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Improving the Framework for Energy Policy to Harness Renewable Energy Resources for Sustainable Development in Developing Countries

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Energy usage has been rising around the globe as a result of economic growth in the last decade. The selection of acceptable Renewable Energy Sources (RES) for energy supply and the evaluation of different RES technologies are complicated decision-making processes in sustainable energy planning. However, finding alternative energy supplies is difficult owing to limited nonrenewable resources such as oil, gas, and coal. Furthermore, past studies employed multi-criteria decision-making (MCDM) procedures, which were effective with quantitative data but not qualitative data. This paper provides a systematic decision support framework for policymakers based on multi-criteria decision making by combining Benefit, Opportunity, Cost, and Risk (BOCR) model with the Analytic Network Process (ANP). Since fossil fuel prices are not constant and continue to rise, the governments in developing countries must develop an energy mix based on various resources other than conventional fuels. More efficiently harnessed local and sustainable energy alternatives may help solve climatic and economic problems in fossil-fuel-producing nations. However, it would require adjustments to national energy policy to properly include renewable energy alternatives in energy planning. This proposed study will underwrite significantly to understand better a systematic decision support system using MCDM. In addition, this study can also succour the government in planning and assisting the government and policymakers in selecting the adequate RES supply for the country.

1. Introduction

Energy planning and decision-making problems are solved using various technological, financial, environmental, psychological, and social standards, such as examining energy tasks, choosing between energy alternatives, nuclear power plant site options, and creating an energy strategy. Most developing countries worldwide are at a crossroads in transitioning from coal as a cheaper energy source to cleaner energy options to eventually transition to a carbon-free growth path. The Intended Nationally Determined Contribution (INDC) to Carbon Emissions was proposed in the COP21 Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC) in 2015 when different countries indicated their intended contributions to carbon emission reduction. During the 1970s, most energy planning choices used energy models to understand the energy-economy linkages. However, as environmental concerns grew increasingly prominent in the 1980s, energy planning decision-making was modified to incorporate environmental awareness. The Life Cycle Cost Analysis (LCCA) investigates and compares the total environmental footprint and the number of hazardous gases produced by various energy sources, including RES.
Various criteria, such as technical, economic, environmental, and social factors, complicate the solution to the issue. There is a need to fulfil a method to decrease the complexity of sustainable energy planning is required since many criteria must. Therefore, there is a need for green energy sources evaluation techniques with MCDM approaches, which is quite apparent for optimal evaluation. Multiple (conflicting) criteria: a quality measure is another criterion that contradicts the cost in public policy decision making. Uncertainty is essential to long-term energy policy analysis, especially for countries that export energy and want to keep making money. The issue includes selecting between primary and secondary energy sources, the amount of power they produce, the

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interests of the people who use them, and how it affects the environment. Alipour et al. (2018) did a study that went beyond looking at energy sources for export. They looked at a policy framework unaffected by uncertainty and internal/external pressures.
Even though there is an existing framework for energy policy and decision making to harness the RES for sustainable development, there is still a lack of a comprehensive framework that aids the stakeholders in making better decisions. Thus, this work aims to provide a systematic decision support framework for policymakers based on multi-criteria decision making by combining the Benefit, Opportunity, Cost, and Risk (BOCR) model with the Analytic Network Process (ANP). This proposed study will underwrite significantly to understand better a systematic decision support system using multi-criteria decision making. In addition, this study can also succor the government in planning and assisting the government and policymakers in selecting the adequate RES supply for the country.
The rest of the paper is structured as follows. In the following section, the background theory of MCDM is outlined. Next, the methodology of ANP and BOCR is discussed. The ANP and BOCR Hybrid Model Framework are outlined next, which is then followed by limitations and barriers in utilising ANP-BOCR Framework for sustainable development before the work is finally concluded.

