainable development (Milne 1996). Level 3 of the model defines the level 2 objectives in more operational terms. However, we keep it open as simply "economic indicators", "social indicators", and "environmental indicators". These indicators should be problem specific and the appropriate ones must be considered by the group responsible for development planning. Level 4 of the hierarchy contains various "sectoral strategies".

through integration of level 2 dimensions. Finally, level 5 contains the "sectoral developmental projects".

Inclusion of level 4 and 5 (in figure 1) was motivated, in part, by the study of Quaddus and Chowdhury (1990). It is noted that main objective of the AHP is to find the priority weights of the level 5 projects. AHP theory assures that while finding the priority weights of level 5 the primary dimensions and indicators of levels 2 and 3 will be integrated in an appropriate way, as preferred by the group.

3.1 The Analytical Hierarchy Process (AHP)

Modelling with hierarchy or tree is not a new concept. However, the AHP as proposed by Saaty (1980) has some unique modelling features which deserve attention. AHP expresses one's mental model into an analytical framework. Via weighting and synthesizing of different levels AHP provides the best solution as perceived by the decision makers. It is noted that AHP does not optimize, it provides "satisfactory" solutions. AHP has two distinct phases to analyze a hierarchy: weighting and synthesizing.

3.2 Weighting in AHP

Weighting scheme in the AHP works as follows. Suppose we wish to compare a set of

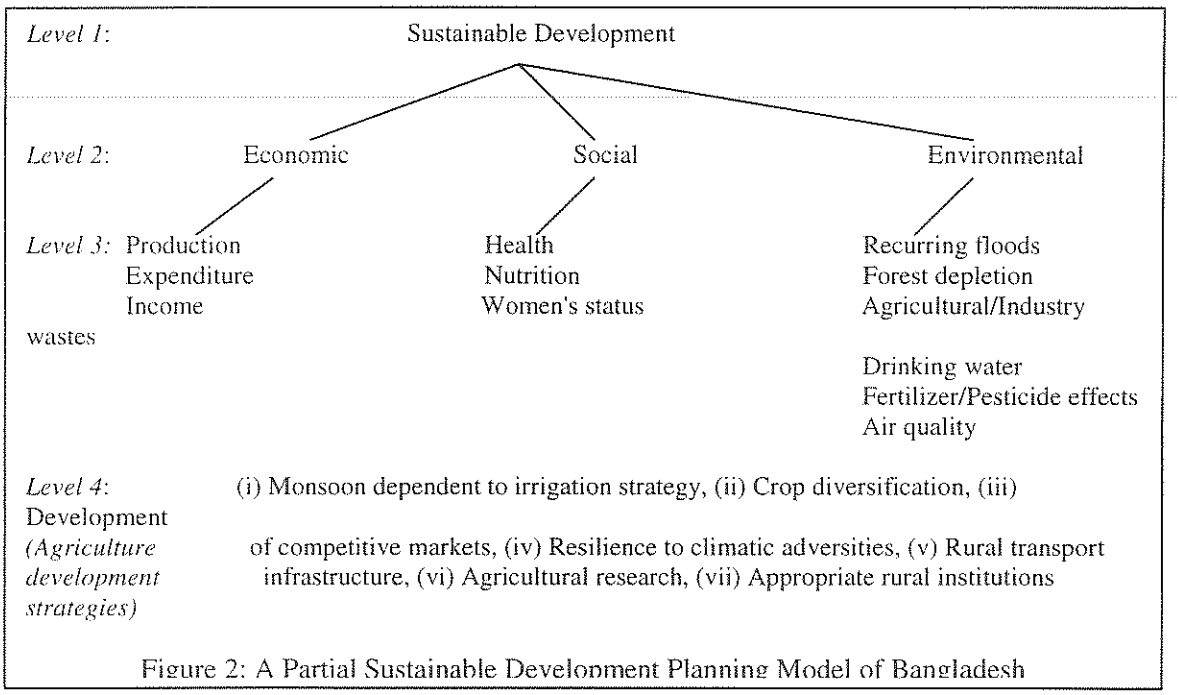

Figure 2: A Partial Sustainable Development Planning Model of Bangladesh

It is assumed that these sectoral strategies will help achieve the indicators of level 3, which in turn achieve the sustainable development

'n' objects, denoted by A_1, A_2, ...A_n, according to their relative weights. Assuming that their

respective priority weights are known, we can construct a ratio matrix $A = (W_i/W_j)$ as follows:

$$A = \begin{array}{c|cccc} & A_1 & A_2 & \ldots & A_n \\ \hline A_1 & W_1/W_1 & W_1/W_2 & \ldots & W_1/W_n \\ A_2 & W_2/W_1 & W_2/W_2 & \ldots & W_2/W_n \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ A_n & W_n/W_1 & W_n/W_2 & \ldots & W_n/W_n \end{array}$$

A numerical value of $W_j/W_i = a$ means that the weight of jth object a times more than that of ith object. Since W_i's are all positive, the A matrix will have positive entries and they satisfay the reciprocal property that $a_{ij} = 1/a_{ji}$.

