SESSION: RENEWABLE ENERGY APPLICATIONS

Shashi Bhattarai
Session Organizer
Knowledge Holding International (K-Hint)
Kathmandu, Nepal
E-mail: shashibhattarai@yahoo.com

SESSION ABSTRACT

This session covers four papers, three relating to application of Analytic Hierarchy Process (AHP) in renewable energy sector, mainly hydropower development related issues in Nepal. The fourth paper is about the diffusion of AHP in Nepal, a bibliographic survey covering academic and non-academic application of AHP over the period of ten years (2003-1013).

Various mode of institutional and financing arrangement for hydropower project development is addressed in the first paper with the use of AHP in combination of impact analysis matrix (IAM). The second paper is on AHP application for prioritization of hydropower projects for development based on the scale or the size of the project. The third paper is about the sustainability assessment of rural renewable energy projects. The renewable projects considered for sustainability assessment in the third paper includes micro-hydropower, solar and bio-gas systems implemented in rural Nepal. The fourth paper is prepared to look at two aspects; firstly, to see how AHP diffusion is happening in Nepal secondly to prepare a bibliographic report of AHP application in Nepal for the period of ten years (2003-2013). The AHP diffusion survey is analyzed its application with respect to chronology and sector of application. It is observed that AHP application in Nepal is mainly for application in the area of water and energy related sectors and diffusion of AHP in Nepal is driven both ways, externally as well as internally.

The authors of the session are all working professionals. Two of them are working PhD students in their respective fields. The third author is professional working in the hydropower sector with the electricity authority of government of Nepal. The fourth author and the session organizer is working professional with keen interest in AHP application and academic support, since last 15 years in Nepal.

Keywords: hydropower, scale, mode of development, Impact Analysis Matrix, prioritization, sustainability, renewable energy, multiple criteria analysis, AHP, diffusion, Nepal

MULTICRITERIAN APPROACH FOR EVELUATION OF MODE OF HYDROPOWER DEVELOPMENT IN NEPAL

Lila Nath Bhattarai
Nepal Electricity Authority
Kathmandu, Nepal
E-mail: lilanathb@hotmail.com

ABSTRACT

This study evaluates different mode of institutional arrangement for hydropower development practiced in Nepal. The institutional arrangements practiced in Nepal so far are either public sector undertakings such as government of Nepal (GoN) and Nepal Electricity Authority (NEA) with multilateral/bilateral funding or GoN/NEA funding; national Independent Power Producers (IPPs) such as national private & national public company and international IPPs through foreign direct Investment. The resource criteria identified to examine the mode of the hydropower development are Technical, Cost and Schedule, Capacity Building, National Hydropower Industries, Environmental and Social, NEA's and National perspectives. Analytical Hierarchy Process (AHP) in combination with Impact Analysis Matrix (IAM) is utilized in the study. AHP was focused to get weights of different criteria and sub-criteria/attributes. The information thus generated through AHP and IAM helped to assess the impacts and tradeoffs that exist for various institutional modes of project development alternatives.

The research study result shows that the hydropower development institutional model in Nepal requires more to focus on national perspective including linkages into local economy. It is followed by capacity building and involvement of national hydropower industries. The study recommends giving highest priority to national developer such as private, public and NEA self promoted projects and the projects funded through grant assistance almost in its entirety by the donor(s).

Keywords: Nepal, Mode of hydropower development, AHP, Impact Analysis Matrix.

1. Introduction

The institutional arrangements practiced in Nepal so far for hydropower development are either public sector undertakings such as government of Nepal (GoN) and Nepal Electricity Authority (NEA) with multilateral/bilateral funding or GoN/NEA funding; national Independent Power Producers (IPPs) such as national private & national public company and international IPPs through foreign direct Investment. It is difficult to claim that any specific approach or mode for hydropower development would be the best option in Nepalese context. Furthermore, a single modality could not meet the growing power demand in the country. However, linkages in to the national economy, capacity enhancement of manpower and hydropower industries, technical aspects of project development, project cost and schedule, etc. would be different in different modality of execution. Owing to this Multiple Criteria Decision Making (MCDM) framework is used for prioritization of hydropower development modality practiced in Nepal. It is expected that the planners and decision makers in hydropower development in Nepal would get added insights in the process of hydropower development in the days to come.

2. Literature Review

Number of literature in context of hydropower development in Nepal covering all the aspects dealt in the study is reviewed. In the theoretical aspects Fung et Al. (2000) and Saaty (1986) are the key literature for the study.

3. Objectives

The objective of the research is to evaluate the different modes of hydropower development practiced in Nepal with due consideration of various factors in the decision making process, taking care of their conflicting objectives and prioritization of them for accelerated hydropower development in the country.

4. Research Design/Methodology

The methodological steps followed in applying MCDM in general and AHP in combination with Impact Analysis Matrix (IAM) in particular to examine diversified modes of hydropower development are presented in the following paragraphs.

