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Research Article

Prioritization of Storage Hydropower Projects under Study in Nepal

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I N F O

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A B S T R A C T

This research aims to find out the factors hindering the storage hydropower projects and prioritize the storage hydropower projects of Nepal. The study has covered six major storage hydropower projects that are under study. Uttar Ganga Storage Hydroelectric Project and Budigandaki Storage Hydroelectric Project are located in Gandaki Province. Dudhkoshi Storage Hydroelectric Project and Tamor Storage Hydroelectric Project lie in Province 1, while Nalsaugad Storage Hydroelectric Project lies in Karnali Province. These all projects are in the stage of feasibility study. The methodology of research followed Analytical Hierarchy Process (AHP) based on Multi Criteria Decision Making (MCDM). Literature review was done with AHP application in different sector including hydropower. Besides this, reviews were done on aspects like energy crisis, present energy status and future demand. Likewise, pair wise comparison was done in different multiple criteria. Additionally, response from client and expertise opinion were conducted. Technical, financial, environmental, policy and political uncertainties and responses from the project personnel were the major criteria that can affect the priority of the storage hydropower projects. Among the factors, Technical Factor was given the highest importance to be considered for the development of storage hydropower project. The findings of the research revealed that Nalsaugad Storage Hydropower Project to be the best on the basis of the multicriteria considered. The sensitivity analysis with respect to factors was done, which shows no significant difference in the ranking of projects at base case and at the case of change in weight of factors. This research is expected to assist by project managers, project directors, and concerned government authorities in prioritizing the storage projects of Nepal.

Keywords: Hydropower Projects, Nepal, Storage

Introduction

The total energy generated from hydropower is only 1278.098 MW (NEA, 2020), although Nepal has got lot of potential in generating electricity due to its numerous rivers and streams. Most of the power plants are of ROR type in Nepal. So high production during monsoon season and deficit during dry season is one of the issues in Nepalese power system planning. Storage projects are needed to solve this problem. The eight storage hydropower projects being studied by various agencies of government of Nepal. The cost of building each of these projects is very large. So, it is not possible to start the construction of all storage hydropower projects at once. In this situation, establishment of priorities of these hydropower projects with due consideration of various actors in the decision-making process and taking care of their conflicting multiple criteria becomes very important to minimize the conflicts regarding the development of hydropower projects in Nepal and to ultimately address the existing energy crisis.

The project proponent from each project explains Ministry of Energy, Water Resources and Irrigation that the project allocated to them as a project manager is the best among other storage hydropower project which are at the stage of study in Nepal. The concerned authority is also unknown that which project is better than other projects and by how much. Prioritization of storage hydropower projects avoids confusion for comparing the storage hydropower projects of Nepal.

The situation of country and the world do not remain as usual. The Pandemic outbreaks affects country. In that situation if the concerned authority is compelled to delay the study of some storage hydropower project by some years, then the concerned authority will be in confusion, which project to delay for some years. In that situation prioritization of storage hydropower projects will be fruitful to avoid confusion.

Research Objectives

The overall objective of the research is to prioritize storage hydropower projects under study in Nepal.

Literature Review

Research Under AHP in Hydropower Sector in Nepal

According to Bhattarai S, the study is conducted regarding the selection of scale of hydropower projects suitable project.[2] The factors and sub factors considered in the study model deserves its full value in the decision-making process with public involvement for the hydropower development. The result concludes, first priority is gained by medium scale, second by small and third by large scale hydropower projects. Out of four factors, socio- economic factors has drawn the first rank then followed by technical on second rank, environmental factors on third rank and international factors on fourth rank In summary , this researcher concluded that most preferred alternatives is medium scale for development, most important factors is socio- economic factor, most important socio- economic sub factor is cheap power & political stability, most important environmental sub- factor is national Independence, most important technical sub- factor is risk, most important actors is government and politicians, most diversified preference among the actors is energy concern people , most stable priority score among alternatives is medium scale.[2]

Diffusion of AHP in Nepal

According to Bhattarai S, this research conducted to accumulate the research done under AHP. The study prompts for the study on the diffusion of AHP in other countries. It is expected that the study has uniqueness on its kind on the study of AHP status focused particularly a country. It is observed that application of AHP in Nepal is more concentrated in the areas where conflicts and controversy is persisting, such as water, energy, environment and forest resources related issues.[2]

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Assessment and Ranking Procedure on AHP

In this paper there are six alternatives to be ranked by one decision maker with respect to a set of six factors, fifteen sub factors and thirty-five co-factors. Numerous multi-criteria techniques are at hand. The selection procedure to identify an appropriate technique is again an MCDM approach. Here, the ability to handle qualitatively expressed criteria, to analyze the sensitivity of ranking, the visual support of the method and the proven applicability to hydropower projects assessment were decisive. The Analytical Hierarchy Process satisfies these conditions using a software called Super Decision. Subsequently, the fundamentals of AHP are discussed briefly to facilitate its understanding and app.[2]

The MCA model is represented by an evaluation matrix X of n decision options and m criteria. The raw performance score for decision option i with respect to criterion j is denoted by xi, j. The importance of each criterion is usually given in a one-dimensional weights vector W containing m weights, where wj denotes the weight assigned to the jth criterion. It is possible for X and W to contain a mix of qualitative and quantitative data.