By post-multiplying A by the column vector W, we obtain

$$AW = nW,$$
$$\text{i.e., } (A - nI)W = 0 \quad \ldots\ldots \qquad (1)$$

Note that we have started with the assumption that W's were known. But in reality W's are not known and, therefore, they need to be estimated. To develop the ratio matrix A we need to compare the 'n' objects in all possible pairs. Saaty (1980) uses a 9-point scale and has done extensive studies. For full description of the scale and its properties see Saaty (1980). To obtain the ratio weight estimates for any pair of A_i (row object) and A_j (column object) the decision maker is asked the following question:

> 'When A_i is compared with A_j how much more strongly does it have the property in question?'

From the responses to all possible pairs of A_i and A_j the A-matrix is developed. Once the A matrix is known the respective weights (W's) for each objective can be found by merely solving equation 1. Solving equation 1 is similar to finding the eigen vector of A matrix with respect to the eigen value 'n'. This eigen vector V is equal to the weight vector W.

3.3 Synthesizing in AHP

In the weighting scheme above, the priority weights of the elements in a single level can be found with respect to each element in the immediate upper level (see figure 1). However, to find the composite priority weights of the bottom most level synthesizing of the hierarchy is needed. This is done in the following fashion:

(i) Start from the 2nd highest level. Construct a 'pair-wise comparison matrix' of the impact of each element of this level with respect to the overall purpose at level 1. There will be n(n-1)/2 comparisons if there are n elements at level 2. Find the priority weights for the elements of the 2nd level by solving equation 1, i.e., finding the eigen vector of the pair-wise comparison matrix.

(ii) Go to the next level (say jth level); find the weights as in step (i) for the elements with respect to each element of the immediate higher level, i.e., (j-1)th level. Develop the jth level 'priority matrix' of weights.

(iii) Post-multiply the jth priority matrix by he (j-1)th priority weight vector. This will give the 'composite' priority weights of the jth level elements.

(iv) Repeat steps (ii) and (iii) until the bottom most level is reached.

In our application we will use a decision support system (DSS) based on AHP – widely known as "Expert Choice" (Expert Choice Inc 1995). In synthesizing, therefore, all the pairwise comparisons have to be done by the user. The rest will be handled by the DSS software. Expert Choice is an extremely user friendly software. It has excellent graphic facilities.

We now present a partial application of our model in the next section.

4. A PARTIAL APPLICATION

Figure 2 presents the sustainable development planning model for Bangladesh. Note that it is a partial model as level 5 does not exist in this model. Level 2 of the model consists of generic objectives of sustainable development as evidenced in various literature. The level 3 specific objectives have been taken from various sources. The "economic" and "Social" objectives have been defined in terms of some specific objectives according to the World Bank indicators (Kelly 1998). These indicators very well apply for Bangladesh also (Government of Bangladesh 1990). The "environmental" objective has been defined in terms of specific objectives as obtained from various documents (Government of Bangladesh 1990).

The level 4 strategies (figure 2) have also been taken from various documents of the Planning commission, Government of Bangladesh (Government of Bangladesh 1990). Note that we only dealt with "Agriculture" sector, as this is the dominant sector in Bangladesh (Quaddus and Chowdhury 1990). Due to the lack of information specific developmental projects could not be included in level 5. This level, therefore, does not exist in figure 2. However,

the model of figure 2 is quite comprehensive. We will be able to see the impact of the Strategies of level 4 in the sustainable planning.

AHP requires pairwise comparisons to assess the priorities at different levels (Saaty 1980). The process starts with the pairwise comparison of level 2 objectives with respect to the overall objective of level 1. It then continues to the next level, until it reaches the bottom most level. The assessment is normally done by asking questions to the assessors. For example, to find the priority weights of level 2 objectives with respect to the overall objective the following question might be asked:

"Between any two objectives (for example, social and environmental) which one contributes more towards sustainable development of Bangladesh?"

In the proposed Decision Conferencing process these pairwise comparisons would be conducted by the group that will be facilitated by a facilitator. In this application, however, the authors have conducted the pairwise comparisons themselves for illustrative purposes. It is noted that the authors are extremely knowledgeable in the socio-economic environment of Bangladesh.

