Decision-Making Analysis to Improve Public Participation in Strategic Energy Production Management

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Abstract. Environmental challenges decisions are often characterized by complexity, irreversibility, and uncertainty. Much of the complexity arises from the multiple-use nature of goods and services, difficulty in monetary valuation of ecological services and the involvement of numerous stakeholders. From this point of view, the objective of this paper is to propose a multicriteria methodological approach based on the Analytic Hierarchy Process methodology (AHP) in order to examine the scope and feasibility of AHP integrated with public participation approach. The main goal is to incorporate the prioritization criteria for the assessment of various energy policies for power alternatives, and evaluate these policies against these criteria. The three types of energy selected are: electricity production from wind farms, thermal power plants, and nuclear power plants. The results show that our model can help in the decision-making process and increase the transparency and the credibility of the process including tangibles and intangibles attributes.

Keywords: Environmental, Analytic Hierarchy Process, Key performance indicators, Public Participation.

1 Introduction

Environmental decisions are often characterized by complexity, irreversibility, and uncertainty. It is essential to use mathematical models, in order to evaluate vagueness and uncertainty (Hošková-Mayerová *et. al.* 2013). Under these circumstances, conventional methods such as cost-benefit analysis are not adapted to evaluate environmental decisions (Ananda, 2003). In this context, public participation and environmental impact assessment are recent developments in all countries; however, considerable advances have been made in their development. From this point of view multicriteria techniques are considered as a promising framework for evaluation since they have the potential to take into account conflictual, multidimensional, incommensurable, and uncertain effects of decisions explicitly (Carbone et al., 2000; Munda, 2000; Omann, 2000). The most widely used multicriteria methods include the Analytic Hierarchy Process (AHP), multiattribute utility theory, outranking theory, and goal programming. In this study we focused our attention on AHP because it proves useful

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when many interests are involved and a number of people participate in the judgment process (Saaty, 2005). So this method can be used in environmental challenges planning as it can accommodate conflictual, multidimensional, incommensurable, and incomparable sets of objectives. On the other hand, principles and practice of public participation can serve to promote environmental equity for disadvantaged social groups. The literature on participation and participatory processes stems broadly from two major areas: political sciences with discussions on democracy and citizenship especially within the context of regional and local planning (Pateman, 1970; Munro-Clark, 1990; Davis, 1996); and development theory (Wignaraja et al., 1991; Vettivel, 1992; Rahman, 1993; Nelson and Wright, 1995; Chambers, 1997). According to Creighton (2005), public participation, in principle, involves every person, although it may not be possible to *"reach"* all the individuals and some may not be interested in being involved. However, it is necessary to ensure that the participants involved represent those who are directly, or indirectly, affected by the proposed project and those who can positively or negatively influence the project outcomes (Lizarralde, 2011). These include (i) government/project initiators; (ii) lay public who are affected, or have interests in, the proposed project; (iii) private organizations, such as design institutes and construction companies; (iv) professional organizations and educational institutions; and (v) pressure groups such as the NGOs and mass media. By involving the public effectively in the decision-making process, project success may increase due to (i) a reduction in project time and cost (Creighton, 2005); (ii) the development of more innovative plans and solutions through the incorporation of the community's collective wisdom (CCSG, 2007); (iii) the accomplishment of needs or concerns of a cross-section of society without sacrificing the project goals (Woltjer, 2009); (iv) community acceptance, which can increase the legitimacy of government decisions (Moore & Warren, 2006); (v) an opportunity to promote mutual learning (Manowong & Ogunlana, 2008); (vi) a desire to protect individual and minority rights (Plummer & Taylor, 2004); (vii) an achievement of sustainable project lifecycle management (Varol, Ercoskun, & Gurer, 2011); and (viii) the promotion of collaborative governance (Enserink & Koppenjan, 2007). However, the success of public participation does not depend only on the genuine attitude of the project organizers in soliciting public opinion, but also requires the careful planning and organization of every participatory activity. The effectiveness of this practice in preventing or reducing environmental inequity definitely depends upon the use of participation methodology catering to the cultural and social needs of such groups. These methods need to provide appropriate forms of information, suitable venues for participation, and access to expertise and education which enable the public to understand policy issues and formulate preferences. The extent to which public preferences are incorporated in policy decisions determines the worth of public participation programs in promoting environmental equity (Hampton, 1999). From this point of view we noted that some of the participatory methods developed so far have often been criticized as lacking efficacy because of poor rigor and need of better structuring and analytical capabilities. In spite of this criticism, several studies applying the AHP to incorporate public participation have concluded that the AHP method is worth pursuing (Kangas, 1994, 1999; Ananda and Herath, 2003, Mau-Crimminsa *et al.* 2005). Thus, the objective of this paper is to propose a multi criteria methodological approach based on the AHP in order to examine the scope and feasibility of AHP integrated with public participation and stakeholder preferences in environmental challenges planning (De Felice *et al.* 2010). Our project is based on the assumption that the barriers to effective decision-making that exist between local communities and other stakeholders cannot be broken down by one party acting alone. The study is applied in a real case study concerning three different energy production processes: electricity production from wind farms, thermal power plants, and nuclear power plants because fossil fuels, renewable energy and nuclear (Entzinger and Ruan, 2006) are known as the three major energy sources of the world. Forsberg (2009) emphasized that these energy sources are treated as competing energy resources and economics and environmental constraints determine which energy source will be selected. In all projections, the world energy consumption is expected to increase depending on various demographic, technological and economic growth assumptions particularly in developing countries (Nakicenovic and Swart, 2000; Duffey, 2005; Fiore, 2006). The paper is organized as follows: the Analytic Hierarchy Process approach is described in section 2, the research approach and methodology is analyzed in section 3, the model and case study are proposed in section 4. Lastly, in the Conclusions the results are analyzed.