A great variety of MCA algorithms can be used to either rank or score the decision options. The MCA algorithms will define, by some means, one or both of these functions:

$r_i = f_1 (W, X)$ and $u_i = f_2 (W, X)$

Here, r_i is an ordinal number representing the rank position

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of decision option i and *u*i is the overall performance score of option i. The solution of *r*i and *u*i occurs within a broader MCA decision making process.

The MCA process generally contains the following stages: choosing decision options and evaluation criteria, obtaining performance measures (xi, j) for the evaluation matrix, Transforming them into commensurate units, weighting the criteria, ranking or scoring the options, performing sensitivity analysis and finally making a decision.[4] One of the most widely applied techniques is the Analytic Hierarchy Process is pairwise comparison. This approach involves comparing criteria and alternatives in every unique pair giving n (n-1)/ 2 comparisons. The comparisons can be made to attain criteria weights and decision option performance scores. Various scaling systems can be used. AHP decision makers are asked to express a preference for one criteria/ option over another in each pair on a nine-point scale.

The AHP is based on the axiomatic foundation as follows.[7] The reciprocal property that is basic in making paired comparisons.

Homogeneity that is characteristic of people's ability for making paired Comparisons among things that are not too dissimilar with respect to a common property and, hence, need for arranging them within an order preserving hierarchy.

Methodology

Study Population of Storage Hydropower Projects/ Alternatives

The research was carried out taking references of the different government bodies in hydropower sector. The respondents are consultant, clients and hydro experts. There are 54 storage hydropower projects in existence in Nepal. Out of them six projects are selected as a study project because they are ongoing study by GON or GON bodies. All other storage hydropower projects other than in the study are in basket of Department of Electricity Development except Sunkoshi-2 and Sunkosh-3. The study of Sunkoshi-2 and Sunkoshi-3 is being carried by Ministry of Energy Water Resource and Irrigation. However, the availability of data of Sunkoshi-2 and Sunkoshi-3 Storage Hydropower Project at the time of study by the researcher was not adequate, so these projects are not included at the time of study. The study population is the whole population of undergoing study storage hydropower project except Sunkoshi-2 and Sunkoshi-3.

Data Collection Tools and Techniques

Primary and secondary types of the data were collected and used in the study. The main primary and secondary data are.

Primary Data

Primary data were collected from questionnaire survey and key informant interview. To mark the weightage of multiple criteria opinions from key informant were taken. The key informant was asked to fill the form developed by researcher. The questionnaire survey was conducted with all the project manager/ technical staff of study project to know their view on rank of study projects.

Questionnaire Survey

Questionnaire survey with project coordinator or with the engineer of the study project was done in order to obtain the perceptions, understanding and prioritization of the study project. The standard form to rank the prioritization of storage hydropower projects was filled up by the project's chief or the technical experts of each study projects based on the multiple criteria affecting the projects. Data were personally collected from the informants. The method of collecting primary data is suitable particularly in following cases.

- Where detailed and supplementary information can be collected
- Where the area of investigation is limited
- Where there is need for personal interview
- Where importance is given to originality
- Where importance is given to purity

Key Informant Interview

The information regarding factors, sub- factor and co-factors were formulated after extensive literature review, brain storming, newspaper, journal and articles. Information was collected regarding factors, sub factors and co-factors that plays major role for the storage hydropower project were presented to the key informant having sound theoretical understanding and high working experience in storage hydropower development in Nepal. Researcher consulted seven persons working in this field with 3 different professions as presented in Table 1. A form was developed for key informant interview opinion process. The key informant filled the weightage for factors, sub-factors and co-factors.

Secondary Data

The collections of secondary data are done before input of data in super decision analysis software focusing on objective of the study. These data were collected from study reports from concerned departments, NEA annual report, load dispatch center (LDC), power purchase agreement (PPA) department, EIA report, Environmental Monitoring Report, minute of agreement (MOA), contract agreement, correspondences, documents from websites, research books, and journal articles and other published and unpublished literature and reports.

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Table 1.Key informant opinion

S. No.	Professional	Number	Organizations
			IOE, TU Pulchowk Campus-1 Nepal
1	Academicians	2	Engineering College-1
			NEA, Engineering Services DMD-1
			Generation Company CEO-1, DG OF
2	Developers/Client	3	DOED-1
3	Consultants	2	Kansai-1 Tractable Gmbh-1

Data Analysis

The primary and secondary data collected were first analyzed in excel spread sheet and then in super decision analysis software.

First Step

Formulation of the hierarchical structure based on defining problem with a focus on the dimensions, and Multiple Criteria within each dimension. This was the process to decompose the problem into hierarchical tree. This step is very crucial which finally leads to results. Related various literature have been reviewed for the formation hierarchical structure. Hierarchical structure is shown in Table 2.