Figure 3 shows the composite priority weights of the level 4 strategies. It is observed that "crop diversification" strategy has the highest priority of 0.198 followed by the "agricultural research" strategy (priority weight of 0.175). In the context of Bangladesh both of these strategies are extremely useful and sustainable. Various sensitivity analyses can now be performed for deeper understanding of the problem. This may result in fine tuning the hierarchical model (figure 2), if necessary. Figure 4 shows the sensitivity graph for "recurring flood", one of the indicators of the "environmental" objective (see figure 2). Recurring flood is one of the major environmental problems in Bangladesh. Current priority weight of this variable is 0.187. Figure 4 shows that if this weight increases to 0.4 or above then "Monsoon" strategy (i.e. monsoon dependent to irrigation strategy) becomes the new highest priority strategy. This is an extremely valuable information.

Similarly, other sensitivity analyses can also be performed to understand the problem better. For the current problem it has been observed that along with "recurring floods" "Drinking water" and "Fertilizer/pesticide effects" are also extremely sensitive. Priority weightings of these variables, therefore, need extreme caution.

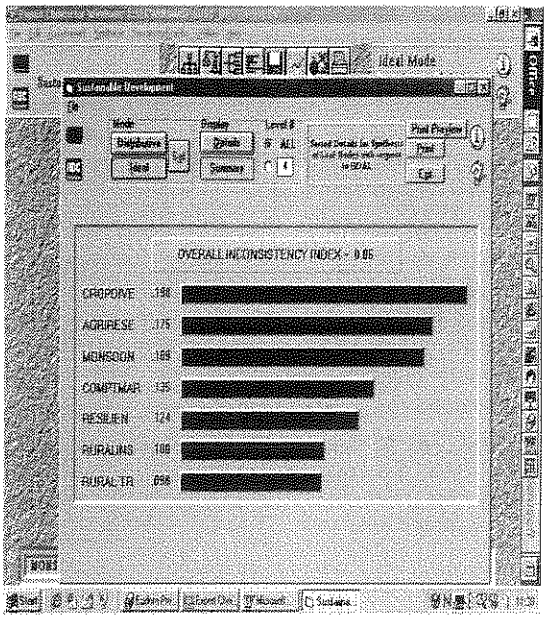

Figure 3: Composite priority weights of level 4 strategies

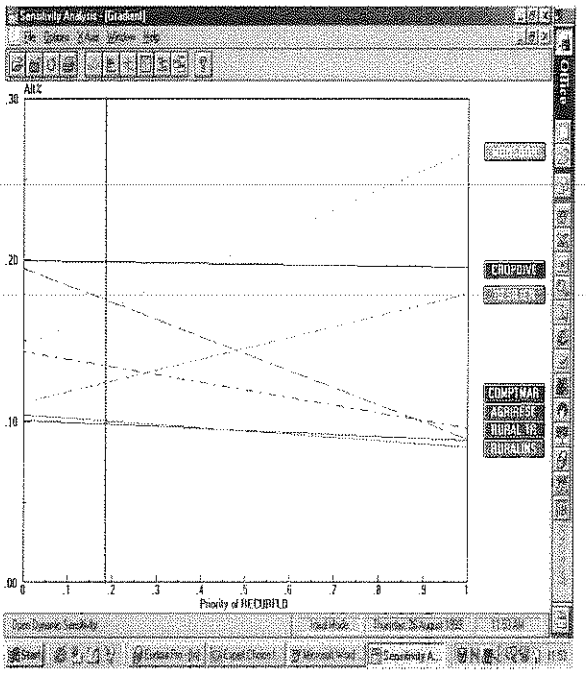

Figure 4: Sensitivity graph for "recurring flood"

5. CONCLUSIONS

Sustainable development planning is a very complex task. There is no general agreement on how to go about developing sustainable development plans. Literature concentrates on various issues of sustainable planning but lacks in prescribing a methodology. In this paper we

propose a hierarchical modelling approach to sustainable planning by taking a "decision making" approach. The backbone of our modelling approach is the analytical hierarchical process (Saaty 1980). We also promote the decision conferencing process, a kind of group support, for the model development and analysis in a group environment (Quaddus et al 1992). An integrated model is thus developed based on various issues as discussed in the literature.

A partial application of the model is presented for Bangladesh. The model is calibrated by the authors for illustrative purposes. The results show that there are a number of environmental variables which are sensitive to the final outcome. The planners must identify these and pay special attention for feasible ad sustainable planning.

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