Chapter 1
Introduction

1.1 Planning and Decision Support

Decision means choosing from at least two distinct alternatives. Decision making, on the other hand, can be defined to include the whole process from problem structuring to choosing the best alternative (e.g. Kangas 1992). Most decisions we face every day are easy, like picking a meal from a restaurant menu. Sometimes the problems are so complex, however, that decision aid is needed.

Decision making can be considered from at least two points of view: it can be analyzed, how the decisions should be made in order to obtain best results (prescriptive approach), or, it can be analyzed, how people actually do decisions without help (descriptive approach) (e.g. von Winterfeldt and Edwards 1986). The first approach is normative; it aims at methods that can be used to aid people in their decisions. These decision-aid methods are usually based on an assumption that decisions are made rationally. There is evidence that people are not necessarily rational (e.g. Simon 1957). However, this is not a problem in decision aid: it can realistically be assumed that decisions actually were better, if people were instructed to act rationally. Decision-aid methods aim at helping people to improve the decisions they make, not mimicking human decision making.

The planning situation can be characterized with three dimensions: the material world, the social world and the personal world (Mingers and Brocklesby 1997; Fig. 1.1). The material world dictates what is possible in a planning situation, the personal world what we wish for, and the social world what is acceptable to the society surrounding us. All these elements are involved in decision making, with different emphasis in different situations.

The decisions can be made either under certainty or uncertainty, and the problem can be either unidimensional of multidimensional. In addition, the problem can be either discrete (i.e. the number of possible alternatives is limited) or continuous (i.e. there is an infinite number of possible alternatives), and include either one or several decision makers.

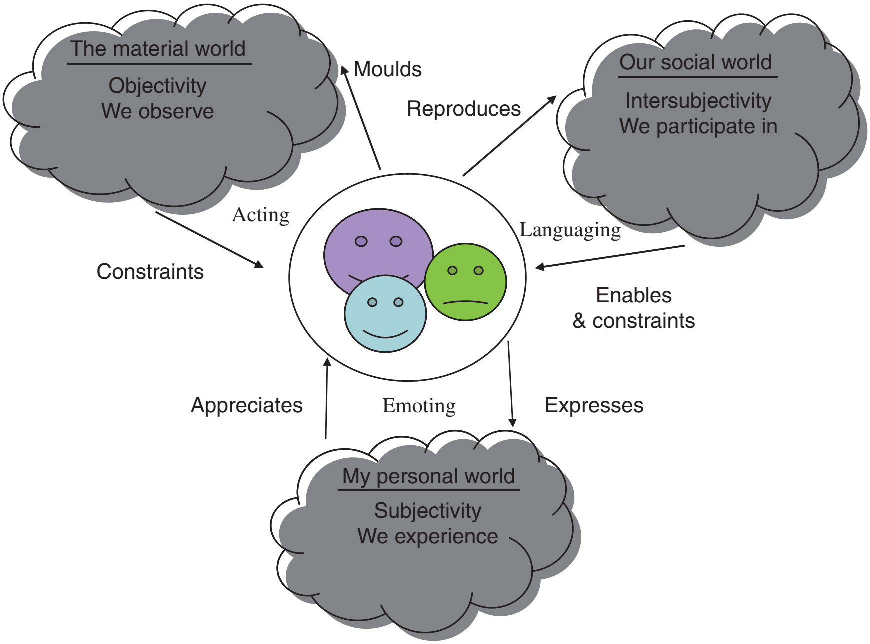

Fig. 1.1 Three dimensions of problem situation (Modified from Mingers and Brocklesby 1997)

If the problem is unidimensional problem with certainty, the problem is straightforward to solve. If the alternatives are discrete, the best is chosen. If the decision has to be made under uncertainty, also the discrete unidimensional case is of interest. Modern utility-theoretic studies can be considered to begin with the works of Ramsey (1930) and von Neumann and Morgenstern (1944) dealing with the unidimensional case under risk.

In a multidimensional case under certainty, the problem is to define the tradeoffs between the attributes or criteria. Such tradeoffs are subjective, i.e. there are no correct tradeoff values that the decision makers should use (Keeney and Raiffa 1976). The most challenging problems are those with multiple dimensions including uncertainty. There may be uncertainty in all parameters of decision analysis, for instance, the future consequences of different actions or the preferences of the decision maker with respect to different criteria may be uncertain. There exist, therefore, several applications of decision-support tools accounting for the uncertainty.

Another complication is that there may be several decision makers or other stakeholders involved. In such cases the problems may be messy: it is not clear what are the alternatives among which to choose from, or what are the criteria with respect to which the alternatives should be compared. For such situations, there exist several problem structuring methods (Mingers and Brocklesby 1997).