Table 2.Formulation of hierarchical structure

Goal	"Prioritization of Storage Hydropower Projects under Study in Nepal".						Level 1
Factors	Technical Condition	Financial Condition	Impact on Environment	Policy and Political	Uncertainties	Respondents from each project	Level 2
Sub-Factors	1.Hydrological Condition	4.Financial Cost of Project	5.Impact on Natural Environment	7.Change in policies	11.Natural Hazard	15.Respondents	Level 3
	2.Geological Condition		6.Impact on Social Environment	8.Corruption and Nepotism	12.strikes and Boarder Blockade		
	3.Lead Time			9.Political Instability	13.Unforseen site condition		
				10.Lack of Monitoring	14.Unpredictable weather		
Co-Factors	1aReliability of Flow data	4a.Unit generation cost	5a.Impact on forest	7a.frequent changes of Polices	11a.Landslides	15a.Respondents Adhikhola	Level 4
	1bsedimentation	4b.Installed Capacity	5b.Impact on protected areas	8a.corruption	12a.Political Strikes	15b.Respondents Dudhkoshi	
	1cRisk of golf	4c.Annual Energy production	5C.impact on fishes	9a.political instability	13a.unforseen site condition	15c.Respondents Uttarganga	
	2aseismicity	4d.Donar Interest	5d.impact on conservation species	10a.lack of monitoring authority	14a.unpredictable weather	15d.Respondents Tamor	
	2bGeological condition of site	4e.IRR of the project	6a.Impact on locality			15e.Respondents Budigandaki	
	2cNatural Hazard	4f.Energy production in dry season	6b.Impact on household				
	3alength of access road		6c.Impact on agriculture				
	3bDifficulty level of funding		6d.Impact on ethnic minorities				
Alternatives	Adhikhola	Dudhkoshi	Uttar Ganga	Nalsaugad	Tamor	Budigandaki	Level 5

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Levels of hierarchy structure could be defined as below.

Level 1: Main goal of research lies in level 1.

Level 2: Based on the goal, n mummer of dimensions can be identified. So dimension of factors for storage hydropower projects lies in level 2.

Level 3: Within in each factor, specific sub factors lies in level 3.

Level 4: Within each sub factors Co-factors lies in level 4.

Level 5: Alternatives lies in level 5.

Second Step

The weightage of each item was asked to fill by seven key informants. The geometric mean was taken for the weightage assigned by each key informant. The geometric mean was taken because it incorporates the volatility in data set. The weightage calculation sheet is presented in Appendix A2.

Third Step

In third step, pair-wise comparison matrix construction with dimension level with respect to goal, was formulated. Each project was compared with other study projects. The evaluated marks on multiple criteria, obtained by the project was divided with the marks obtained by another project which gives the ratio as shown in Table 3. This ratio explains by much times the project is better than another projects. The matrix of all the multiple criteria is attached in Appendix C.

Fourth Step

Pair-Wise comparison matrix for all the multiple criteria are entered in super decision analysis software and a final model is generated by super decision.

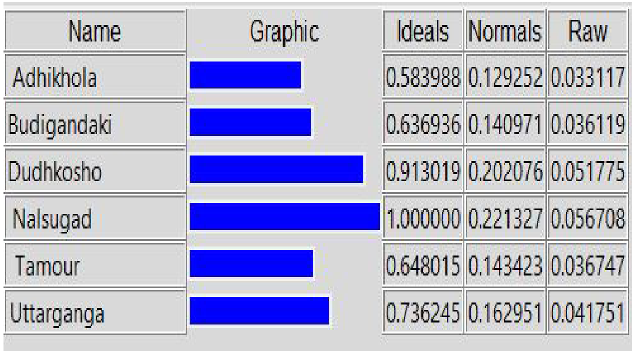
Research Matrix

To achieve the desired objective of research, various surveys and collection of data were carried out. The detail of activities is presented in Table 4.

Result and Discussion

Result Overview

The result of multicriteria analysis on super decision analysis software depicts that Nalsaugad storage hydropower project is most appropriate for development among other study hydropower projects under study.



Name	Graphic	Ideals	Normals	Raw
Adhikhola		0.583988	0.129252	0.033117
Budigandaki		0.636936	0.140971	0.036119
Dudhkosho		0.913019	0.202076	0.051775
Nalsugad		1.000000	0.221327	0.056708
Tamour		0.648015	0.143423	0.036747
Uttarganga		0.736245	0.162951	0.041751

Figure 1.Prioritization of storage hydropower projects

Table 3.Sample of matrix formulation

	Reliability of Flow Data				
	Budigandaki	**Dudhkoshi**	**Nalsaugad**	**Tamour**	**Uttar Ganga**
Adhikhola	0.326	0.240	0.264	0.240	0.696
Budigandaki	1.000	0.736	0.811	0.736	2.137
Dudhkoshi		1.000	1.266	1.149	3.333
Nalsaugad			1.000	0.908	2.634
Tamour				1.000	2.902

Table 4.Research matrix

Objective	Data Required	Data Source	Tools	Outcomes
1) To present the scenario of storage hydropower projects which are under study in Nepal	Multi criteria	Feasibility study reports	Literature Review and Documentation	Present Status of Storage hydropower projects which are under study in Nepal
2) Prioritization of storage hydropower projects under study in Nepal.	Evaluation of Factors, Sub-Factors and Co-Factors of Alternative Projects	Feasibility Study Reports of each Alternative Projects	Questionnaire Survey, Key Informant Interview and Super-Decision Analysis Software	Prioritization of storage hydropower projects under study in Nepal.