Respondents: A total of 25 actors generally experts in their respective field consisting of 10 technical and academicians, 5 political and planners, 5 economists and hydropower developers and 5 activists including sociologists and journalist were interviewed with the use of pair wise comparison questionnaire that measures intensity of importance in the AHP subjective judgment in accordance to Saaty (1986). The collected information were first checked for consistency using consistency index. Geometrical mean was derived in the group and in the totality which represents the weights to the criteria and the attribute.

Alternatives: The development alternatives of hydropower projects practiced in Nepal are summarized in table 1.

Table 1
Development alternatives of hydropower projects practiced in Nepal

S. N.	Modality of Execution	Projects Selected	General Description of Alternative
1	Bilateral / Multilateral Funding		
	Group – 1 (Major Part Soft – Loan)	Kaligandaki A	Projects developed with the use of foreign assistance in the form of soft loan
	Group – 2 (Major Part Grant)	Middle Marsyangdi	Projects developed with majority contribution from foreign assistance in the form of grant
	Group – 3 Minor Part Soft Loan)	Modi	Projects developed with minority of loan assistance and where key decisions were taken by Nepalese engineers
	Group – 4 Almost Entirely Grant	Andhi Khola & Jhimruk	Projects developed with almost entire financing from the foreign grant assistance and addressed Nepalese capability building in design and construction
2	NEA Self Promoted Project	Ilam	Project developed mobilizing the technical and financial resources of GoN and NEA
3	Public National Developer	Chilime	Project developed by a public company named Chilime Hydropower Company Limited (CHPCL) with the use of indigenous resources
4	Private National Developer	Piluwa	Projects constructed by national entrepreneurs
5	Private International Developer	Khimti	Projects developed by foreign developers utilizing foreign investment

Criteria and Attributes: The following Seven resource criteria and their attributes are used in the study.

Table 2
Criteria and Attributes

Criteria	Sub-criteria or Attributes
Technical Aspects (TA)	Four Attributes: Lining of headrace tunnel (HRT), Regulating Pondage (Pondage), Electrical & Mechanical Equipment (EMW), Sitng of Structures (Siting).
Project Cost & Schedule (PCS)	Six Attributes: Average Cost (ACD), Specific Energy cost (EC), Engineering Cost (ESC), Pre-operating Cost (POE), Electromechanical Cost (EMC), & Construction Schedule (CSch).
National Hydropower Industries (NHI)	Six Attributes: Engineering & management (EMCS), Const. of Infrastructure (CInfra), Surface works (CSS), Underground works (CUGS), Hydro-mechanical works (HMS) & Electromechanical works (EMS).
Environmental & Social Aspects (ESA)	Five Attributes: Acquisition & displacement (Land), Encroachment & mitigation (EMW), Rural electrification (RE), Community & rural development (CRD), Environmental & social conditions (ESC).
Capacity Building (CB)	Four Attributes: Technical Capability (TC), Financing Capability (FC), Manpower (MP), Key decisions (KD).
NEA's Perspectives	Four Attributes: PPA rate or Gen. cost (PPA), Dry month's energy (DryE),

Criteria	Sub-criteria or Attributes
(NEAP)	Ownership (OWN), Escalation & its limit (EL).
National Perspectives (NP)	Seven Attributes: Mode of Financing (MoF), Use of dividend & return (DR&IP), Currency of payment (CP), National employment (NEC), Fiscal linkage (FL), Contribution to self reliance (CSR), Money retained in Nepal (MRN).

Rating system for Criteria Attributes: A standard quantitative rating scale (e.g. 1-4) is used for all resource attributes, with the larger value representing the more preferred or beneficial condition. The ratings for each attribute for all alternatives form an Impact Analysis Matrix (IAM).

5. Data Analysis

5.1 Criteria Weight

Out of 25 actors surveyed only15 respondents; 5 from technical group; 3 from economists group, 3 from political group and four from activists group met the consistency requirement**.** An Excel sheet was developed for computation of weightage of criteria and attributes with the use of AHP principle. The resource criteria and attributes are viewed based on (i) Individual Preference**,** (ii) Groupwise Preference and (iii) Collective Preference calculating the geometrical mean of the weightage preferred by each individual. The total desirability of alternative mode of hydropower development has been worked out with the use of weighted average method; however, priorities of resource criteria and fractional attribute weights are determined with the use of AHP. The group wise preference of criteria is presented with the help of geometrical mean of the weightings within a group. Collective preference for criteria by the actors is judged with the use of geometrical mean (G.M.) derived by treating equally to each group and to each individual separately. The preference derived from both the methods show the same trend. The study result demonstrates that the national perspective is the highly preferred criterion. It is followed by capacity building in the second position and national perspective in the third position. The technical aspects followed by project cost and schedule are the least preferred criteria. The preference of actors for environmental and social aspects and NEA's perspective are below average.