2. Background

Multicriteria analysis is a sub-discipline of operational research that refers to any systematic method of establishing overall preferences among different solutions that fulfil several objectives. It has often been used in government to evaluate objectives that are not simply monetary (Popiolek and Thais, 2016). For example, in planning and managing renewable energy, MCDM approaches it in a way that is good for the environment and helps solve problems like conflicting criteria and many different goals when making decisions about energy planning. There are other ways to look at things, like the Analytic Hierarchical Process (AHP) and the Simple Multi-Attribute Rating Technique (SMART). Modern stakeholders carry out initiatives in a fast-paced environment (Lehtinen et al., 2019). Multicriteria optimisation approaches may be practical in discovering optimal solutions. In this case, weighting, criteria selection, aggregation and decision assessment are the four steps of MCDM. Depending on the goal and characterisation of the problem, each step might use a variety of approaches. Alternative approaches include hybrid ANP-DEMATEL (Decision Making Trial and Evaluation Laboratory) and AHP. The weighting of the criteria in MCDM might impact the outcome.
Policymakers are persons, groups of people, experts, stakeholders, organisations, and administrative authorities who, directly or indirectly, affect the decision-making process by their preferences or judgements (Georgopoulou et al., 1997). In conducting sustainable energy planning, policymakers should be involved throughout the process. However, Strantzali and Aravossis (2016) find that during the evaluation process of a group discussion, most participants' priorities are at odds with each other. Another thing to remember about their preferences is that they express them in higher-level descriptors, which are more qualitative (Sarabando and Dias, 2010). Regarding sustainable energy planning, policymakers' criteria preferences are categorical into two separate areas: one consists of the preferences that policymakers have regarding criteria and the other consists of the preferences that policymakers have regarding alternatives. Many preferences from several perspectives are evaluated; they may be expressed as weights, which reflect the relative importance of the criteria associated with a choice's objective. For instance, private investors may be more concerned with profitability and are thus more focused on economic criteria than other standards. Likewise, concerns about the local environment might lead people to believe that environmental concerns are more significant than other concerns. The facts for each alternative when it comes to each criterion may be hard to get, making addressing any decision-making challenge more complex. According to Kumar and Samuel (2017), MCDM approaches are very relevant in today's sustainable energy management and policy making. Because of this, policymakers and government officials must have a solid understanding of sustainable energy planning to participate in the review process. Even more, by using MCDM, all the conflicting criteria and numerous goals in energy planning choices can be solved.

3. Methodology

Adopting the ANP technique in this study is best to determine the best possible policy for renewable energy planning since resolving interdependence among decision-making criteria is the most crucial aspect of the research purpose. Subsequently, the BOCR is used to evaluate the energy situation and the criteria for evaluating renewable energies in developing countries. Then, ANP analysis is to rank various types of RES depending on the given criteria.

3.1 Analytic network process method

Saaty (2004) proposed ANP, a variant of AHP that uses a network structure rather than a hierarchy to allow for reliance and feedback. AHP calculates priority scales without assuming element connections (Saaty, 1980). ANP addresses the interaction and interdependence of elements (clusters and nodes within a cluster) inside a network of criteria. Several examples demonstrate that the ANP has solid predictive content. In a pairwise comparison with a third element/underlying control criterion, for example, the judgement indicates the relative relevance or influence of one of two elements over the other. ANP considers all feedback and interactions between choice criteria, making it harder to solve complicated decision issues than hierarchical techniques (Saaty, 2004).

3.2 Benefits, opportunities, costs, risks analysis (BOCR) method

It might be difficult to define criteria and sub-criteria for new cases when employing the ANP technique. Therefore Tchangani (2015) suggest using BOCR and Strength-Weakness-Opportunity and Threat (SWOT) technique to solve the concerns. A decision maker's aims and objectives are the primary focus of these analyses. Although ANP enables the assessment of effect and reliance, decision-makers may not always fully comprehend it. The benefits criterion in the BOCR analysis technique relates to current income or profits obtained from increased renewable energy consumption. The opportunity criterion is the anticipation of favourable spin-offs, future earnings, or increased renewable energy consumption revenue. The risk criteria relate to the predicted repercussions of expanding renewable energy usage, whereas the cost criterion refers to existing losses and negative development. The BOCR provides a potentially extensive examination of the alternatives by considering these four major components. Alternatives are evaluated from most excellent (best) to lowest (worst) value under two criteria in the BOCR analysis: Benefits and Opportunity. The highest-valued option is the worst on the list regarding the Cost and Risk criterion (Wijnmalen, 2007).