2 The Analytic Hierarchy Process: Theory Approach

The AHP was developed by Thomas Saaty (Saaty, 1980) in the early 1970s. The strength of the AHP approach lies in its ability to structure a complex, multiattribute, multiperson, and multiperiod problem hierarchically. In addition, it can also handle both qualitative (through representing qualitative attributes in terms of quantitative values) and quantitative attributes. The general approach followed in AHP is to decompose the problem and make pairwise comparisons of all the elements (attributes, alternatives) at a given level with respect to the related elements in the level above. AHP usually involves three stages of problem solving: the principles of decomposition, comparative judgments, and synthesis of priority. Some key and basic steps involved in this methodology are:

1. State the problem.
2. Broaden the objectives of the problem or consider all actors, objectives, and the outcome.
3. Identify the criteria influencing the behavior.
4. Structure the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria, and alternatives.
5. Compare each element in the corresponding level and calibrate them on the numerical scale. This requires $n(n-1)/2$ comparisons, where n is the number of elements with the considerations that diagonal elements are equal or 1 and the other elements will simply be the reciprocals of the earlier comparisons.
6. Perform calculations to find the maximum eigenvalue and consistency index CI.
7. If the maximum eigenvalue and CI are satisfactory then decision is taken based on the normalized values; otherwise the procedure is repeated till these values lie in a desired range.

We note that pairwise comparisons of the elements in each level are conducted with respect to their relative importance toward their control criterion based on the principle of AHP. Saaty suggested a scale of 1-9 when comparing two components. The score of a_{ij} in the pairwise comparison matrix represents the relative importance of the component in row (i) over the component in column (j), i.e., $a_{ij}=w_i/w_j$. The score of 1 represents equal importance of two components and 9 represents extreme importance of the component i over the component j. The reciprocal value of the expression ($1/a_{ij}$) is used when the component j is more important than the component i. If there are n components to be compared, the matrix A is defined as in (1):

$$A = \begin{bmatrix} 1 & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \cdots & 1 \end{bmatrix} \quad (1)$$

After all the pairwise comparison is completed the priority weight vector (w) is computed as the unique solution of: $Aw= \lambda_{max}w$ where λ_{max} is the largest eigenvalue of matrix A.