5.2 Fractional Attribute Weight

After checking consistency requirement in each criterion, the weight given to different attributes is derived with the use of AHP developed in a spread sheet. The geometrical mean of weight preferred by each individual is calculated and presented in the Impact Analysis Matrix. The statistical parameters such as maximum, minimum, standard deviation and variance are also derived to judge the degree of divergence and consensus in individual's preference in group and in totality.

5.3 Project Development Alternatives

The Impact Analysis Matrix is derived to the seven criteria and nine projects clustered into eight alternatives described above. The criteria ranking is based on the AHP results in respect of the choice and importance preferred by the different actors surveyed. The criteria ranking is established choosing a scale of unity for the lowest Normalized

Weights (NW) derived with the use of AHP. The Normalized Attribute Weights (NAW) in any criteria totals to 1. It represents the preference of one criterion in comparison to others by the actors surveyed. The weighted average of each criteria represents the preferred one alternative with respect to the other in consideration of the attributes of the criteria considered.

It is found that highly preferred hydropower development modalities are: national public model, NEA self promoted project, national developer model and the hydropower projects developed using grant assistance by the donor almost in its entirety. The projects developed with soft loan from donor where key decisions are taken by national manpower and institutions like Modi in Group 3 under donor assisted modality are second preferred choice. The projects with foreign assistance as soft loan where international competitive bidding is practiced like KGA in Group 1 under donor assisted projects is the third preferred choice of development alternative. The projects with grant assistance with tied-aid where Limited competitive Bidding is practiced and the entire decision is taken by the donor like MMHP in Group 2 under donor assisted projects is least preferred alternative. Similarly, the projects developed by international developers like Khimti is also least preferred alternatives.

6. Limitations

An important part of this decision-making framework is the assignment of an impact response or rating value for every attribute under each development alternative which the researcher did himself based on limited project information may not reflect the actual conditions.

7. Conclusions

The study gives the insights to the decision makers on various mode of institutional arrangement for the hydropower development in Nepal particular, however the piece of knowledge has equal value to the decision makers of other country of similar socio-economic condition.

The study suggests that the national perspective followed by capacity building and national hydropower industries is highly preferred criteria for selection of hydropower development model in Nepal. However project cost and schedule followed by technical aspects are least preferred criteria. The capacity building of national institutions, financial institutions, manpower are important. Involvement of national hydropower industries for the planning and development of hydropower projects is found to be third preferred choice. Thus, the key actors collectively prefer a hydropower development model that maximizes the national interest through linkages in the national economy and capacity enhancement through reasonable involvement of national hydropower industries. It can also be inferred that reasonable weight is required to be given for social and environmental aspects and NEA's perspective, whose health ultimately affects the consumer at large in the Nepalese context.

8. Key References

Flug M., L. H. Seitz & J. F. Scott (2000). Multi Criteria Decision Analysis applied to Glen Canyon Dam, *Journal of Water Resources Planning and Management*, Sept/Oct. 2000.

Saaty, T. L. (1986). Axiomatic Foundation of the Analytic Hierarchy Process, *Management Science*, 32, 841-855.

PRIORITIZING HYDROPOWER DEVELOPMENT USING ANALYTICAL HIERARCHY PROCESS – A CASE STUDY OF NEPAL

Rana Pratap Singh
University of BOKU
Vienna 1180, Austria
Email: rnprtpsngh@yahoo.com

H. P. Nachtnebel
University of BOKU
Vienna 1180, Austria
Email: hans_peter.Nachtnebel@boku.ac.at

ABSTRACT

Relevancy of multi criteria decision analysis and effectiveness analytic hierarchy process (AHP) for hydropower prioritization is focus of this research. Increased social and environmental awareness in Nepal, not only out dated ad-hoc or economics based approach; rather call for multi criteria analysis tool in project selection. Prioritizing hydropower scale in Nepal using AHP is further established as easy and appropriate approach. This study organized in a framework of six criteria (factors) along with associated sub-factors and five alternatives (scale of hydropower plant). Subjective value judgment based on secondary sources gathered and used for further processing. Final prioritization generated using AHP based software called Expert Choice, found Medium hydropower as most appropriate scale of power generation and is closely followed by big hydropower on ranking.

Keywords: Nepal, hydropower, scale, prioritization, AHP

1. Introduction

Nepal has huge hydro potential of 83,000 MW but only 727 MW explored till date and country, is engraved with extreme energy poverty. Limited resources, socio-ecological constraints and conflicting interest of stakeholder demands prioritizing among available alternatives. Hydropower decision making process is extending beyond the classical model and shifts the conception of optimal solution of a problem to satisfactory one (Guitouni 1998). Hydropower is full of tangible as well as non-tangible factors which needs subjective judgment and comparison. Information required comes haphazard and unorganized which need to be in structured properly. This is prompting analysts to explore and apply multi criteria analysis (MCA) method with suitable tool. Since 1980's, there are several methods invented and one widely applied is pair wise comparison and outranking methods (Kerry 2007). This includes AHP, ELECTRE, PROMETHEE etc. One most popular and trustable tool called Analytical Hierarchy Process (AHP) is used in this study.