4. The ANP-BOCR Model Framework

There are fundamental seven significant steps in the proposed research. This approach's general conceptual structure is shown in Figure 1. Next, this strategy is used to prioritise RES and develop policies that maximise the social and economic advantages of the research country.

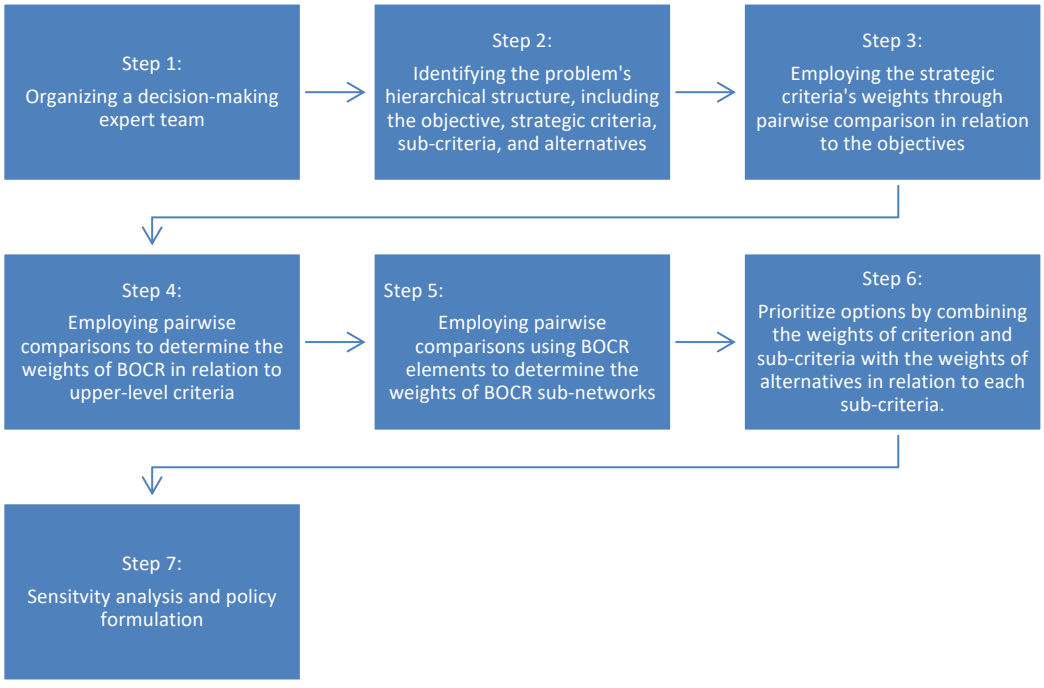

Figure 1: Conceptual framework of the proposed decision-making process

4.1 Organising a decision-making expert team (Step 1)

The expert panel will include academic fellows, industry representatives, and the government institution panelist. Diverse fields such as economics and management, energy systems, environmental engineering, science and technology policy, and technological foresight are among the areas of competence.