As we said, in addition to final preference weights, the AHP permits to calculate the consistency index (Anderson et al., 1994; Saaty, 2000). This index measures preference transitivity for the person doing the pairwise comparisons. To illustrate the meaning of preference transitivity, if a person prefers choice A over B, and B over C, then do they prefer A over C? This index provides a useful check because the AHP method does not inherently prevent the expression of preference intransitivity when ratings are being performed. The AHP consistency index compares a person's informed preference ratings to those generated by a random preference expression process. The consistency index (CI) of the derived weights could then be calculated by Equation (2):

$$CI = \frac{\lambda_{max-n}}{n-1} \quad (2)$$

An arbitrary but generally accepted tolerable level of inconsistent preference scoring with the AHP is less than or equal to 10% of the total number of judgments. Finally, there is an issue of aggregation of individual decisions to form a group consensus decision. Saaty (2000) suggests that there are two possible types of group decision situations: (1) a small group of individuals working closely together with homogeneous preferences or (2) a larger number of individuals, possibly geographically scattered, with non-homogeneous preferences. The former requires a deterministic approach while the latter requires a statistical approach to group synthesis (Saaty, 2000). Definitely, the AHP facilitates multiple criteria weighting in complex choice situations. An advantage of the AHP is that it is capable of providing numerical weights to options where subjective judgments of either quantitative or qualitative alternatives constitute an important part of the decision process. This is often the case with natural resources planning on public lands. Thus, the purpose of this study was to test the AHP as a means of improving public participation in an energy production process.

3 Research Approach and Methodology

The main objective of our work is to develop a participatory decision-making model to use when dealing with key environmental decisions together with local communities and other important stakeholders. To achieve this participatory decision-making model, the following objectives are envisaged:

- Balance the starting knowledge level of all partners.
- Analyze and parameterize conflicts of interest in natural resource management.
- Identify the reference cases.
- Model the decision-making process helping the local communities.
- Model the participation process.
- Improve decision-making procedures.
- Develop proper support for participation, discussion, learning, evaluation, prioritization, communication, traceability, etc.
- Improve the capability of local communities to become a partner when defining natural resource management policies.
- Develop procedures for collective working on line.
- Construct an Analytic Network Model to enhance participatory approaches.

To structure the decision problem we identified and structured objectives which required careful empirical and literature investigations (De Felice and Petrillo, 2010). They provide the basis for quantitative modeling. According to Keeney (1992) we can classify objectives in two types: fundamental objectives and means objectives. The fundamental objectives are the issues or attributes that stakeholders genuinely care about, and means objectives are ways to accomplish the fundamental objectives. Objective hierarchies can be constructed using this classification. For example, ecologically sustainable development could be the fundamental objective and economic, social and environmental objectives could be the means objectives in case of forest decisions. According to these consideration we identified attributes to measure these objectives. Research framework is illustrated in Figure 1.

Here below is the description of the methodological steps:

- **STEP 1. Definition of the problem.** The aim of this step is to identify the environmental problem with the local community.
- **STEP 2. Constructing the AHP model.** The decision-making process will be structured by AHP techniques in respect of social, environmental and economic principles. Problem components as well as tangible/intangible decision variables will be defined and clustered. Relations among components will be defined as well as the definition of the scale of preferences. Problem structuring will be carried out by considering scientific literature as well as judgments of experts and public decision makers.
- **STEP 3: Evaluation of priorities**. The aim of this step is to evaluate priorities among different alternatives.

