Chapter 2
Multi-Criteria Analysis

Decision-making is the study of identifying and choosing alternatives to find the best solution based on different factors and considering the decision-makers' expectations. Every decision is made within a decision environment, which is defined as the collection of information, alternatives, values and preferences available at the time when the decision must be made. The difficult point in decision-making is the multiplicity of the criteria set for judging the alternatives. The objectives are usually conflicting and, in most of the cases, different groups of decision-makers are involved in the process. To facilitate this type of analysis, a family of tools referred to as Multi-criteria decision-making methods gained ground due to the need to have a formalized method to assist decision-making in situations involving multiple criteria.

2.1 Introduction

Multi-criteria decision-making methods is a branch of a general class of Operations Research models that is suitable for addressing complex problems featuring high uncertainty, conflicting objectives, different forms of data and information, multi interests and perspectives, and the accounting for complex and evolving biophysical and socio-economic systems [1]. This major class of methods is further divided into Multi-objective decision-making and Multi-attribute decision-making. These methodologies share the common characteristics of conflict among criteria, incommensurable units and difficulties in design/selection of alternatives. The main distinction between the two groups of methods is based on the number of alternatives under evaluation. Multi-attribute decision-making methods are designed for selecting discrete alternatives while Multi-objective decision-making methods are more adequate to deal with multi-objective planning problems, when a theoretically infinite number of continuous alternatives are defined by a set of constraints on a vector of decision variables [2–4]. In Multi-objective decision-making (also known as multi objective programming or a vector optimization/maximization/minimization problem), the alternatives are not predetermined but instead a set of objective

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functions are optimized subject to a set of constraints. The most satisfactory and efficient solution is sought. In this identified efficient solution it is not possible to improve the performance of any objective without degrading the performance of at least one other objective. In Multi-attribute decision-making a small number of alternatives are to be evaluated against a set of attributes which are often hard to quantify [5].

Following Tsoutos et al. [6] there are four starting reasons that justify the use of Multi-criteria decision-making methods: (i) It allows for investigation and integration of the interests and objectives of multiple actors since the input of both quantitative and qualitative information from every actor is taken into account in form of criteria and weight factors; (ii) It deals with the complexity of the multi-actor setting by providing output information that is easy to communicate to actors. The user-friendliness of the method lies on two aspects: the suggested criteria are estimated and given values that are consistent and comparable with the input data (as a measure of appropriateness); and the 'simple' format of the output of the method that makes the method's results meaningful and directly applicable for the interested actors; (iii) It is well-known and applied method of alternatives' assessment that also includes different versions of the method developed and researched for specific problems and/or specific contexts and (iv) It is a method that allows for objectivity and inclusiveness of different perceptions and interests of actor without being energy and cost intensive.

These methods can provide solutions to increasing complex management problems. They provide better understanding of inherent features of decision problem, promote the role of participants in decision-making processes, facilitate compromise and collective decisions and provide a good platform to understand the perception of models and analysts in a realistic scenario. The methods help to improve quality of decisions by making them more explicit, rational and efficient. Negotiating, quantifying and communicating the priorities are also facilitated with the use of these methods [7].

It should be noted that methods and results are not necessarily comparable. Every method has its restrictions, mostly due to model assumptions, which should be considered when the method is used. Inconsistences might arise because [8]: (i) the choice problem formulations do not reflect the same preference structures, (ii) the ways in which preference information is processed vary between different methods and (iii) the methods interpret the criterion weights differently.

2.2 Model Building

Multi-criteria decision-making may be considered as a complex and dynamic process including one managerial level and one engineering level. The managerial level defines the goals, and chooses the final optimal alternative whereas the the engineering level defines the alternatives, points out the consequences of choosing any one of them from the stand point of various criteria and performs the multi-criteria ranking of alternatives. The engineering level performs the optimization procedure. At the managerial level, public officials, called decision-makers have the power to accept or reject the solution proposed by the engineering level [9]. The decision-making process usually includes five main stages: defining the problem, generating alternatives and establishing criteria, criteria selection, criteria weighting, evaluation, selecting the appropriate multi-criteria method and finally ranking the alternatives. The main steps of Multi-criteria decision-making are the following:

Step 1. Defining the problem, generating alternatives and establishing criteria

A decision-making problem should start out by clearly defining the problem, discerning the alternatives, identifying the actors, the objectives and any points in conflict, together with the constraints, the degree of uncertainty and the key issues. After this, the problem can be framed indicating the evaluation criteria.

Step 2. Assigning criteria weights

The next steps include the assignment of criteria weights. These weights, that show the relative importance of criteria in the multi-criteria problem under consideration, can be determined by techniques such as Analytical Hierarchy Process and Sismos approach.

Step 3. Construction of the evaluation matrix

The phase in which the model is built constitutes a process from which the 'essence' of the problem is extracted from the complex picture drawn up so that the problem can be assessed adequately. At the end of this step, the MCDM problem can be expressed in matrix form as follows:

$$
\begin{array}{ll}
\text{Criteria} & C_1, C_2, \ldots, C_n \\
\text{Weights} & W_1, W_2, \ldots, W_n \\
\text{Alternatives} &
\end{array}
$$

$$
\begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{bmatrix}
\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}
\tag{2.1}
$$

where x_{ij} is the evaluation given to alternative ith with respect to criterion jth, w_j is the weight of criteria j, n is the number of criteria and m is the number of alternatives.

Step 4. Selecting the appropriate method

A multi-criteria method must be selected and applied to the problem under consideration in order to rank alternatives. The data and the degree of uncertainty are key factors for the decision-maker when selecting among several multi-criteria methods.

Step 5. Ranking the alternatives

Finally, the alternatives' ranking is ordered and the best ranked alternative is proposed as a solution.

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