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MULTI INDICATORSDECISION MAKING IN PRIORITIZATION OF THE INDICATORS FOR HYDROPOWER SECTOR SEA IN LAO PDR USING FUZZY AHP: PREPARING FOR FUTURE SEA FOR HYDROPOWER SECTOR IN LAO PDR

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ABSTRACT

Studying of performance indicators for Strategic Environment Assessment (SEA) of hydropower projects in Lao People's Democratic Republic (Lao PDR) is quite lack of information. To be ready in advance for future SEA implementation particularly for Hydropower Sector is urgently necessary for government technical staffs, especially for technical staffs of Ministry of Natural Resources and Environment to Lao PDR (MoNRE). This paper focuses on indicating and ranking Indicators which will be set in SEA for Hydropower Sector respectively. **13** technical staffs form Department of Environmental and Social Impact Assessment (DESIA), MoNRE are interviewed to give weighting for each Indicators for pairwise comparison in order to achieve goal of finding the most suitable performance indicators for SEA in hydropower sector. Fuzzy AHP is used to indicate and rank these performance indicators. The research finding shall encourage the government technical staffs, especially technical staffs of MoNRE to be ready in advanced the future SEA implementation in Lao PDR as well as having preliminary data to propose decision makers well-timed. Also, it shall contribute to strategic-related research using particular Multi IndicatorsDecision Making (MCDM) or Fuzzy AHP.

KeyWords

Performance indicators, Strategic Environmental Assessment: SEA, Fuzzy Analytic Hierarchy Process: Fuzzy AHP, Environmental Impact Assessment: EIA, Analytic Hierarchy Process: AHP, Hydropower, Multi IndicatorsDecision Making.

INTRODUCTION

IN Lao PDR, SEA is not directly becomes a legal requirement to Strategy, Policy and Program (hereafter called SPP) approval process for line ministries. In Mekong mainstream, SEA seeks to identify the potential opportunities and risks, as well as contribution of these proposed projects to regional development, by assessing alternative mainstream Mekong hydropower development strategies. As its particular role, SEA has different scale and scope of its impact i.e. SEA scale of impact is at regional and national level, while SEA scope of impact mostly focuses at sustainable development and socioeconomic development matters.

In particular the SEA focuses on regional distribution of costs and benefits regarding economic development, social equity and environmental protection. As such, the SEA supports the wider Basin Development Planning (BDP) process by complementing the MRC BDP assessment of basin-wide development scenarios with more in-depth analysis of power related and cross-sector development opportunities and risks of the proposed mainstream projects in the lower Basin [1]. An overview of SEA in the Greater Mekong Subregion (GMS) [2], during the past decade, the value of SEA has gained recognition in the GMS, reflected by supportive legal frameworks and its emerging use in development policy and planning processes. Thailand has begun drafting SEA legislation. Both Cambodia and Myanmar have recently shown interest in developing a legal basis for SEA. In the countries without a legal basis established, SEA has mainly been applied as capacity-building pilot exercises.

Some key different between Environmental Impact Assessment (IEA) and SEA, EIA driven approaches capture for single project and multiple projects, while SEA driven approaches capture for single sector and multiple sectors [3] i.e. hydropower project and cascade dam of hydropower project in northern part of Lao PDR.

Barry Dalal-Clayton and Barry Sadler, 1999 [4] studied rapidly evolving approach-SEA and some of key finding regarding Scope of SEA. Most practitioners view SEA as a decision-aiding rather than a decision-making process (like EIA) - a tool for forward planning to be flexibly applied at various stages of the policy-making cycle. Under this broad perspective, SEA encompasses assessments of both broad policy initiatives and more concrete programmes and plans that have physical and spatial references (e.g. town and regional plans, regional development programmes). With this scope of coverage one problem becomes readily apparent. The methodologies to be applied at the opposite ends of the decision-making spectrum differ markedly. However, the principles of EIA apply at all levels. Wei Li, Yuanbo Xie and Fanghua Hao, 2014 [5] researched Applying an improved rapid impact assessment matrix method to strategic environmental assessment of urban planning in China via four categories: physical and chemical (PC), biological and ecological (BE), sociological and cultural (SC) and economical and operational (EO). They also used the Analytic Hierarchy Process (AHP) methodology that has been utilized in a wide range of decision making areas, provides a viable and rigorous procedure for determining such weights for these categories.