4.2 Identifying the hierarchical structure problem (Step 2)

The primary purpose of this study is to prioritise RES selection using the ANP-BOCR hierarchy structure. For each BOCR subcriteria, five criteria are utilised to analyse the problem's purpose, including technology, economy, security, global effect, and human well-being (HW) (Kabak and Dadeviren, 2014). Figure 2 shows the relationship between criterion, BOCR sub-criteria, and subnetwork. One-way arrows represent a one-way dependency between two levels, while the curved arrow above the BOCR subnetwork demonstrates feedback inside the sub-criteria cluster network. Subnetwork benefits include using native resources, protecting the environment, developing related businesses, and implementing international obligations like UNFCCC and Kyoto Protocol (Alizadeh et al., 2020). Subnetwork prospects include creating green jobs and reducing energy prices. Investment, operation, maintenance, land usage, and environmental harm are subnetwork expenses. The hazards subnetwork comprises foreign technology dependence, lack of a financial mechanism to develop RE, insufficient technological infrastructures, unstable energy resources, lack of public knowledge of RE, and commercial failure. Each subnetwork links hydro, geothermal, solar, wind, and biomass.
HW criteria are crucial to sustainable development (Anand and Sen, 2000). Renewable energy deployment promotes economic growth by expanding business options and boosting living standards. It also improves air quality and reduces climatic impacts (Kabak and Dadeviren, 2014). Energy security is the ability of a system to keep running even when there are significant changes in supply or price. Renewable energy technologies increase energy supply and distribution, making energy more secure. Unfortunately, RES rely on technologies that are hard to understand. Here, the BOCR criteria are used to plan energy and climate policy at a high level.

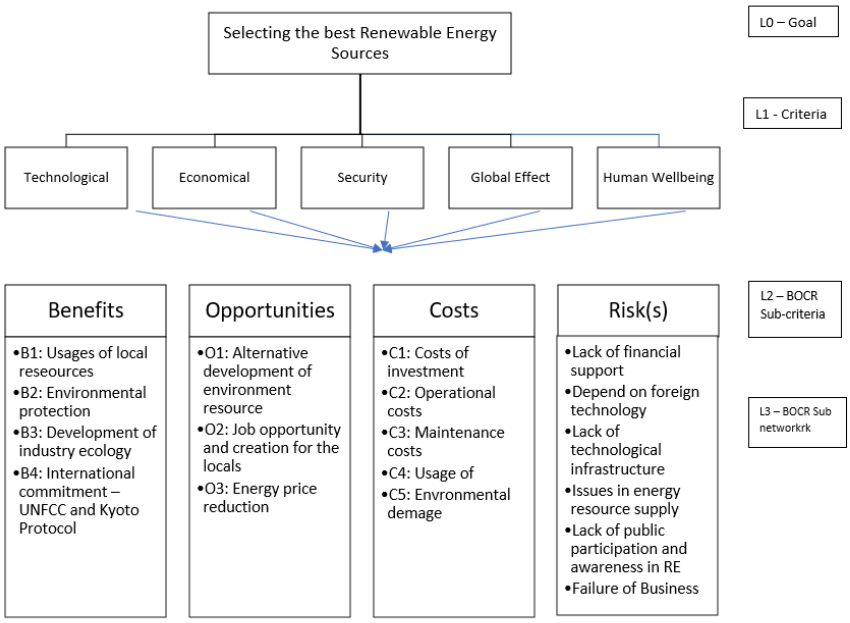

Figure 2: The hierarchical structure of ANP-BOCR

4.3 Employing the strategic criteria's weights through pairwise comparison in relation to the objectives (Step 3)

The inconsistency rate (IR) for each comparison table is calculated using the super decision programme (Saaty, 1996). Finally, the weights of the strategic criteria are derived using the geometric average and a pairwise comparison matrix.

4.4 Employing pairwise comparisons to determine the weights of BOCR in relation to upper-level criteria (Step 4)

The weights of the four aspects of the BOCR were assessed by an expert team who used linguistic factors suggested by Cheng (1997) to compare the mutual significance of the elements. Next, the weights of each component are determined using an arithmetic average once the values for the linguistic judgements have been assigned. Finally, multiply the value of each factor by the weight of strategic criteria to get the final weight of the components.

4.5 Employing pairwise comparisons using BOCR elements to determine the weights of BOCR sub-networks (Step 5)

A pairwise comparison matrix produced by the expert team determines the weights of the BOCR sub-network. Next, the 'supermatrix' of relative weights is created by taking a geometric average of the comparison findings. Finally, the super decision software determines the weights of each item in the sub-network (Saaty,1996).

