community increases in part because of their perceived ownership of the model itself. Third, the integrity and credibility of the model to the local communities are enhanced if the model is perceived to have been developed with heavy local input and participation.

Historically, modeling in general and model-building in particular has been the exclusive domain of experts and trained scientists. However, for participatory modeling to be embraced at the local level, it must be configured in a form that is simple, transparent, and stripped of the typical complexity that often characterizes many models. The modeling paradigm must be such that stakeholders with little or no formal training in modeling can grasp the modeling process, feel comfortable in sharing their input and knowledge, and are able to contribute their expertise with relative ease. Mendoza and Prabhu (2002) describe such a paradigm using what they call soft qualitative modeling approach. Their model embraces many of the principles of qualitative system dynamics (Wolstenholme, 1999) and cognitive mapping (Eden, 1988). The qualitative system dynamic orientation of the model enables the accommodation or structuring of model components in a dynamic process, hence, causality or influence relationships can be accommodated. In addition, the modeling process itself is implemented following the open and flexible procedures of cognitive mapping.

3. Multi-criteria analysis

Multi-criteria analysis (MCA) is a general approach dealing with problems that involve multiple dimensions or criteria. It is a robust approach, which is amenable to a wide variety of applications. Mendoza and Prabhu (2000a) describe a number of features that make MCA a very appropriate tool for community-based land revitalization management. Specific attributes of MCA deemed appropriate and useful for CLRFM include: (1) it is capable of accommodating multiple criteria in the analysis; (2) it can work with mixed data where analysis need not be data intensive and allows the incorporation of both qualitative and quantitative information; (3) it permits direct involvement of multiple experts, interest groups and stakeholders and (4) analysis is generally transparent to participants.

Capability to accommodate multiple criteria in the analysis is a big advantage to CBLRM because of the inherent multiple-use nature of forest management. Typically, most forests are managed for a variety of uses some of which may be in conflict or exclusionary. Moreover, CBLRM, particularly in the tropics, typically involves many stakeholders, each demanding that their concerns and objectives are heard and adequately considered in the management of the land. MCA's ability to incorporate multiple views from different stakeholders makes it an excellent tool for participatory planning and decision-making. Also, decisions in CBLRM are frequently made without or with little quantitative data; hence, MCA's ability to deal with mixed data add some rigor to what otherwise would be a highly subjective and qualitative planning and decision-making process.

In normative decision analysis, the most preferred choice is generally between two or more alternatives, which can be defined as: $x_1, x_2, x_3, \ldots, x_n$. The ultimate choice is often based on a single criterion measured in terms of an objective value represented by Z. In a formal model, the decision-making problem can be described as:

$$\text{optimize } Z = f(x_1, x_2, x_3, \ldots, x_n)$$

where $f(x_1, x_2, x_3, \ldots, x_n)$ is the objective function.
Formally, MCA is an extension of the problem described above, accommodating multiple objectives or criteria. That is, the problem can be described as follows:

$$\text{optimize } Z_1 = f(x_1, x_2, x_3, \ldots, x_n)$$
$$\text{optimize } Z_2 = f(x_1, x_2, x_3, \ldots, x_n)$$
$$\text{optimize } Z_n = f(x_1, x_2, x_3, \ldots, x_n)$$

where, $Z_1, Z_2, \ldots, Z_n$ are the different criteria.

Typically, the decision environment is such that each criterion has varying degrees of importance. That is, their relative impacts are different because they affect the decision in different ways. Consequently, the varying degrees of importance of each criterion must be measured, and their relative effects individually evaluated. In addition to measuring their relative importance and evaluating their individual effects, MCA also provides the structured process, and the means to measure the cumulative impacts of all criteria. That is, MCA offers a systematic (i.e., organized and structured) and systemic (i.e., embracing individual and collective effects) procedure to measure and reflect not just the individual effects, but also the cumulative impacts of all criteria. In other words, MCA allows for the establishment of a composite measure by which all criteria are measured and evaluated simultaneously. Moreover, because MCA typically involves multiple criteria, often the decision environment also involves multiple participants (e.g., public planning). MCA also allows the accommodation and direct participation of a number of stakeholders or interest groups. That is, MCA can encompass multiple decision makers whose individual concerns and opinions must be sufficiently accom-modated.
We chose four objectives as suitable for model formulation:

1. Minimization of new development. This encourages redevelopment
2. and efficient urban land utilization
3. Minimization of redevelopment. This encourages only the economically defensible spatial change. By varying the importance between objective one and two, we allow for tradeoff between new development and redevelopment
4. Minimization of the incompatibility of adjacent allocated land uses. This helps to promote a quality of environment
5. Minimization of distance to already developed areas, which acts as a coarse-equivalent to accessibility.

4. Integrating MCA with Participatory Modeling

The previous sections describe the merits and approaches of MCA and participatory modeling in broad terms and generally as stand-alone models. This section describes some general principles dealing with the integration of the two approaches along with some case studies that illustrate their application in CBLRM. In describing these applications, two types of models and case studies are presented: *static* *integration models* where the dynamics of the components of forest ecosystems are not addressed directly, and dynamic integration models that deal with the interactions of the ecosystem's components. This overview is not exhaustive and is limited primarily to the work of the authors, and related works from other authors. In particular, static integration models are briefly described and the results from case studies are only summarized. Readers are referred to relevant literature for more details.

4.1. Static Integration Models

In this type of integration, MCA is simply an organizing tool for evaluating the relative importance of different forest management components. A classic example of this integration is the assessment or evaluation of criteria and indicators (C&I) of forest sustainability. In conducting C&I evaluations of different forests, Mendoza and Prabhu (2000b) used MCA in different ways: (1) as a way to facilitate the decisions of each individual/participant regarding the importance of each criterion/indicator, (2) as a way to assess the relative importance of each criterion/indicator in order to select a set deemed most significant and (3) as a way to 'aggregate' all the evaluations made by participants/experts to arrive at a 'consensus' or group-based evaluation of all criteria/indicators. MCA served as the evaluation tool in assessing the relative importance of each indicator element of the decomposed C&I hierarchy (Mendoza and Prabhu, 2000a)._Based on this relative importance measure, the 'sustainability index values' of indicator elements at higher levels in the hierarchy can be estimated as:

$$SIC_i = \sum s_j w_j \quad (1)$$

where, SICi is the sustainability index of criteria *i*, s_j the score of indicator *j*, w_j is the relative weight of indicator *j*.

Clearly, the MCA process can be used in assessing the importance of individual indicator elements, or in a general sense, the aggregated sustainability index values of broader indicator elements. The integration is considered loose and static because the dynamic relationships among the indicator elements are not considered. Moreover, the C&I hierarchy is simply a list of 'ordered' indicator elements. Participation from stakeholders or participants involves soliciting their input in assessing the relative importance of the individual indicator elements. Participatory modeling essentially consists of laying out the 'ordered' set of indicator elements, provide measures of their relative importance, and then aggregate these measures to estimate sustainability values at various levels in the hierarchy. The integration is also deemed static because the relationships between the elements are not considered as dynamic processes organized as a set of interacting elements.

4.2. Dynamic Integration Models

Unlike the static integration described above, dynamic integration provides a framework where the relationships of the eco-social components of forest management are considered systematically, recognizing and accommodating their dynamic and functional interactions. Hence, dynamic integration consists of identifying each element, estimating its relative importance as well as determining

Causality relationships including feedback loops or influence diagrams between and among the elements. While static integration may be viewed as loose coupling of MCA with participatory modeling, dynamic integration, on the other hand, aims for a tight coupling of the two methods. The integration may be viewed as combining system dynamics on one hand, and MCA on the other. The integrated model provides a framework for participatory decision-making in two major areas: model development and decision-making.

Enabling participatory modeling requires a framework that is transparent and easily within the grasp of participants who are neither trained nor have experience in modeling. This is particularly true in CBFM where most local communities have inadequate or little training and could not easily adapt to thinking in terms of models. These limitations necessitate framing the process of modeling outside the traditional view of modeling as a problem-solving tool. Instead, modeling takes the form of a problem-structuring tool (Rosenhead, 1989). The differences, advantages, and disadvantages of these two modeling paradigms are worth noting especially in the context of CBFM in general and participatory modeling in particular.