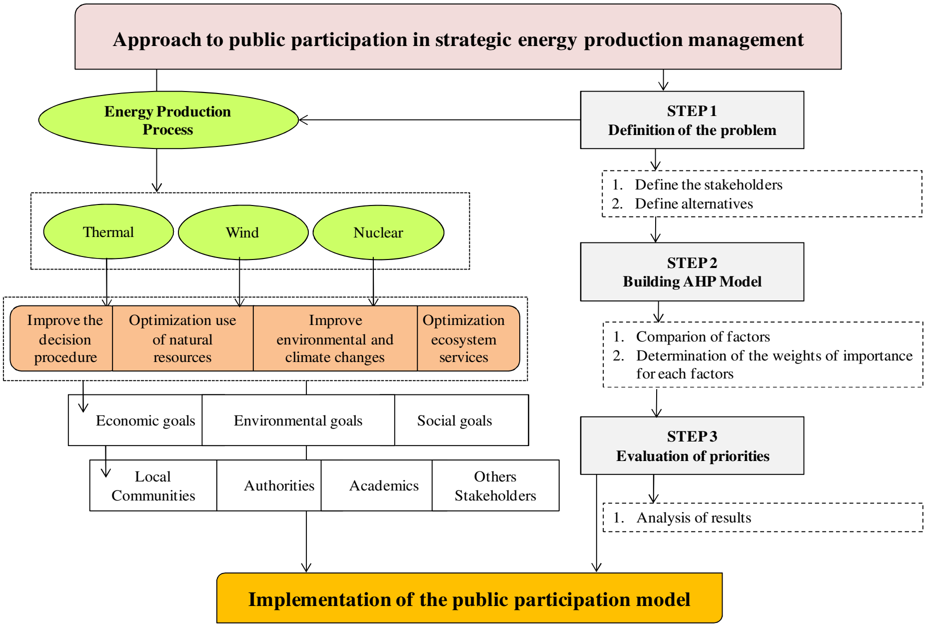

Fig. 1. Research framework

4 Case Study

The objective of this paragraph is to examine through a simple case study the scope and feasibility of our methodology in incorporating stakeholder preferences into energy environmental policies.

4.1 STEP 1. Definition of the Problem

The main objective is to identify a priority schedule within the framework of the global environment and energy policies to assist decision makers in the selection of energy production options. To achieve this aim, an approach based on comparisons of three basic energy production processes: nuclear, renewable energy (wind) and thermal power have been implemented.

4.1.1 Selection of Stakeholders

Identifying or rather selecting stakeholder groups (policy makers, planners, and administrators in government and other organizations is a difficult task. The process of selection has to be open and transparent. We chose a group composed of Industrials, Citizens, Environmentalists, Agriculturists, and Tourism Operators.

4.1.2 Selection of Alternatives

As alternatives we chose three types of energy: electricity production from wind farms, thermal power plants, and nuclear power plants. In Table 1 the alternatives are described.

Table 1. Characterization of Alternatives

Alternatives	Features	Capacity factor	Investment costs (average value)	Operating and maintenance costs/capital %
Nuclear Plants	Public acceptance does not exist due to some uncertainties related to nuclear energy such as economic performance, proliferation of dangerous material, the threat of terrorism, operation safety, and radioactive waste disposal.	60–100%	€3000/kW	50
Thermal Plants	Coal is an essential energy source to generate electricity for thermal power plants. The poor quality of this lignite is responsible for a considerable amount of air pollution.	70–90%	€1300/kW	97
Wind Plants	Wind power as a practical electric power generation is now becoming more prominent among renewable and the other energy options and all researches focused on improving wind energy generation. Wind energy is accepted by public, industries, and politics as a clean, practical, economical, and eco-friendly option.	20–40%,	€1100/kW	25

Other points to be considered include:

- Environmental risks, impacts, and waste-emissions of wind energy production systems can be neglected compared to others, and depend on regional characteristics.
- Nuclear energy is able to compete with other energy sources when the operating cost is less than 210$/kWh year or 2.4cent/kWh (Yildirim and Erkan, 2007).

- Energy policies are restricted by global and international long-term objectives of environmental policies.
- The capacity factor is defined as the ratio of the actual energy produced in a given period to the hypothetical maximum possible capacity (i.e. running full time at rated power).

4.2 STEP 2. Constructing the AHP Model

Developing effective energy policy requires that policy-makers take into account the multiple objectives of multiple stakeholders and their conflicting interests. From this point of view the structure of the proposed AHP Participatory Model is shown in Figure 2.