Jenni Neste and Timo P. Karjalainen, 2013 [6] reviewed literatures with respected to the use of multi- Indicatorsdecision analysis in Environmental Impact Assessment. Some key finding is about setting Indicators where Multi- Indicators techniques could be particularly useful in situations where there are a large number of alternative sites for a development, where there a large number of potential Indicators to be taken into consideration or where subjective judgments by different stakeholders of the different alternatives (i.e. people from ministry of agriculture and forestry brainstorm to irrigation projects) is needed to try to reach an objective consensus in the final decision-making process or to make these processes more open and accountable. They also considered about further research needs. There is a great need for innovative approaches and real-life examples how MCDA can be used to support SEA for multi sectors SEA particularly energy sector.

Some key EIA fundamental principle is that it combines multi-dimensional process, which regulation and implementation varies in different national legislations. In Lao PDR, EIA become legal requirement for investment project approval process. It was defined that the Project Developer shall apply the List of Investment Projects and Activities as the reference for the screening process to determine whether its proposed investment project and activities categorized into 2 groups namely: Group 1 which should conduct an Initial Environmental Examination Process and Group 2 which should conduct an Environmental and Social Impact Assessment Process [7]. It involves the identification, prediction and evaluation of impacts arising as a consequence of decisions, and these impacts may be multidimensional in nature (Balasubramaniam & Voulvoulis, 2005). AHP helps to elicit the complex judgments of different experts in a common platform (Ramanathan, 2001).

Literature Review

Fuzzy Analytical Hierarchy Process

Fuzzy AHP is used to determine the preference weights of evaluation [17]. This research employs fuzzy AHP to fuzzify hierarchical analysis (see figure 1) by allowing fuzzy numbers for the pairwise comparisons and find the fuzzy preference weights. The Triangular Fuzzy Number of Linguistic Variables used in this study could be shown as below table 1.

Table 1. Triangular Fuzzy Number of Linguistic Variables used in this study.

Linguistic term	Triangular fuzzy numbers	Reciprocal triangular fuzzy numbers
Extremely strong	(9,9,9)	(1/9,1/9,1/9)
Very strong	(6,7,8)	(1/8,1/7,1/6)
Strong	(4,5,6)	(1/6,1/5,1/4)
Moderately strong	(2,3,4)	(1/4,1/3,1/2)
Equally strong	(1,1,1)	(1,1,1)
Intermediate	(7,8,9)	(1/9,1/8,1/7)
	(5,6,7)	(1/7,1/6,1/5)
	(3,4,5)	(1/5,1/4,1/3)
	(1,2,3)	(1/3,1/2,1/1)

Source: (E. H. Ibrahim et al. and author).

The stages in the Fuzzy AHP method are as follows:

Step 1: decision maker compare the Indicators or alternative via linguistic term.

Step 2: according to averaged preferences, pairwise contribution matrix is **updated.** Note that if there is more than one decision maker, their all preference is average.

Step 3: according to Buckley [17], the **Geometric Mean** of fuzzy comparison value of each criterion is calculated.

$$r_i^- = \left(d_{i1}^- \otimes d_{i2}^- \otimes d_{i3}^- \otimes d_{i4}^- \right)^{1/n}, i = 1, 2, \ldots n \tag{1}$$

Step 4: find the fuzzy weight of each criteria

$$w_i^- = r_i^- \left(r_1^- \otimes r_2^- \otimes r_3^- \otimes r_4^- \right)^{-1}, i = 1, 2, \ldots n \tag{2}$$

Step 5: defuzzy by center of area.