Checkland (1981) refers to the traditional modeling technique as consistent with 'hard systems thinking', with the aim of 'solving' a problem, finding the 'right answer', or making decisions about a problem with its rigid assumptions, well-defined phenomena, and highly structured process. Viewing these as limitations in 'real world' problems, particularly among problems dominated by purposeful and unpredictable human designs and goals, Checkland (1984, 1988) proposed an alternative paradigm called 'soft systems methodology' that is not aimed at solving the problem, but is simply a platform to understand the problem and identify the factors and issues. Other authors advocated similar types of approaches following the same modeling and management philosophy (Keeney, 1992; Eden, 1988, 1989; Rosenhead, 1989).

The integrated model used in this paper is adopted from Belton and Stewart (2001). The proposed integrated model is a five-step process starting with the soft or qualitative value and problem exploration state in step 1, moving through the middle stages in steps 3 and 4, to the development of action plans in step 5 (Fig. 1). The intent of the initial stages is to draw out the values or objectives of the stakeholders.

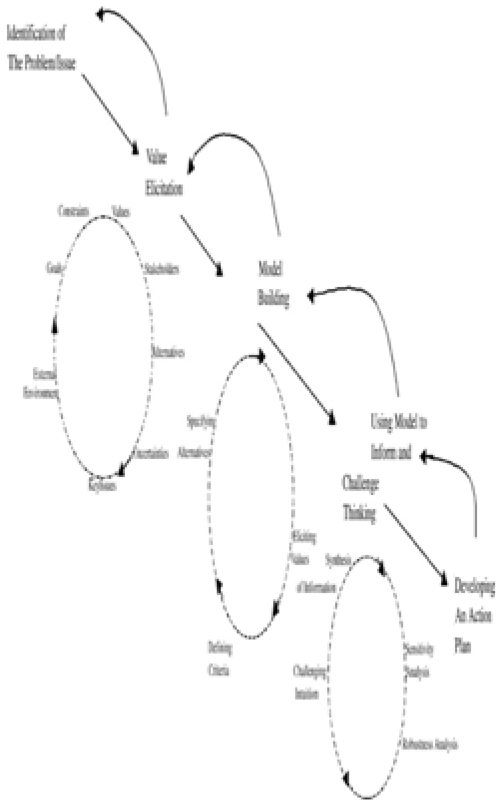

Figure 1: Structuring framework of decision support systems (Belton and Stewart, 2001).

Belton and Stewart (2001) consider the transition as essentially a phase of problem structuring with the aim of ‘‘beginning to think about managing uncertainty and complexity and to understand how to move forward’’. The middle stages, particularly steps 3 and 4, are where formal quantification or systematic structuring occurs. Clearly the steps are interactive, cyclic, and iterative within and among the steps (Fig. 1). Participatory modeling, in its different forms, is reflected throughout the entire process. The dynamic integration of MCA into this decision framework can be implemented in steps 3 and 4.

Before presenting the dynamic integration at the latter stages, two ‘soft’ methods that are appropriate for the initial stages, namely cognitive mapping and qualitative system dynamics, are briefly described below. Eden (1988) proposed ‘cognitive mapping’ as an approach to strategic thinking, particularly in exploring values, issues, concerns, perspectives, goals, objectives, or ‘worldviews’ (Checkland, 1981). Eden (1989) defined the cognitive map as a model amenable to formal analysis that is designed to mimic the way a person defines or perceives an issue. It is organized as a set of ideas or concepts framed as a network of nodes, arrows, or links to represent the relationships of the concepts or ideas. While cognitive mapping provides some rigor and structured analysis beyond the enumerative listing of problem components, it is still lacking in terms of more formal analysis demanded of most planning and decision-making models. Cognizant of the need for such analysis, Wolstenholme (1990, 1999) and Coyle (2000) proposed the use of qualitative system dynamics. Qualitative system dynamics was initially proposed to complement the capabilities of cognitive mapping. The development of the concept has since evolved towards adapting and applying the aspects of system dynamics without the use of quantification and simulation (Sterman, 2000), two key components of traditional system dynamics.