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Description of the Factors and Sub-factors and Co-factors

Following below are the factors, sub-factors and co-factors that affect the storage hydropower projects of Nepal. All these factors, sub-factors and co-factors are taken from literature review. The reason for selecting this criteria is, all this criteria evaluates the risk and favorable aspects of storage hydropower projects.

Technical

Hydrological Condition

Level of detailed hydrological investigations has to be done before the storage hydropower projects are put into construction. If this information is well known then in it will not create any problems during construction. Better hydrological investigation will result into proper sizing of hydropower components. So, this activity has to be planned properly. The hydrological sub factors are also divided into three co-factors.

Reliability of Flow Data

The greater number of time discharge of a river is directly measured and longer the period of gauge data, the more is the reliable of the flow data. From the reliable flow data, accurate stage discharge curve can be plotted.

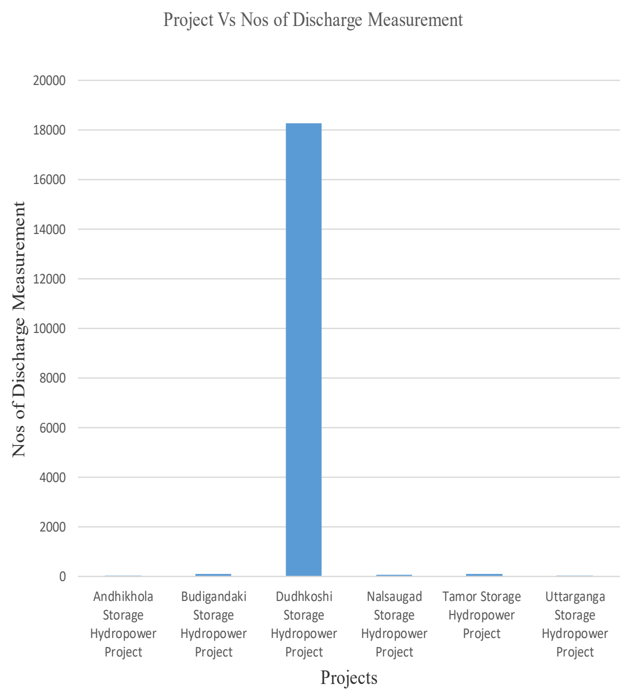

Figure 2.Project vs. Nos. of discharge measurement

Dudhkoshi Storage Hydropower Project have the greatest number of flow data measured. Dudhkoshi River have installed gauge near to present dam axis of project since 1964. Uttar Ganga Storage Hydropower project have least number of directly measured flow data.

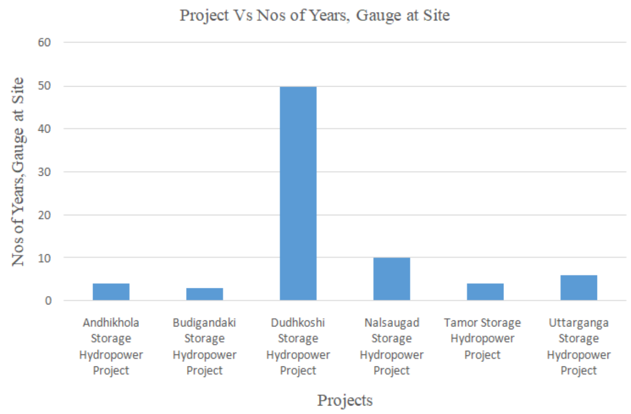

Figure 3.Project Vs number of years, Gauge at Site

Dudhkoshi Storage Hydropower Project have the gauge data at dam axis for more than 50 years whereas Budigandaki Storage Hydropower project have gauge data record of only three years.

Sedimentation

The longer the period the data of sediment is measured, the more accurate is the estimation of quantity of sediment calculated. It makes easier to calculate the dead storage and live storage of sedimentation in storage hydropower projects.

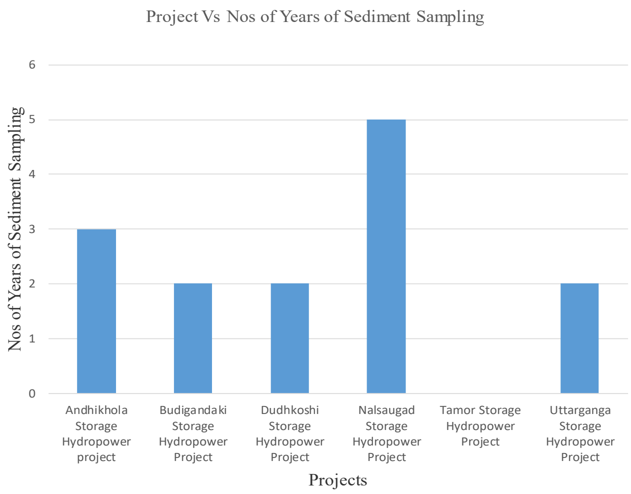

Figure 4.Project vs. Nos of years of sediment sampling

Nalsaugad Storage Hydropower project have taken the sediment data for more than five years whereas Tamor Storage Hydropower project have not taken any sediment sample yet. The sediment yield in Tamor Storage Hydropower project is the estimation obtained by correlation.