1 Literature Review

This research is based on secondary information gathered from several published water resources and Hydro power related studies, peer reviewed scientific and professional journals, academic researches, news articles, project reports and publications. Information and data used is from recent years and relevant to Hydropower in Nepal. Nepal Electricity Authority (NEA), Department of Electricity Development (DOED), Water and Energy Commission Secretariat (WECS), Ministry of Energy (MOE), Ministry of Water Resources (MOWR), Ministry of Science and Technology (MOEST), Independent Power Producers Association Nepal (IPAN), universities and many similar organizations, updated web sites, publications, reports, conference and proceedings were reviewed for diverse information and data. Similarly published scientific research and related reports, publications were studied to apply AHP in proper manner. In this regard consequences of hydropower (Goldsmith 1984), selection of appropriate MCA (Guitouni 1998), MCA in water resource planning (Hazkowicz 2007), AHP-fundamentals and processing (Satty 1987), AHP analysis on appropriate scale of hydropower in Nepal (Bhattarai 1997) were very much informative and helpful to conduct the present research.

9. Objectives

The primary objective of this study is prioritizing hydropower using AHP as easy, efficient and effective tool. Additionally AHP results will help to understand relative prominence of alternative with respect to set criteria in the present country context and the immediate future.

10. Methodology

This study is based on secondary information processed through Analytical Hierarchy Process (AHP) using software called Expert Choice. It includes five main steps namely literature review, information collection, data processing in AHP, results analysis and conclusion. Attention is paid to understand the past trend, present scenario and possible future scenario at least for coming fifteen years with respect to hydropower in Nepal. Analysis results could apply even afterwards. Criteria used are social, environmental,

economics, technical, political, and associated risk. While compiling the information, a metrics with criteria and sub criteria against the alternative was developed and filled accordingly which was used later to make pair comparisons. Strong importance to economy in project selection at all time is found in several of project reports and scholarly articles. Accordingly economy is weighed 25%, one and half times than average weight (17%) for six criteria applied. In same manner importance of political criteria is estimated 20%, one and quarter times more than average and so is for social criteria. Environmental and associated risk are given due weight 10% but traded off with comparatively important criterion mentioned. Alternatives are Micro, Small, Medium, Big and Large hydropower. All data processed carefully and resulted excellent consistency (inconsistency nearly 0.00) level.

11. Model Analysis

Recent updates of Department of Electricity Development (DOED), Nepal Electricity Authority (NEA), Independent Power Producers Association of Nepal (IPPAN) and several published reports of experts and academia indicate a shift of interest from its earlier preferred scale of small and medium towards medium and big scale hydropower development. Majority criteria prefer medium and large at priority while environmental and uncertainties favour micro and small scale hydropower plants. Economies of scale in power generation are attracting more plants of medium and big size and this factor is most sensitive. While large sizes projects are under discussion all other scales of projects are progressing well. AHP application takes care of individual preference, factor, sub-factors and alternatives with respect to the overall objective.

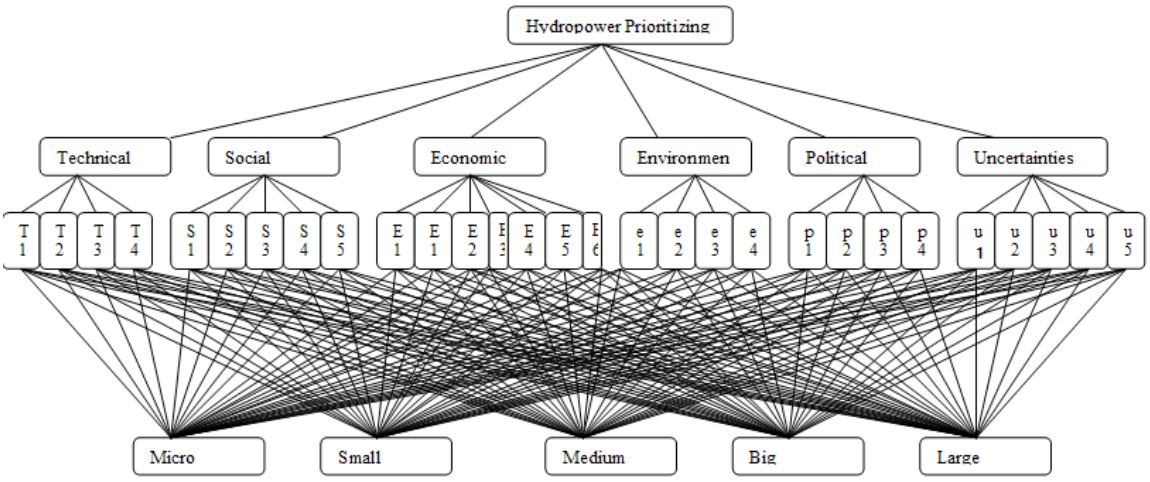

Fig.1 The AHP Model

12. Limitations

Present study is application of AHP based on secondary information for generating weights and thus further fine tuning demands workshop involving stakeholders on Hydropower prioritization.