A rational decision maker chooses an alternative which in his opinion maximizes the utility (Etzioni 1986; von Winterfeldt and Edwards 1986). For this, one has to have perfect knowledge of the consequences of different decision alternatives, the goals and objectives of the decision maker and their weights, in other words of the preferences. Accordingly, the basis of decision making can be divided into three elements: alternatives, information and preferences (Bradshaw and Boose 1990). The basis has to be solid with respect to all elements so that one is able to choose the best alternative. Keeney (1982) divided the decision analysis into four phases which all are necessary parts of the modelling of decision making:

1. Structuring a decision problem
2. Defining the consequences of decision alternatives
3. Eliciting out the preferences of the decision maker
4. Evaluating and comparing the decision alternatives

Generally, in decision-making processes, decision makers are assumed to rank a set of decision alternatives and choose the best according to their preferences. To be able to rank, they select the criteria that are relevant to the current problem and that are of significance in their choice (e.g. Bouyssou et al. 2000). The criteria used in ranking are standards or measures that can be used in judging if one alternative is more desirable than another (Belton and Stewart 2002). Each alternative needs to be evaluated with respect to each criterion.

Belton and Stewart (2002) (Fig. 1.2), on the other hand, divided the decision-aid process to three phases, namely problem structuring, model building and using the model to inform and challenge thinking. This definition emphasises using decision aid as a help in thinking, not as a method providing ready-made solutions. According to Keeney (1992), decision-makers should focus on values, and on creating creative

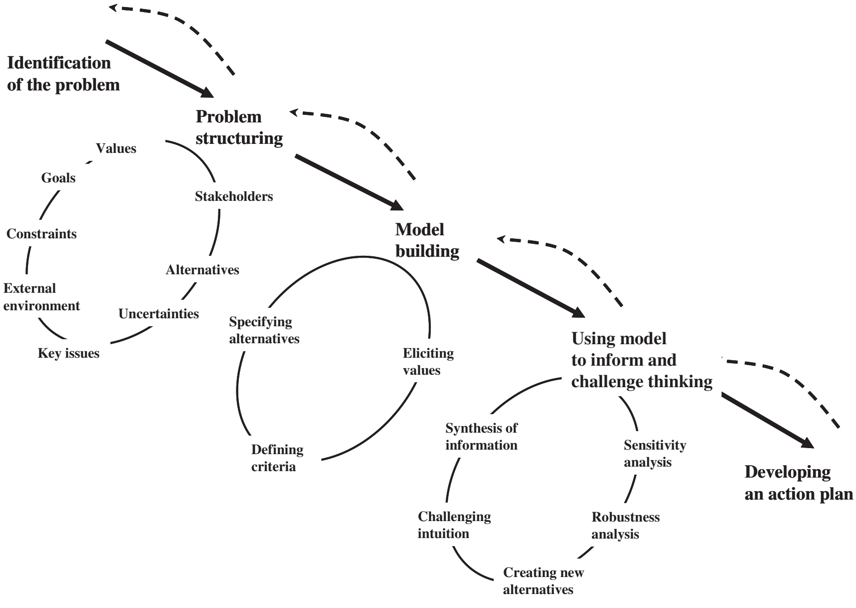

Fig. 1.2 The process of MCDA (Belton and Stewart 2002)

new alternatives based on their values, rather than ranking existing alternatives. He argues that creating the alternatives is the most crucial phase of all in the decision-making process, and it is not dealt with at all in the traditional decision science. Both these perspectives reflect the current view of decision analysis. Some of the older ideas and definitions have been strongly criticized for treating decision makers as machines (e.g. French 1989, p. 143).

As the name suggests, Multiple Criteria Decision Support [MCDS, or MCDA (MCD Aid), or MCDM (MCD Making)] methods have been developed to enable analysis of multiple-criteria decision situations. They are typically used for dealing with planning situations in which one needs to holistically evaluate different decision alternatives, and in which evaluation is hindered by the multiplicity of decision criteria that are difficult to compare, and by conflicting interests. For more fundamental descriptions of MCDS, readers are referred to Keeney and Raiffa (1976), von Winterfeldt and Edwards (1986), French (1989), Bouyssou et al. (2000), Vincke (1992) or Belton and Stewart (2002).

Decision problems can, however, be complex even if there is only one objective. For instance, the case could be such that the decision-maker needs to allocate the resources (e.g. money and land) to competing forms of production (e.g. what tree species to plant) in order to get the best profit. In such cases, the decision-aid methods typically used are mathematical optimization methods. These methods produce exact optimal solutions to decision problems. The most commonly applied of these methods is linear programming LP (see, e.g. Dantzig 1963; Dykstra 1984; Taha 1987; Hillier and Lieberman 2001). There are also many modifications of this basic approach, such as integer programming and goal programming. Optimization methods can also be used in cases where there are an infinite number of possible actions and several criteria (Steuer 1986).