4.6 Prioritise options by combining the weights of criterion and sub-criteria with the weights of alternatives in relation to each sub-criteria (Step 6)

In the final step, a pairwise comparison determines the options' priority concerning each factor in the BOCR sub-network. The Consistency Ratio (CR) (Goto et al., 2008) measures the consistency of subjective inputs in a pairwise comparison matrix. In AHP and ANP techniques, much effort has been made to develop a standard CR metric (Mazurek and Perzina, 2017). According to the literature, allowable CR should be less than or equal to a threshold, which varies depending on the size of the compression matrix and the pairwise comparison procedure (individual or group judgments).

4.7 Sensitivity analysis and policy formulation (Step 7)

Sensitivity analysis aids in the comprehension of many circumstances and their implications for the ultimate choice. In MCDM, sensitivity analysis is used to see how changes in the weights of the criteria and scoring impact the overall ranking of the options (Chatzimouratidis and Pilavachi, 2008). The antagonistic additive prioritising approach in the BOCR sensitivity study is proposed (multiplicative formula).

5. Limitations and barriers to utilising ANP-BOCR Framework for sustainable development

Numerous theoretical methodologies and approaches have been introduced for decision making in the literature. Each technique contains assumptions, benefits, limits, and hypotheses that decision-makers and analysts must weigh (Topcu and Ulengin, 2004). There are several limitations and barriers to utilising ANP-BOCR Framework in energy planning. Horschig and Thrän (2017) reported the drawbacks of bottom-up and top-down energy and climate policy models. According to Horschig and Thrän (2017), bottom-up and top-down energy and climate models are interchangeable. Bottom-up modelling focuses only on the energy sector, whereas top-down modelling focuses on the energy sector's relationship with the economy. Therefore, they are ideal for technological laws, such as efficiency criteria. Bottom-up models, however, have significant faults (Horschig and Thrän, 2017). The biggest problem is the mathematical programming, which implements tax distortions or market failures (Böhringer and Rutherford, 2009). Due to the limitations of bottom-up and top-down models, hybrid modelling progresses significantly. Hybrid modelling techniques require macroeconomic, engineering, and numerical calibration (Sue Wing, 2008).

Evaluating has become more time-consuming as more criteria and prospects have been added. Different methods come up with different answers and take different approaches to include strong or sensitive criteria. Since no historical patterns exist for any area or the whole world, the treatment is much less specific when environmental indicators are involved. Most criteria have weights based on historical data or current surveys, but these things change over time and must be updated. Taking these changes into account is another essential part of decision analysis. Experts, people from the community being served, government organisations, and non-governmental organisations (NGOs) must be involved in choosing the key indices and criteria for energy projects. Also, evaluating many criteria and figuring out their relative weights is highly complex.

6. Conclusions

Countries whose economies depend a lot on fossil fuel production will need to diversify their energy production by using more renewable energy. Nevertheless, these countries have many problems, including rising energy use, high energy intensity, pollution, and economic and political problems. In the end, the proposed concept or idea is a great way to set up a model that can be used to help a country make essential energy policy decisions.

The proposed concept/idea ultimately provides excellent benefits of establishing a model that can help a country make strategic energy policy decisions.

This paper proposed a hybrid MCDM technique for energy planning and policy-making in developing nations. Using the BOCR approach, prospective advantages and opportunities and likely costs and hazards of future RES may be identified. Another advantage of the suggested paradigm is that it allows diverse specialists to participate, enhancing decision-making efficacy. Many decision-makers frequently prefer reducing prejudice and decreasing partiality in the decision-making process. The ANP-part technique allows for simultaneous examination of quantitative and qualitative factors through the decision-making process. The interdependencies of alternate RES are also examined, as well as the BOCR requirements. Traditionally, previously employed ranking systems could not consider the two last-mentioned factors. Finally, utilise the information gained from studying these relationships to determine the weights for the criterion.

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