The combination of cognitive mapping and qualitative system dynamics presents a convenient platform for doing participatory modeling because they are both simple and easily within the grasp of local communities. The process starts with the development of influence diagrams, which are well-known tools of quantitative system dynamics and are also very similar to the concept maps of cognitive mapping (Eden and Ackermann, 1998). Qualitative system dynamics, however, moves analysis beyond a linear ‘laundry list’ thinking through the use of circular causality (Fig. 2). Clearly, qualitative system dynamics, particularly causal loop diagrams, could be useful even without formal simulation or quantification, especially in ‘structuring’ problem elements and examining their overall relationships.

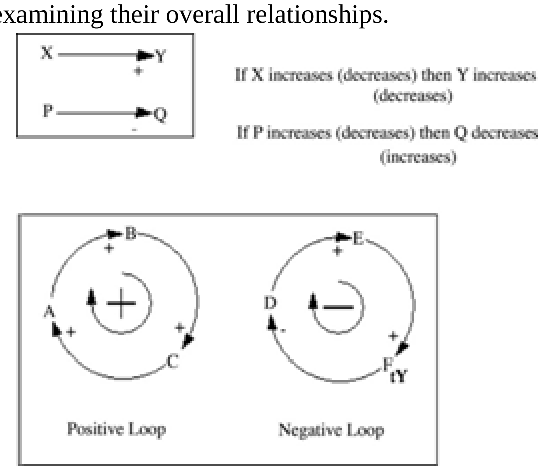

Figure 2: Components of a causal loop diagram (CLD) or circular causality.

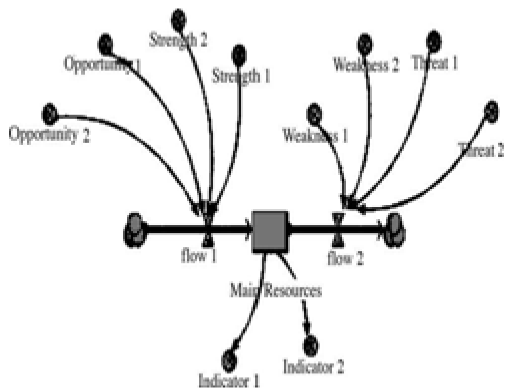

Figure 3: SWOT elements structured in a system dynamics framework.

Similarly, Mendoza and Prabhu (2002b) used the computer-assisted model *Co-View* to develop a collaborative model for developing collective goals, strategies and action plans for a community managed under a resource-sharing arrangement. The model follows the structure of a system-dynamics framework with elements organized around the well-known components of strategic planning, namely SWOT (i.e., Strengths, Weaknesses, Opportunities and Threats including Indicators (Fig. 3).

In the nomenclature and structure of a typical stock-and-flow system dynamics model originally developed by Forrester

(1961), the stock, represented as the Main Resource and sometimes referred to as the state variable, is the resource or entity that is monitored (Fig. 3). The Inflow (Flow 1) represents the positive changes that enhance the favorable condition of the resource; the Outflow (Flow 2) represents the negative changes that adversely affect the condition or status of the main resource. The status or condition of the resource is monitored through the Indicators. Clearly, the change in the status of the Main Resource is determined by, or dependent on, the rate of Inflow and Outflow. These rates are affected by the Inflow and Outflow variables. As depicted in the figure, it is reasonable to assume that Strengths (internal) and Opportunities (external) are entities that support, and are conducive, to favorable change or condition of the Main Resource. On the other hand, Weaknesses (internal) and Threats (external) are entities that undermine, and negatively affect, the condition of the Main Resource.

The structure of the dynamics model shown in Fig. 3 is quite intuitive and transparent, even to those who have no modeling experience. In fact, influence diagrams and graphs closely resemble cognitive maps with its arrows and nodes. The influence diagramssimply add more structure and meaning to the arr ows and nodes by imputing more explicit relationships in terms of causality, changes and impacts.

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