$$M_i = \left(lw_i + mw_i + uw_i \right) / 3 \tag{3}$$

Step 6: M_i is Non-fuzzy number, but it need to be normalized.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \tag{4}$$

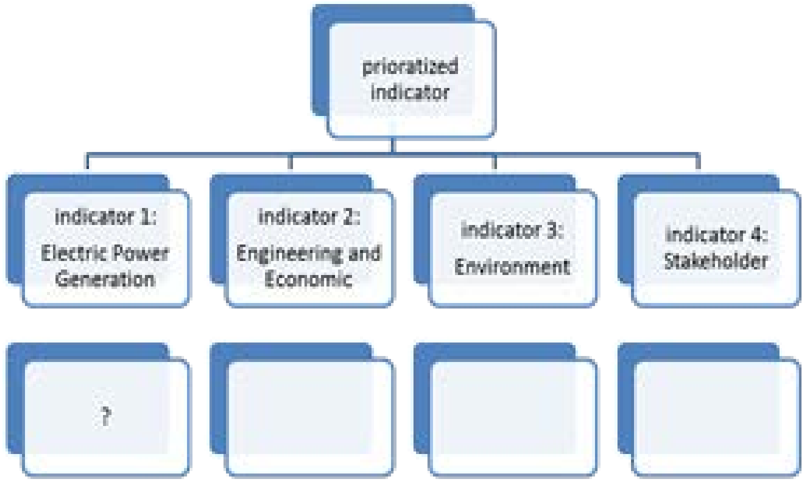

Figure 1. Fuzzy Analytical Hierarchy Process to find the most performance indicator.

Priyabrata Adhikary et al.,[8] studied Selection of Hydro-Turbine Blade Material: Application of Fuzzy Logic (MCDA), the research finding is that from the very approximate data, the model is capable of generating reasonably accurate result. Their multi Indicators decision analysis or fuzzy logic based computational approach to material science and engineering has the potential of making material science and engineering process more effective and efficient. This will, in effect, facilitates an appropriate management of human efforts as well as natural engineering or commercial materials and resources, particularly those that are susceptible to depletion.

Hosseini, S. et al., 2015 [9] fore sighted and estimated the risk of investing in the construction of power plants using AHP. He used 11 Indicators namely: (i) Geographical location: influences of climate and weather conditions, (ii) Technical: having technical science, complexity of the technology used to obtain power quality, (iii) Economic: availability of fuel, fuel prices, the total cost of materials equipment and setup as well as maintenance and ground, (iv) Time: time to build, time start up or coming into orbit, useful life, (v) Administrative: office personnel to build, repair and maintenance, (vi) Environment: soil pollution, water, air, audio etc, (vii) Social and cultural rights: a positive impact on productivity, (viii) Political: sanctions and the arrival of new technologies, (ix) Cultural and natural heritage: damage, the area of land required, (x) Structural architecture: design art, (xi) The tourism: a positive impact on an attraction. Due to time constrain, various criteria may not suitable for small research. Some situation needs only mandatorily–related Indicators such as environmental Indicators for environmental obligations implementation. It also could save time and money in doing efficient research.

Thomas L. Saaty, 2001 [10] studied Decision-Making with the AHP: Why is The Principal Eigenvector Necessary research finding shown that the principal eigenvector of a matrix is a necessary representation of the priorities derived from a positive reciprocal pairwise comparison consistent or near consistent matrix. A positive reciprocal n by n consistent matrix W = (w_{ij}) satisfies the relation $w_{ik} = w_{ij} \; w_{jk}$..

Research finding of “Decision-making with the AHP: Why is the principal eigenvector necessary” shown that if inconsistency is allowed in a positive reciprocal pairwise comparison matrix (which we have shown it must), the principal eigenvector is necessary for representing the priorities associated with that matrix, providing that the inconsistency is less than or equal to a desired value [11]. he also mentioned three ways and illustrated two of them, as to how to improve the consistency of judgments and transform an inconsistent matrix to a near consistent one [12].