Risk of GLOF

When glacial lake outburst flood (GLOF) occurs in the upstream basin of the project site, GLOF may damage the hydropower stations. The type of GLOF and their associated risk are categorized by International Center for Integrated Mountain Development (ICIMOD).

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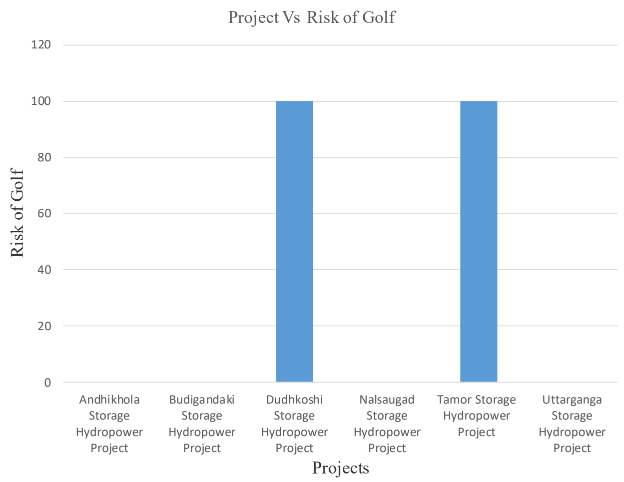

Figure 5.Project vs. Risk of GLOF

Dudhkoshi Storage Hydropower project have potential risk of GLOF from Imja, Khumbu and Ngozumpa GLOF. Tamor Storage Hydropower project have potential risk of GLOF from Nagma Pokhari and Unnamed GLOF. The other storage hydropower projects under the study of researcher do not have potential of risk of GLOF. No GLOF are noticed in their catchment area.

Lead Time

Lead time is the amount of time that passes from the start of a process until its conclusion. Reducing lead time can streamline construction of storage hydropower projects and improve construction, increasing output. By contrast, longer lead times negatively affect construction period of hydropower projects. The lead time is further categorized into three Co-factors.

Length of Access Road/ Transmission Line

The length of access road/ transmission line could influence the development of storage hydropower project significantly. Lesser is the length of access road and transmission line easier for the development of storage hydropower projects.

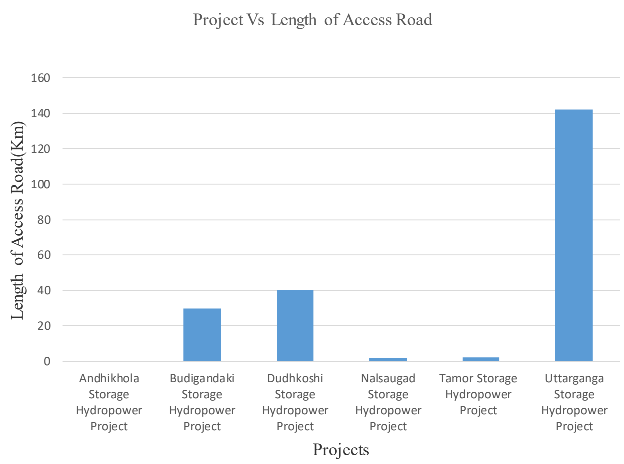

Figure 6.Project vs. Length of access road

Nalsaugad Storage Hydropower project have the highest length of access road of 142 km to reach to the site from khalanga, the district headquarters of Jajarkot. Adhikhola Storage Hydropower project have to construct only 1.58 km length of road from existing Siddhartha highway to reach to the site which is the least length of access road among studied projects by the researcher.

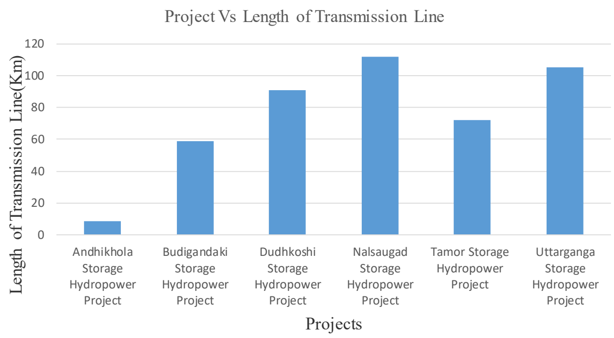

Figure 7.Project vs. Length of transmission line

The generated energy of Adhikhola Storage Hydropower project will be evacuated to the INPS through 8.5 km long 220 kV double circuit transmission line near KG-A powerhouse at tower no. AP-47 of Kusma - New Butwal Transmission line whereas other projects under the study by the researcher have longer length of transmission length. Nalsaugad Storage Hydropower project have highest length of transmission line of 142 km.

Difficulty Level of Funding

In general, the larger project requires the higher cost as well as the longer construction period. It takes longer time for financing for such project. Therefore, the difficulty level of financing could be estimated with the cost of each project.