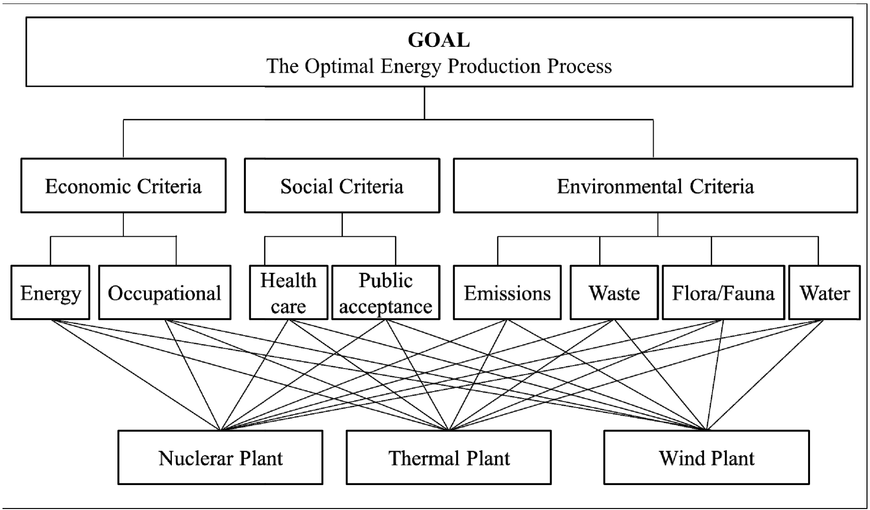

Fig. 2. Proposed AHP Participatory Model

The use of *multicriteria approach* involves developing a decision model comprising decision attributes (criteria), sub-criteria, and alternatives. Criteria and sub-criteria are described in Table 2.

Table 2. Criteria and Sub-criteria

Criteria	Sub-criteria	
Social Goals *Social benefits achieved from the development of sustainability level.*	Health Care	Activities that not ensure safeguard of population
	Public Acceptance	Acceptance of qualitative and quantitative consequences on the environment.
Economic Goals *Processes associated with planning, scheduling, and coordinating activities. The effectiveness in managing assets to support environmental demand satisfaction.*	Energy	Evaluation of total energy production.
	Occupational	Activities can build value through new jobs.
Environmental Goals *Activities can build value through sustainable methods.*	Emissions	The evaluation and implementation of actions to reduce environmental impacts.
	Waste	The needs to reduce waste due to energy production.
	Flora/Fauna	Evaluation of actions helps to maintain biodiversity and reduce environmental damage.
	Water	The need to satisfy the requirements for water preservation.

In Table 3 a scenario with key relationships of AHP factors is shown.

Table 3. Relation between Sub-criteria and Alternatives

Sub Criteria	Nuclear	Wind	Thermal
Health Care	High risks	No risks	Low risks
Public Acceptance	High resistance	Low resistance	Medium resistance
Energy	High production	Low production	Medium production
Occupational	High value	Medium value	Medium value
Emissions	Radiation	Noise	CO2, NO_x, SO_2, HM, HW, and fly ash
Waste	High. Radioactive waste. Difficult and expensive disposal and storage	No waste	Medium
Flora/Fauna	Bad preservation	High preservation	Bad preservation
Water	Bad	Good	Bad

4.2.1 Comparison of Factors

Since the problem has been structured as a hierarchy, the relations between elements in succeeding levels are obtained by making pairwise comparisons.

4.2.2 Determination of the Weights of Importance for Each Factor

The weights of the decision objectives from the stakeholder group's point of view and that represent the results of our model are presented in Table 4.

Table 4. Weights of decision objectives

Criteria	Sub Criteria	Nuclear	Wind	Thermal	Consistency Index (CI)
Social	Health Care	0,157	0,593	0,249	0,051
	Public Acceptance	0,155	0,519	0,326	0
Economic	Energy	0,686	0,126	0,186	0,09
	Occupational	0,593	0,157	0,249	0,051
Environmetal	Emissions	0,117	0,614	0,268	0,07
	Waste	0,09	0,279	0,626	0,082
	Flora/Fauna	0,121	0,558	0,319	0,0175
	Water	0,131	0,66	0,208	0,051

4.3 STEP 3: Evaluation of Priorities

The global priorities can be calculated on the basis of: 1) the weighting scheme for the stakeholder groups; 2) the importance of objectives from the point of view of the stakeholder groups; 3) the relative priorities of decision alternatives with respect to the objectives. Final results, the following score; 1) Nuclear 0.190; 2) Wind 0.271; 3) Thermal 0.537.