13. Conclusions

This research methodology using AHP is simple and easy to apply. It is applied to Nepalese hydropower context to understand the preferred scale of power plant. This tool could be of use for the researchers, professionals, planners and all other stakeholders in Nepal and countries alike. The secondary information based AHP application for hydropower development scale prioritization and trend indication is new approach and is contribution to hydropower avenues.

Medium scale of power generation is best suited followed by big hydropower in present country context and immediate future. Small hydropower is on third priority followed by mini and micro as fourth preferred scale of hydropower. Large hydropower of more than 1000 MW is at the least preference in Nepalese context at the moment. In hydropower prioritization, economic factor is of most importance and likely to remain on highest weightage where large size could be of interest in long run.

14. Key References

Bhattarai, S. (1997). Appropriate scale of hydropower development for Nepal: Analytical Hierarchy Process approach, *Master's Thesis, Infrastructure Planning and Management Program, Asian Institute of Technology, Bangkok, Thailand.*

E. Goldsmith, N. Hildyard (1984). *The Social and Environmental Effects of Large Dams, Sierra Club Books, USA.*

Guitouni. A, Martel J.M (1998). Tentative guidelines to help choosing an appropriate MCDA method. *Eur. J. Oper Res 109: 501-521*

Hajkowicz S, Collins Kerry (2007). A Review of Multiple Criteria Analysis for Water Resources Planning and Management. *Water Resources Management 21:1553-1566*

Saaty TL (1987) The analytic hierarchy process – what it is and how it is used. Math Model 9:161–176. In Hajkowicz S, Collins Kerry (2007) *A Review of Multiple Criteria Analysis for Water Resources Planning and Management. Water resour Manage 21:1553-1566*

FRAMEWORK FOR SUSTAINABILITY ASSESSMENT OF RENEWABLE ENERGY PROJECTS IN NEPAL

Ram Prasad Dhital
Institute of Engineering
Tribhuvan University, Nepal
E-mail: rpdhital@yahoo.com

Parakram Pyakurel
Alternative Energy Promotion Centre, Nepal
Email: parakram_pyakurel@yahoo.com

Tri Ratna Bajracharya
Center for Energy Studies, Institute of Engineering
Tribhuvan University, Nepal
E-mail: triratna@ioe.edu.np

Rajendra Shrestha
Mechanical Engineering Department, Institute of Engineering
Tribhuvan University, Nepal
E-mail: rsfluid@hotmail.com

ABSTRACT

Long term sustainability of renewable energy projects in Nepal has been challenging issues due to projects are built in with a certain amount of investment subsidy from government. After installation of the energy system, it is the responsibility of the participating community or the users to operate, maintain and manage the system. The sustainability of renewable energy projects considered largely depends on how much revenue it can generate from its users for operation, maintenance and management. Revenue from users' depends upon multiple factors categorized as technical, financial / economic, social, institutional and environmental. As such, sustainability of the projects needs to be evaluated based on the multiple criterions in a holistic manner. The paper is built on identifying the all possible factors relating to sustainability of renewable energy projects form the prospective of all concern people i.e. project implementers to end users, in addition to the all the concerned stakeholders, in the changed context of climate change and green economy. The paper reviews briefly the literature on utility of multi criteria methods for sustainability assessment of renewable energy projects. Assessment of relative standing of AHP is further conducted. An appropriate AHP based framework for sustainability assessment of the projects is recommended with due consideration to identified factors of sustainability concern from peoples' prospective with the wider representation.

Keywords: sustainability, renewable energy, multiple criteria analysis, AHP.

1. Introduction

Renewable energy technologies (RETs) were promoted in Nepal since the early seventies but these technologies have been widely disseminated only after the establishment of a dedicated organization called Alternative Energy Promotion Center (AEPC) in 1996. With the support of various development partners and the firm commitment of the government, some 2000 micro hydro projects generating 20 MW electricity, 250,000 solar home systems, 250,000 biogas plants and 500,000 improved cooking stoves have been installed in different parts of the country (AEPC, 2011)

Rural and renewable energy projects are built with a certain amount of investment subsidy from government. After installation of the energy system, it is the responsibility of the participating community or the users to operate, maintain and manage the system. The sustainability of renewable energy projects considered largely depends on how much revenue it can generate from its users for operation, maintenance and management. Revenue from users' depends upon multiple factors categorized as technical, financial / economic, social, institutional and environmental. As such, sustainability of the projects needs to be evaluated based on the multiple criterions in a holistic manner. The sustainability evaluation of rural and renewable energy projects are of great importance because annually around 2 billion Nepalese rupees is being spent in the renewable energy sector according to AEPC's annual budget. It can be argued that about 30 billion Nepalese rupees have been mobilized from the Government of Nepal, many external development partners, local government and the community in this sector. Therefore, it is a great concern of everybody to understand whether such a huge investment has impacted on sustainability of the energy systems installed.