However, although this research focuses on AHP method, some desired Fuzzy Analytic Hierarchy Process (FAHP) literatures also reviewed.

Pin-Yu Chu et al. [13], applied fuzzy AHP to integrating decisions of members in the technical committee using 4 Indicators mainly: (i) Scientific & Technological merit, (ii) project execution. The results indicate that scientific & technology merit criterion (0.389) is most important considered in overall technical committees. Besides that, the project execution (0.260) is more important criteria than potential benefits (0.204). In addition, the paper reveals results: (1) the fuzzy AHP is an appropriate method in multi-criteria R&D projects selection; (2) the crisp judgment matrix is suitable to integrate subject judgments of technical committee.

Oliver Meixner, [14] studied fuzzy AHP and group decision analysis and its application for the evaluation of energy sources of energy via 5 Indicators namely (i) Cost: price of a certain energy source, estimated as Euros per kWh (production cost of electricity), (ii) Availability of an energy source: for some energy sources (like wind or solar energy) we have to consider reduced availability depending on climatic and geographic conditions. Other energy sources are more or less available continuously (like coal or natural gas), (iii) Climate: environmental impacts of energy sources operationalized via CO2-equivalents per kWh, (iv) Degree of dependency: dependency of a nation on foreign deliverers; via this criterion we tried to include the possible lack of different raw materials within a coun-

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try, which are necessary for energy production, e.g. crude oil, natural gas or coal and (v) Utilizability: refers to the fields of application of a specific energy source; mainly connected with the question of centralized vs. decentralized energy production. Therefore, author decided to use the geometric mean also for lower bound l_{ij} and upper bound u_{ij} which delivers satisfying fuzzy group weightings. Geometric mean operations are commonly used within the application of the AHP for aggregating group decisions (Davis, 1994, 52).

Yu-Cheng Tang, 2011 [15] researched an Application of the FAHP to the lead-free equipment selection decision with seven Indicators mainly: (1) Acquisition cost of equipment and parts , (ii) Compatibility, (iii) Response and maintenance time, (iv) Education and training, (v) Equipment size and pollution control. Some of the results of pairwise comparison is that C2 is an important criterion to be considered when DMs make decisions.

Yu-Cheng Tang and Malcolm J. Beynon, 2005 [16] studied an Application and Development of a FAHP within a Capital Investment Study. After discussion with the DM concerning the nature of the application, he decided to restrict the number of Indicators to five areas namely: (i) equipment, (ii) comfort (C1), (iii) safety (C3), (iv) image (C4), and (v) price (C5) respect to five types of cars or five alternatives: (i) Proton Persona (A1), (ii) Honda New Civic (A2), (iii) Vauxhall Merit (A3), (iv) Volkswagen Polo (A4), and (v) Daewoo Lanos (A5). The final results show that the most preferred car is the Honda, then Volkswagen, the Vauxhall, the Daewoo and the Proton which is least preferred car in the Decision Makers' mind. From the comparison between the Indicators found that the first two preferred Indicators out of five Indicators are safety and price. This meant that the DM cares about the cost (car price) and safety more than other criteria. From an author point of view, the more certainty of information the less fuzziness results.

Research Methodology

Research methodologies in our case comprise two stages as follow:

A. Data Collection Technique

The data for this study is obtained by collecting primary and secondary data.

1. Primary data obtained by conducting interviews and questionnaires on existing stakeholders, Community and Government Agencies, particularly 13 technical staffs from DESIA.
2. Secondary data is the data obtained from documents such as SEA reports for multiple sectors such as urban planning, land use planning, hydropower projects, etc.
3. Four Indicators used in this study are Indicators 1 (energy power generation), Indicators 2 (engineering and economic), Indicators 3 (environment) and Indicators 4 stakeholder.

B. Data analysis

This study used Fuzzy AHP analysis.

Results and Discussion

A. Evaluation Indicators

Table 2. Averaged preferences for pairwise contribution.