4.3.1 Analysis of Results

We can note that nuclear power has a higher priority of economic goal because of its high capacity factor, efficiency and ever ready generating electricity. Social and environmental goals have lower priority numbers than the thermal plant and wind plant. The thermal plant has the lowest priority from social goals because of huge amounts of waste and high air pollution profiles related with climate changes and global warming. Environmental and social factors make wind power the leader in the public eye as it has negligible negative impacts on the environment and on human health. Public acceptance of social factors, which is the reason for the lowest priority number for nuclear power, is the main indicator on decision-making. Figure 3 shows the results of sensitivity analysis of economic goal. The vertical dotted line is initially set at 0.5 on the X-Axis for the priority of the Goal (left figure). The respective priorities of the alternatives is indicated by the Y-Axis values where their lines intersect the vertical line: Nuclear is 0.393, Thermal is 0.242, and Wind is 0.365. Grab the vertical line with and move it to the right to see that there is a crossing point around 80% (0.80) after which the Nuclear is again the best choice. Sensitivity can be done for the other criteria. The sensitivity analysis shows how the alternatives were prioritized relative to other alternatives with respect to each objective as well as overall objective.

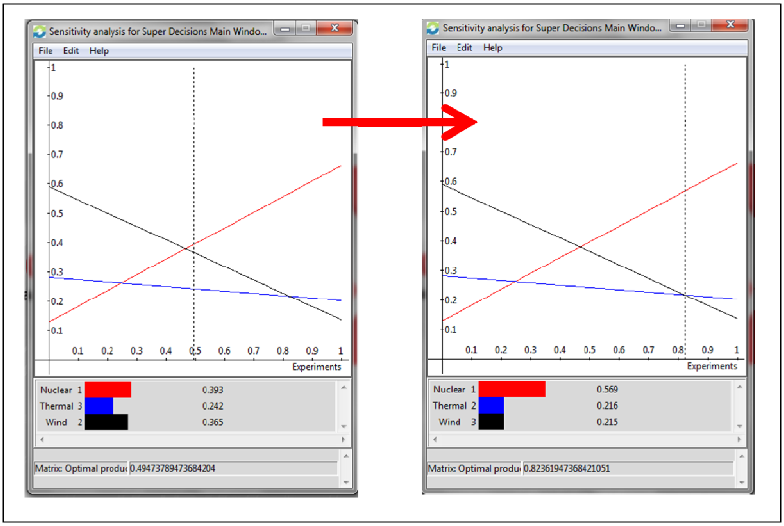

Fig. 3. Sensitivity analysis

5 Conclusions

Quantifying stakeholder preferences in environmental management is a complex task. From this point of view the methodologies of public participation can be judiciously selected and modified to promote equity. The most critical aspect of promoting equity through participation is the extent to which public preferences are incorporated in policy decisions which govern environmental quality. Limited incorporation reduces participation programs to an inconsequential democratic drama. In this context, the objective of this paper was to propose a multicriteria methodological approach based on the Analytic Hierarchy Process methodology (AHP) in order to examine the scope and feasibility of a modeling process integrated with public participation for environmental assessment. AHP allows for participation of more than one person as a decision maker, which is important in dealing with several stakeholder groups. Another advantage of the AHP is the ability to include many decision makers in an electronic meeting environment. Therefore, we decided to use the AHP in this study for the following reasons: (1) the AHP is a structured decision quantitative process which can be documented and replicated, (2) it is applicable to decision situations involving multi-criteria, (3) it is applicable to decision situations involving subjective judgment, (4) it uses both qualitative and quantitative data, (5) it provides measures of consistency of preference, (6) there is ample documentation of AHP applications in academic literature, (7) the AHP is suitable for group decision-making.

The results of this study could:

- Provide valuable information regarding decision-making tools for strategic environmental management.
- Facilitate discussions on the environmental matter;
- Increase public awareness of environmental/social/economic effects of alternatives;
- Spread environmental information;
- Increase e-participation (e-Democracy) of people in the decision-making process to achieve public awareness consensus;
- Point out decision makers and procedures of decision processes.

The end result of the model is a measure of the decision maker's relative preference of one attribute over another attribute. It is concluded that the model is an effective way to improve participatory decision-making in complex decision situations and to clarify public preferences more rigorously. The application presented here has some limitations therefore future research should focus on: (1) integrating AHP model with benefits, opportunities, costs, and risks analysis; (2) improving cooperation between the respondent and the analyst; (3) designing innovative and user-friendly questioning protocols; (4) developing full-scale case studies.

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