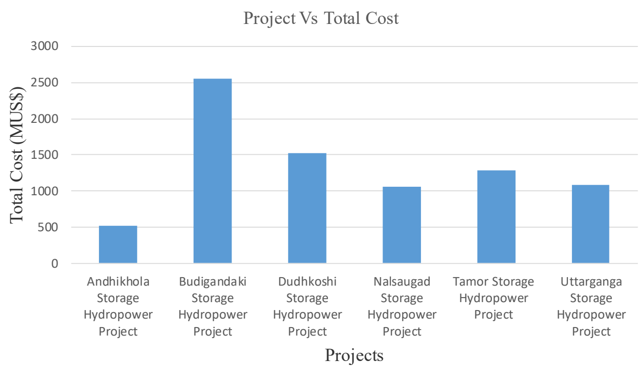

Figure 8.Project vs. Total cost

Budigandaki Storage hydropower project have highest cost of 2500 million united states dollar (MUS$). Adhikhola Storage Hydropower project have least cost of 500 MUS$. Larger the capacity of the project, more the cost.

Reliability of Development Plan

In general, the more advanced study level a project has, the higher the reliability of the project. Budigandaki Storage Hydropower Project have completed its detail project report (DPR). Nalsaugad and Dudhkoshi Storage Hydropower Projects are ongoing DPR. Tamour and Uttar Ganga Storage Hydropower Project have completed feasibility study whereas Adhikhola Storage Hydropower Project is still ongoing its feasibility study.

Geological Condition

Nepal is a country with a diverse geographic structure, consisting of the himalayan mountain region and flat-terrain regions. Without proper geological investigation construction of underground structures of storage hydropower projects is in high risk.

Seismicity

The "Seismic hazard map" was prepared in Nepal as a reference for evaluation of seismic activities. The Himalayas are the place for the collision of Indian subcontinent and Eurasia continent. Most of the earthquakes have occurred in Lesser Himalaya, the area between MCT and MBT, and many in western Nepal. It may be better to differentiate the impact of MCT, MBT, and HFT in terms of each seismic risk.

Distance to Large Tectonic Thrust

Distance of the project from the fault line and technic thrust is a governing factor for risk assessment of storage hydropower project.

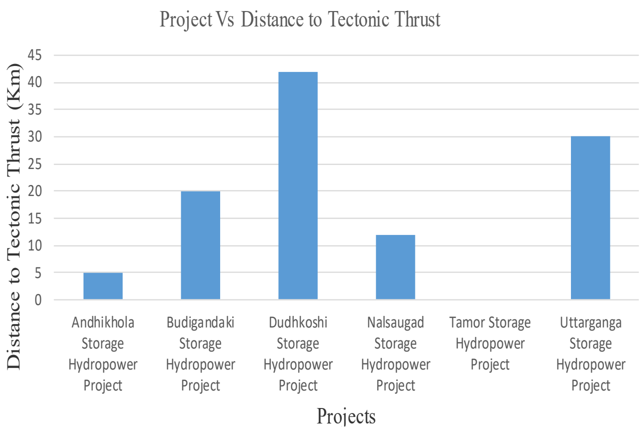

Figure 9.Project vs. Distance to tectonic thrust

Dudhkoshi Storage Hydropower project lies 41.85 km from the large tectonic thrust whereas Tamor Storage Hydropower project is located near the MCT Zone of Taplejung Window. Adhikhola storage hydropower project also lies only 5 km far from the Badi Gad fault.

Geological Condition of Site

Average depth of bed rock at dam axis and powerhouse site, Rock Quality Designation (RQD) value along the alignment of headrace tunnel are considerable factors while evaluating the geological condition of storage hydropower projects.

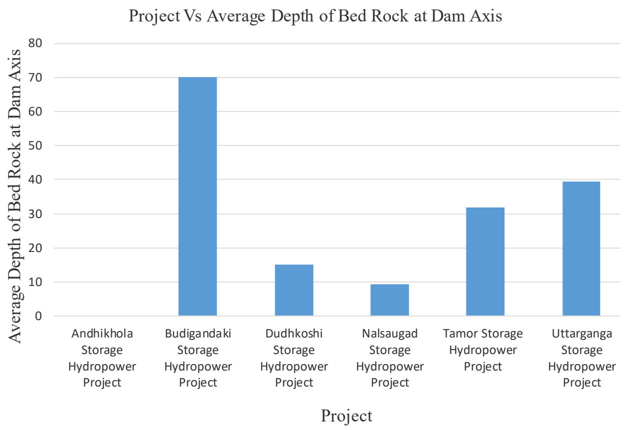

Figure 10.Project vs. Average depth of bed rock at dam axis

Bed rock is found at larger depth in Budigandaki Storage Hydropower project, whereas Adhikhola Storage Hydropower project still do not have completed its geological investigation. Geological investigation was conducted in previous location of dam axis, but now dam axis of the project is shifted to 2 km upstream due to technical reason.