In many cases the real problems are too complicated for these exact methods. Then, either the problem is simplified so that it can be solved with exact methods, or the solution is searched using heuristic methods (e.g. Glover 1989; Glover et al. 1995; Reeves 1993). These methods can produce a good solution with fairly simple calculations, but they cannot guarantee an optimal solution. The benefit in these methods is that the true decision problems can be described better than with exact methods, where the problems often have to be simplified in order to fit to the requirements of the methods. It is more useful to get a good solution to a real problem, than an exact solution to a misleadingly defined one.

1.2 Forest Management Planning

Forest management planning is a tool of central importance in forestry-related decision making. The aim in forest planning is to provide support for forestry decision making so that the mix of inputs and outputs is found that best fulfils the goals set for the management of the forest planning area. The current use of forests is typically multi-objective. Ecological, economic and social sustainability is aimed for. Forests should produce reasonable incomes while at the same time promoting conservation and recreational considerations. In other words, forests are being used simultaneously for multiple purposes (e.g. Kangas 1992; Davis et al. 2001).

Forestry decision making often includes numerous decision-makers or other stakeholders. They could be owners of the forests, local inhabitants, people connected with tourism and recreation services, private persons or officials concerned with nature conservation, or personnel of forestry enterprises. Each of them can have different objectives concerning the use of forests or other natural resources, which further complicates the evaluation.

Forest planning problems are typically described so that each stand in the forest has several different treatment schedules that are possible alternatives for it. For instance, harvests with two different rotation times produces two different schedules for one stand. Each schedule may include several treatments with a different timing. It may be that the schedule for one stand includes one or two thinnings before the final harvest, and planting after it. The development of the stand is then predicted, with respect to all relevant criteria. The predictions are typically based on forest simulators including growth and yield models for forest.

With different combinations of standwise treatment schedules, a huge number of different production programmes for the whole area could be obtained. Among these programmes, those that are efficient with respect to the criteria involved are worth further investigations. This means that programmes dominated by some other programme should be excluded from the analysis. Normally, the end result of forest planning is a management plan, which presents a recommended production programme for the forest area, with predictions of the consequences of implementing the plan.

Briefly, the main phases in a forest planning process are:

(i) Forest data acquisition and assessing the present state of the forests
(ii) Clarifying the criteria and preferences of the decision maker(s) regarding the use of forests and, in participatory planning, clarifying the criteria and preferences of other interested parties
(iii) Generating alternative treatment schedules for forest stands within the planning area and predicting their consequences
(iv) Producing efficient production programmes for the forest area
(v) Choosing the best production programme from among those deemed to be efficient with respect to the criteria and preferences as clarified in phase (ii)

These phases do not necessarily proceed in this order, and they can be applied iteratively, interactively, and/or simultaneously.

Forest planning can be either strategic, tactical or operational planning. In strategic planning, the basic idea is to define what is wanted from forest, and in tactical planning to define how these goals are obtained. In forest context, strategic planning typically means time horizons from 20 years upwards. Long horizons are especially needed when assessing the sustainability of alternative decisions. Strategic plans are usually prepared to cover fairly large areas, from woodlot level in private forests to regional level in the forestry of big organizations. For practical reasons, there planning calculations are not very detailed.

In tactical forest planning, on the other hand, the time horizon is typically 5–20 years. The number of alternative forest plans, each consisting of a combination of forest-stand treatment schedules, can be considerable, practically infinite. It also means that the resulting plans are detailed, typically including standwise recommendations. In operational planning, carrying out these standwise recommendations is planned in great detail. In practise, strategic and tactical planning are often integrated so that both strategic and tactical solution are produced at the same time. Planning is continuous work, and whenever the planning environment or needs of decision maker(s) change, the plan is updated.

1.3 History of Forest Planning

The earliest forest management planning methods for large areas were based on the concept of fully regulated even-aged forests (e.g. Kilkki 1987; Davis et al. 2001). Fully regulated forest is an ideal state of forests. It means that a forest area has a steady-state structure and conditions, and a stable flow of outcomes. The growth is equal to annual harvest, and harvest is the same each year. The area harvested each year can be calculated simply by dividing the total area A by the selected rotation time R. Thus, it ensures a sustainable yield, which has been an important objective of forestry.

Real forests, however, do not fulfil the requirements of fully regulated forests. Yet, it must be decided how large an area and how much volume to cut. Traditional methods of forest planning provide two different types of methods: those based on area control and those based on volume control (Recknagel 1917; Davis et al. 2001, p. 528).