The following key questions are needed to be addressed to assess sustainability of renewable energy projects installed in Nepal:
1. How can sustainability of rural and renewable energy projects be measured objectively?
2. Are existing renewable energy projects sustainable?
3. What factors promote or hinder the sustainable operation of renewable energy projects?

This paper identifies various possible factors relating to sustainability of renewable energy projects form the prospective of all concern people i.e. project implementers to end users, in addition to the all the concerned stakeholders, in the changed context of climate change and green economy. Analytical Hierarchy Process (AHP) is then used to build a framework of sustainability. The assigning of numerical values for the factors affecting sustainability is then carried out so that sustainability can be measured objectively and the projects can be ranked and evaluated based on their degree of sustainability.

1 Literature Review

There have been a number of attempts to define criteria for the assessment of the sustainability of the market products. In this respect, the Working Group of United Nations Environment Programme (UNEP) on Sustainable Development has come out with qualitative criteria for the assessment of the product design (Afgan et al., 2008)

Multi Criteria Decision Analysis (MCDA) is one tool for quantifying sustainability. MCDA is a form of integrated sustainability evaluation. It is an operational evaluation and decision support approach 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 (Wang et al. 2009). Analytical Hierarchy Process (AHP), one of the MCDA tools, has been adopted to prepare a framework for sustainability assessment in this paper. AHP based multiple criteria analysis deals with the relative priority of importance of each factor by comparison with respect to a certain criteria. A hierarchical structure of these factors is formed by grouping them into different levels. The application of the hierarchical structure allows the factors to be broken down into details. AHP based multiple criteria analysis starts from building tree like structure with criteria at higher level and factors and sub-factors are at lower level. Objective of evaluation lies at the top and the options or alternatives to be evaluated are placed at the lowest level of the hierarchy. The AHP simplifies the process for identification and assessment of criteria, factors and sub-factors related to a problem (Panthi & Bhattarai, 2008). The hierarchical structure of goal, dimensions and factors developed for this study is guided as in Bhattarai & Adhikari (2011) for rural drinking water facilities.

The sustainability framework for rural micro projects with focus on water projects have been developed so far but there are no frameworks that focus exclusively on rural and renewable energy projects of Nepal.

1 Hypotheses/Objectives

The hypothesis set in this study is that a general framework can be developed to measure the sustainability of rural and renewable energy systems of Nepal with main focuses Micro hydro power technology and solar home systems. It is also assumed that AHP framework is most suited for framework development in Nepalese context. The overall objective of this study is to develop a framework to measure sustainability of rural and renewable energy projects and eventually assess the sustainability of renewable energy projects that have been installed for a year or more.

15. Research Design/Methodology

Site surveys at different villages in rural areas of Nepal where renewable energy projects have been implemented or are planned for electrification were carried out. The local management committees that are responsible for operation and maintenance of such projects were interviewed. The technologies considered were micro hydro power plants, solar photovoltaics and biogas systems because those are the main technologies used in rural areas of Nepal. The main aim of these surveys was to identify sustainability criteria in local/national context. Furthermore, consultations with energy experts, professionals working in the field of rural electrification and energy companies that implement rural electrification in Nepal were carried out. Sustainability criteria were then identified based on surveys and consultations. Eventually, straight line equations have been developed that act as sustainability metric and the framework developed is based on AHP.

16. Data/Model Analysis

The five dimensions/criteria considered to prepare the sustainability framework are: Technical, Economic, Environmental, Social and Institutional. Various factors have been considered within each of the 5 dimension to measure the sustainability. A total score of 10 is assigned to each dimension/criteria and this total score is obtained either by a straight line equation or summation of scores of factors within the given dimension/criteria. The figure below shows the hierarchical structure of the sustainability framework:

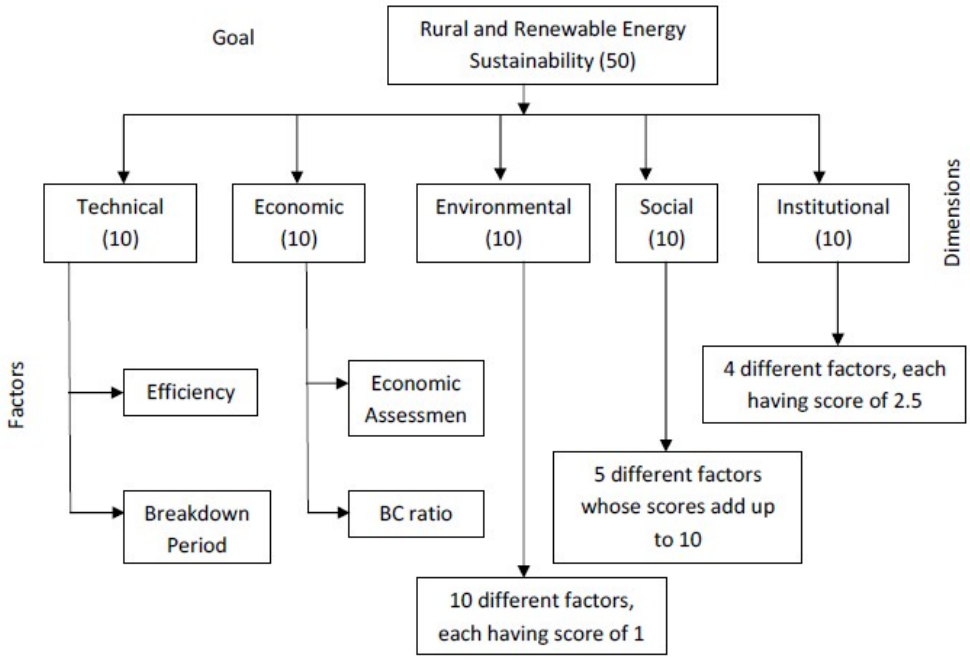

Fig: Hierarchical structure of goal, dimensions and factors with their weights for rural and renewable energy sustainability

The pre-assigned weight as per APEC guidelines helped to generate sustainable score of projects based on the sustainable matrix (a weighted table), however, further analysis using sensitivity feature for AHP processing software helped to rank project based on sensitivity with respect to various factors under consideration.

17. Limitations

The factors/indicators affecting the sustainability have been developed mostly by considering micro hydro power technology and solar home systems. Therefore, the indicators may not be fully applicable for other energy technologies. Equal weighting has been given to all the 5 criteria and the assigning of numerical parameters are based on AEPC quality guideline.

18. Conclusions

The capability of rural electrification project to sustain itself is one main criterion to be considered before project development to prevent any premature failure of the project. AHP has been used to develop sustainability framework for rural and renewable energy systems of Nepal in this study. The Sustainability Matrix (SM) has been developed by taking into account various sustainability factors and the Matrix thus developed measures the sustainability of rural electrification project. The framework further helps in decision making for project development and also rank various projects based on their sustainability processing further utilizing AHP processing commercial software. Besides, the framework assesses projects from various angles and helps design better rural electrification projects. It is expected that the framework for sustainability developed in this paper shall provide input to the integrated rural and renewable energy planning and policy making.

19. Key References

AEPC (2011). Alternative Energy Promotion Centre (AEPC), *Annual Report for 2010.*

Afgan, N. H. & M. G. (2008). Sustainability assessment of a hybrid energy system. *Energy Policy 36 (2008) 2903– 2910.*

Bhattarai, S. & Adhikari, B. Kanta (2011). Analytic Hierarchy Process for Rural Micro Project Sustainability Monitoring in Nepal, *Proceeding of International Symposium on Analytic Hierarchy Process 2011 – ISAHP 2011, Pittsburg, Creative Decision Foundation, 2011.*

Panthi K & Bhattarai S. (2008). A Framework to Assess Sustainability of Community-based Water Projects Using Multi-Criteria Analysis, *First International Conference on Construction In Developing Countries (ICCIDC-I), Karachi, Pakistan.*

Wang, Jiang-Jiang & Y.-Y. J.-F.-H. (2009). Review on multi-criteria decision analysis aid in sustainable energy. *Renewable and Sustainable Energy Reviews 13 (2009) 2263–2278.*

DIFFUSION OF ANALYTIC HIERRCHY PROCESS IN NEPAL: OVERVIEW FOR THE PERIOD OF 2003 - 2013

Shashi Bhattarai
Knowledge Holding International
Kathmandu, Nepal
E-mail: shashi.bhattarai@khint.com.np

ABSTRACT

The paper is overview of diffusion of analytic hierarchy process (AHP) in the form of application and research in Nepal and Nepalese issues during the period of ten years (2003-1013). AHP application in development decisions are reviewed in 2003, since then, it has been observed that the AHP has been diffused not only in development decisions, academia and industry within Nepal, but has been utilized to address the issues and problems of Nepal by Nepalese round the globe.

The article of review of diffusion of AHP in the Nepalese contest is seen from academics, industry and individuals perspectives. Real life applications, published papers and involvement of Nepalese within social media related to AHP has been discussed.

The overview of diffusion survey reveals that Nepalese professionals are active in AHP related social media, research and application of AHP in diverse Nepalese context is increasing. Courses in business school are being offered; Nepal has been included among four countries in Asia in European Commission research project related to application of MCDM in general and AHP in particular, masters and higher level of thesis are being prepared, application in business and industry within the short period of ten years can be seen. The indication of faster diffusion of AHP in Nepal observed to be the appropriate tool of multi criteria analysis in Nepalese context. This AHP diffusion survey is observed to be eye opener for other developing countries of the region to look at the utility of AHP based multi criteria analysis in the context of respective countries. It is also observed that Energy and water related problem had mostly attracted for the application of AHP in Nepal.

Keywords: AHP, Application, Diffusion, Developing countries, Nepal.