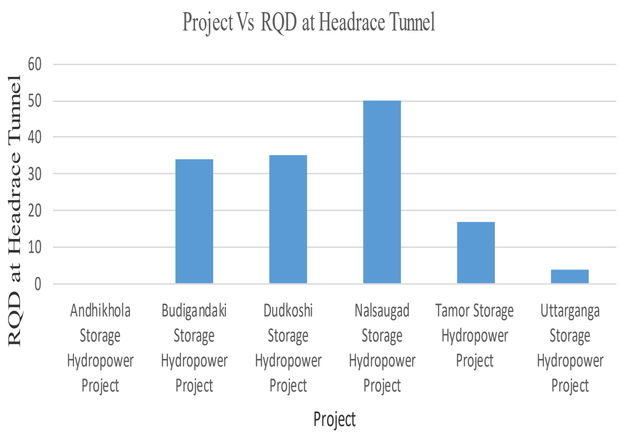

Figure 11.Project vs.RQD at headrace tunnel

Nalsaugad Storage Hydropower project have highest rock quality designation (RQD) value of 50 along the alignment of headrace tunnel whereas no geological investigation is being carried out in Adhikhola Storage Hydropower due to change in its layout.

Financial Condition

Return on the investment is one the important factor for development of storage hydropower projects. How beneficial is the project for developer is explained in financial condition of the project.

Unit Generation Cost

A unit generation cost is one of the important indices of economic efficiency of project, the smaller the unit cost is, the smaller investment is required to yield the same benefit.

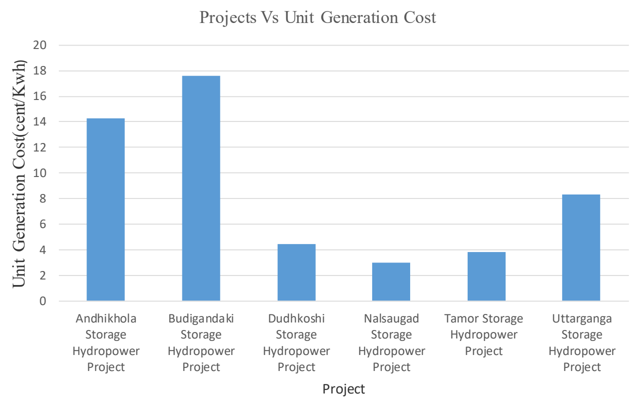

Figure 12.Projects vs. Unit generation cost

Budigandaki Storage Hydropower project have highest per unit generation cost of 17.6 Cent/KWhr. Adhikhola Storage Hydropower project also have higher per unit generation cost of 14.3 Cent/KWhr. Nalsaugad Storage Hydropower is best in per unit generation cost which have cost of only 2.95 Cent/KWhr.

Installed Capacity

It takes time and greater effort to the implementation of project since large-scale projects require large costs in general and financing of these projects is associated with much difficulty.

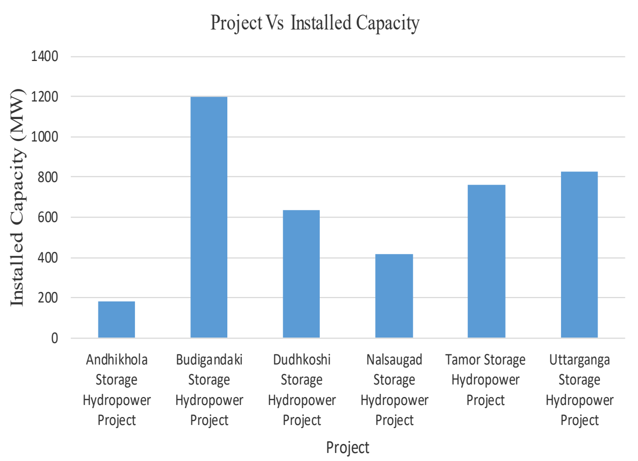

Figure 13.Project vs. Installed capacity

Budigandaki Storage Hydropower project of 1200 MW is the largest project in installed capacity whereas Adhikhola Storage Hydropower project of 180 MW is the smallest project in installed capacity in comparison with other projects under study.

Annual Energy Production

Annual energy production also indicates a project scale. In general, projects with large energy production are more preferable than those with smaller energy production. On the other hand, these projects have a tendency of having large installed capacity.

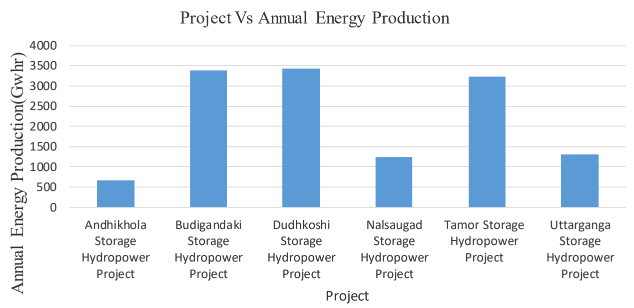

Figure 14.Project vs. Annual energy production

Dudhkoshi Storage Hydropower Project can produce 3443 GWhr of annual energy which is the highest energy production and Adhikhola Storage Hydropower Project can produce 674.5 GWhr of annual energy which is the lowest energy production among other projects under study.

Donor Interest

Storage hydropower projects requires huge amount of money for the development. To manage investment only by Nepal government is not possible for the development of storage hydropower projects. So, the storage hydropower project having donor will be advantageous for the development. Dudhkoshi Storage Hydropower Project is the only project among study project where Japan International Cooperation Agency (JICA) is interested to donate on the project.