Indicators	EPG			EnE		
EPG	1.00	1.00	1.00	4.00	5.00	6.00
EnE	0.17	0.20	0.25	1.00	1.00	1.00
Env	0.13	0.14	0.17	0.13	0.14	0.17
Sta	0.11	0.13	0.14	0.14	0.17	0.20

Indicators	Env			Sta		
EPG	6.00	7.00	8.00	7.00	8.00	9.00
EnE	6.00	7.00	8.00	5.00	6.00	7.00
Env	1.00	1.00	1.00	6.00	7.00	8.00
Sta	0.13	0.14	0.17	1.00	1.00	1.00

Table 3. Geometric Mean of fuzzy comparison value of each criterion is calculated.

			L	
EPG	1.00	4.00	6.00	7.00
EnE	0.17	1.00	6.00	5.00
Env	0.13	0.13	1.00	6.00
Sta	0.11	0.14	0.13	1.00

			m	
EPG	1.00	5.00	7.00	8.00
EnE	0.20	1.00	7.00	6.00

Env	0.14	0.14	1.00	7.00
Sta	0.13	0.17	0.14	1.00

			u	
EPG	1.00	6.00	8.00	9.00
EnE	0.25	1.00	8.00	7.00
Env	0.17	0.17	1.00	8.00
Sta	0.14	0.20	0.17	1.00

Table 3 (a). Geometric Mean of fuzzy comparison value of each criterion.

Indicators		ў$_i$	
	l	M	u
EPG	3.60	4.09	4.56
EnE	1.50	1.70	1.93
Env	0.55	0.61	0.69
Sta	0.21	0.23	0.26
ColSUM :	**5.86**	**6.64**	**7.44**
Reverse pow of (-1)	0.17	0.15	0.13
Increasing order	0.13	0.15	0.17

Table 4. Find the fuzzy weight of each criteria.

		w$_i$	
Indicators	l	m	U
EPG	0.484	0.616	0.778
EnE	0.201	0.256	0.330
Env	0.074	0.093	0.117
Sta	0.028	0.035	0.045

Table 5. De-fuzzy by center of area.

Indicators	lwi	mwi	uwi	(lwi+mwi+uwi)	**M$_i$**
EPG	0.484	0.616	0.778	1.88	0.63
EnE	0.201	0.256	0.330	0.79	0.26
Env	0.074	0.093	0.117	0.28	0.09
Sta	0.028	0.035	0.045	0.11	0.04

Table 6. Normalization of Non-Fuzzy Number M$_i$

Indicators	Mi	Ni	ranking
EPG	0.63	0.614	1.000
EnE	0.26	0.258	2.000
Env	0.09	0.093	3.000
Sta	0.04	0.035	4.000

The finding is that the top priority assigned to Indicators 1 (energy power generation) due to energy-related strategy and Indicators 2 (engineering and economic) as per its value of 0.258 second ranked, Indicators 3 (environment) third ranked with a value of 0.093 and the last rank is Indicators 4 stakeholder with lowest overall utility value of 0.035.

Conclusion

The finding is that the top priority assigned to Indicators 1 (energy power generation) due to energy-related strategy and Indicators 2 (engineering and economic) as per its value of 0.258 second ranked, Indicators 3 (environment) third ranked with a value of

0.093 and the last rank is Indicators 4 stakeholder with lowest overall utility value of 0.035.

This research shall contribute to preliminary data for strategic–related research using fuzzy AHP particularly in energy sector SEA in Lao PDR.

The emerged strategic–related research using fuzzy AHP particularly in energy sector SEA in Lao PDR could perceive remarkable benefit from it.

Acknowledgment

This work was done and inspired by lacking of strategic–related research using fuzzy AHP particularly in energy sector SEA in Lao PDR. It was successful because of assistance of 13 technical staff of Department of Environmental and Social Impact Assessment (DESIA), MONRE who has experiences in average period for over 9 years. In addition, DDG of Energy Policy and Planning, Ministry of Energy and Mine also give some implied supervision regarding scientific survey. Finally, without DG and DDG of DESIA this work shall not be done.

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