Area control method is the simplest way to regulate the harvests. If a constant area A/R is harvested each year, the forests are fully regulated after R years. On the other hand, the harvested volume may vary a lot between years. This method assumes a constant site quality, but it is also possible to utilise different rotation times for different sites.

The oldest volume control method is the Austrian formula, first published already in 1788 (Speidel 1972),

$$C_t = I + [(V_c - V_f)/a] \tag{1.1}$$

where C_t is the annual cut, I is the annual increment of forests, V_c is the current volume of the growing stock, V_f is the volume of the desired state (i.e. fully regulated forest) and a is the adjustment time. This means that the harvest is the growth of the area, corrected so that the volume of fully regulated forests is achieved after the adjustment period. This method ensures a constant harvest level in short term. Yet, the method does not necessarily ensure the fully regulated condition on longer term (Davis et al. 2001, p. 545). Later on, these methods were developed to more advanced cutting budget methods, which enable controlling both area and volume at the same time (e.g. Lihtonen 1959; Kuusela and Nyyssönen 1962; Davis 1966).

In single stands, planning has been concentrated in defining an optimal rotation time (e.g. Gregory 1972; Johansson and Löfgren 1985). There are several criteria for selecting the rotation time. The simplest of them is to select the rotation, which maximizes the mean annual increment (MAI) of forests (rotation of maximum sustained yield). This is achieved by harvesting the stand when MAI is equal to current volume increment. The most famous of the rotation calculation methods is, however, the Faustmann formula (Faustmann 1849). In this formula, the value of land is maximized over infinite number of rotations (the rotation of maximum land rent). In continuous form the formula is (Viitala 2002)

$$\underset{\{u\}}{Max} L = \sum_{i=0}^{\infty} (pV(u)e^{-ru} - c)e^{-iru} = \frac{pV(u)e^{-ru} - c}{1 - e^{-ru}} \tag{1.2}$$

where p is the price of timber (no assortments assumed), $V(u)$ is the volume at the end of rotation time u (only clearcut assumed), r is the rent and c defines the costs of regeneration (no other costs assumed). This rotation time is the economically optimal rotation for any given stand. In continuous form, the optimization problem can be analytically solved, and general results, i.e. cutting rules, can be produced. In this form, however, thinnings cannot be included. In a discrete form, thinnings can be included, but the problem can no more be analytically solved. The discrete form is (Viitala 2002)

$$\underset{\{u\}}{Max} L = \frac{\sum_{i=0}^{u} (R_i - C_i)(1+r)^{u-i}}{(1+r)^t - 1} \tag{1.3}$$

where R denotes the revenues and C costs in year i.

The next phase for large area planning was the introduction of linear programming and complex models that were developed to predict forest development under different scenarios (e.g. Duerr et al. 1979; Clutter et al. 1983; Kilkki 1987; Buongiorno and Gilles 2003). The first applications of linear programming to forest planning were published in the 1960s (e.g. Curtis 1962; Kilkki 1968). In the next decades, forest planning models based on linear programming were developed in many countries, for instance, the FORPLAN model in USA (Johnson 1986; Johnson et al. 1986; see also Iverson and Alston 1986), and MELA model in Finland (Siitonen 1983, 1994). Also models based on simulation were generated in many countries, i.e. models that were not used to find an optimal solution but more to make if-then calculations of different cutting scenarios. Such models were, for instance, HUGIN in Sweden (Hägglund 1981) and AVVIRK in Norway (e.g. Eid and Hobbelstad 2000). Many of these models have been developed until recent years, but new ones have also been published. These models have, however, also been criticized. For instance, the approaches based on LP were not regarded as sufficient with respect to ecological considerations (e.g. Shugart and Gilbert 1987). There were also problems due to the spatial dimensions of the problems, non-linearities and uncertainty. To alleviate these problems, methods for spatial and heuristic optimization were adopted to the forestry calculations (Pukkala 2002).

Any optimization method, however, cannot answer the question of how to value the different criteria in planning. This is because the values are inherently subjective. The criteria are often contradictory, and need to be carefully weighted in order to find the best solution. To deal with the valuation problems, in the last 10 years multicriteria decision aid has also been adopted in forestry decision making (Pukkala 2002; Kangas and Kangas 2005). However, as optimization methods provide efficient solutions located in different parts of the production possibility frontier, and MCDA methods can be used to analyse the values and preferences, these methods complement rather than compensate each other.

Nowadays, numerous decision makers or other stakeholders are often involved in forest planning. Each of them can have different objectives concerning the use of forests or other natural resources, which further complicates the evaluation. Multicriteria decision-aid methods can often be used also in these situations (e.g. Kangas 1994). However, methods based on social choice theory have also been developed for participatory planning and group decision making.

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