1. Introduction

Analytic Hierarchy Process (AHP) and its application, progress and prospects in Nepal has been earlier studied in 2003 (Bhattarai, 2003) focusing on development decisions. Considering 2003 study as base, further diffusion of AHP in Nepal is being studied covering till 2013. This study summarized how application of AHP at different fields and time is being changing in low economy and less developed country like Nepal over a period of ten years. This paper is expected to serve as an example a country specific survey of diffusion of AHP and expected to set as guide to prepare other country report on AHP diffusion.

1 Literature Review

The paper is expected to serve as the bibliographic report on AHP application in Nepal. Literature survey is the major part of the paper. Some typical literatures are cited at this stage of the paper. More detailed analysis of literature is expected to cover the full paper on this topic.

1 Hypotheses/Objectives

It is assumed that the diffusion of AHP in Nepal will also follow technology diffusion phenomena and will give the innovation adaptation prospective. Further the study is expected to demonstrate the application of AHP will be more concentrated in the areas where conflicts and controversy is persisting.

20. Methodology

The study is based on literature survey, mainly abstract level, industry & academia consultation and analysis. Analysis of AHP diffusion in terms of field of application and chronological distribution over the period of 10 years will be conducted. The AHP technology diffusion will be further seen form innovation adaption perspectives.

21. Data Analysis

The study will be follow a typical application or adoption or diffusion survey approach mainly based on the literature survey or the secondary information. A systematic analysis of diffusion of AHP in Nepal will be presented with respect to time and theme of application or research field.

22. Limitations

The study is conducted with the very limited time and resources. This study may not serve as complete AHP diffusion survey in Nepal for the period of 2003 – 2013. However, this initiation to be considered as starting point for the filling the gap, if any.

23. Conclusions

This study is expected to serve all who will be working for application or promotion of AHP in Nepal. The audience may be from academia or a practicing professional. The study will also expect to prompt for the study on the diffusion of AHP in other countries or region. It is expected that the study will be first of its king on the study of AHP diffusion focused particularly a country.

It is observed that Energy and water related problem had mostly attracted for the application of AHP in Nepal.

24. Key References

Bhattarai, S. (2003), Analytic Hierarchy Process for Development Decisions: Progress and Prospects in Nepal, *Proceedings of International Symposium on Analytic Hierarchy Process (ISAHP 2003), Bali, Indonesia.*

P. Kayastha, M. R. Dhital & F. De Smedt (2013). Application of the analytical hierarchy process (AHP) for landslide susceptibility mapping: A case study from the Tinau watershed, west Nepal, *Computers & Geosciences, Vol 52, pp 398–408*

Reed B.F., C. Chan-Halbrendt, J. Halbrendt, C. Lai, T.J.K. Radovich, & P. Limbu (2012). Analysis of farmer and extension agent preference in Nepal using Analytic Hierarchy Process, *Proceedings of 24th Annual College of Tropical Agriculture and College of Engineering Student Research Symposium*, University of Hawaii, Department of Natural Resources and Environmental Management.

Bhatta, G. Datt, Werner Doppler (2010). Farming Differentiation in the Rural-urban Interface of the Middle Mountains, Nepal: Application of Analytic Hierarchy Process (AHP) Modeling, *Canadian Center for Science and Education, Journal of Agricultural Science, Vol 2, No 4 pp 27 - 51*

Khadka C., & Vacik H. (2011). Evaluating Sustainable Community-based Forest Management: A Reflection on Nepal's Experience with the Analytic Hierarchy Process, *Proceedings of the International Symposium on the Analytic Hierarchy Process 2011, ISAHP 2011, Creative Decision Foundation, USA.*

Panthi, K. (2007). Prioritizing and Estimating Hydropower Project Construction Risks: A Case Study of Nyadi Hydropower Project, *University of New Mexico http://hdl.handle.net/1928/3298 (accessed 23 Jan 2014).*

Lamichhane, R. & Phayung Meesad (2011). A Usability Evaluation for Government Websites of Nepal Using Fuzzy AHP, *Proceedings of The 7th International Conference on Computing and Information Technology (IC2IT2011), Bangkok, Thailand, pp 99 – 104* (http://202.44.34.144/nccitedoc/admin/ic2it_files/IC2IT-20112505125956.pdf accessed 24 Jan 2014).

Thapa, Rajesh B. & Y. Murayama (2010) Drivers of urban growth in the Kathmandu Valley, Nepal: Examining the efficacy of the analytic hierarchy process. *Applied Geography.*30:1.70-83.Jan

Chand, Narendra B. (2011). Production Efficiency of Community Forestry in Nepal: A Stochastic Frontier Analysis, *Doctor of Philosophy Thesis, Lincoln University, New Zealand.*

Sharma, K. & Bhattarai S. (2012). Treatment Decision using Analytic Hierarchy Process (AHP) based Framework, *Nepal Journal of Neuroscience (ISSN 1813-1948 Print; ISSN 1813-1956 Online), Vol. 8, pp 125-132 (November 2011)*.