Financial Indicator

The financial parameters such internal rate of return, B/C ratio etc., indicates whether the project is financially beneficial or not. The financial internal rate of return of Dudhkoshi, Tamour, Budigandaki and Nalsinghaud Storage Hydropower projects are 10.1, 6.19, 8.8, 8.92 respectively. Uttar Ganga Storage Hydropower Project and Adhikhola Storage Hydropower Project have negative return on financial investment.

Energy Production in Dry Season

Nepal has energy deficit especially during dry season. So, the storage project having higher amount of energy in dry season have more value in evaluation.

Impact on Natural Environment

Impact on Forest Area

Impact on the forest area is evaluated by the size of the affected forest area per unit output. In case many small projects are developed, the total lost forest area may be larger than the lost forest area by one project with large project area. Therefore, affected area per unit output is used for evaluation.

Adhikhola Storage Hydropower Project have highest impact on forest affecting 13878.28 ha (77.10 ha/MW) of land whereas Uttar Ganga Storage Hydropower Project have

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least impact on forest. Uttar Ganga Storage Hydropower Projects affects only 1331.5 ha (0.0707 ha/MW) of forest land.

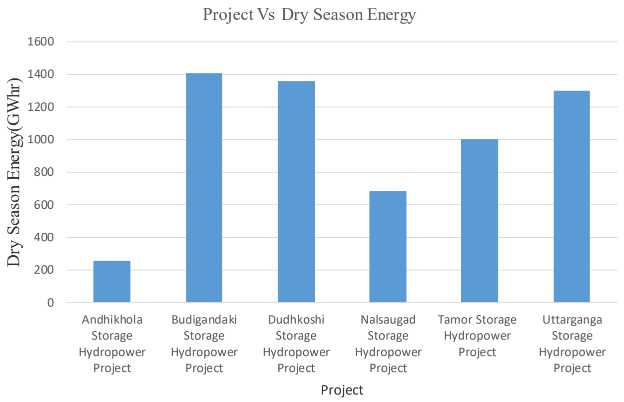

Figure 15.Projects vs. Dry season energy

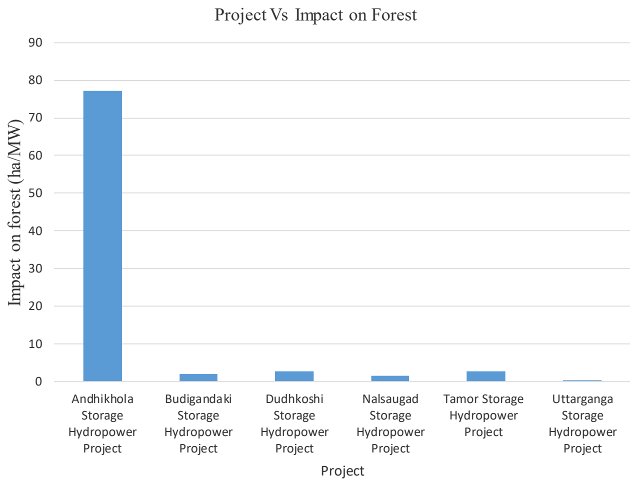

Figure 16.Projects vs. Impact on Forest

Impact on Protected Area

The World Heritage, National Park including its buffer zone, Wildlife Reserve, Ramsar Convention or Key Biodiversity Area are the protected area declared by government of Nepal. Dhorpatan Hunting Reserve Area lies on reservoir area of Uttar Ganga Storage Hydropower Project which is protected area. No any project under study other than Uttar Ganga Storage Hydropower Project lies on protected area.

Impact on Fishes

The impact on fishes is evaluated by the impact to water system. The number of species are affected by project construction lesser is the importance of project.

Adhikhola Storage Hydropower project has highest Nos. of impact on fish species. Adhikhola Storage Hydropower project impacts 34 Nos. of species of fishes. EIA of Tamor Storage Hydropower project is remaining to conduct so data for impact on Nos. of fish species by Tamor Storage Hydropower project is not known.

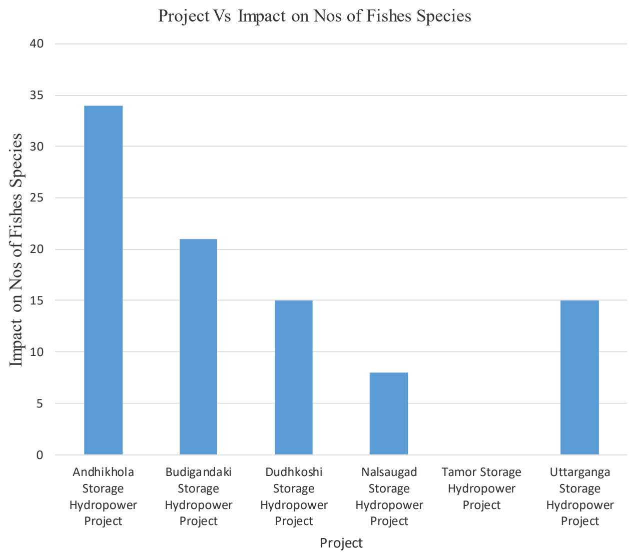

Figure 17.Project vs. Impact on Nos. of fishes species

Impact on Conservation Species

The impact on conservation species is evaluated by the impact to the seven rare land species. The rare species is identified from IUCN list.

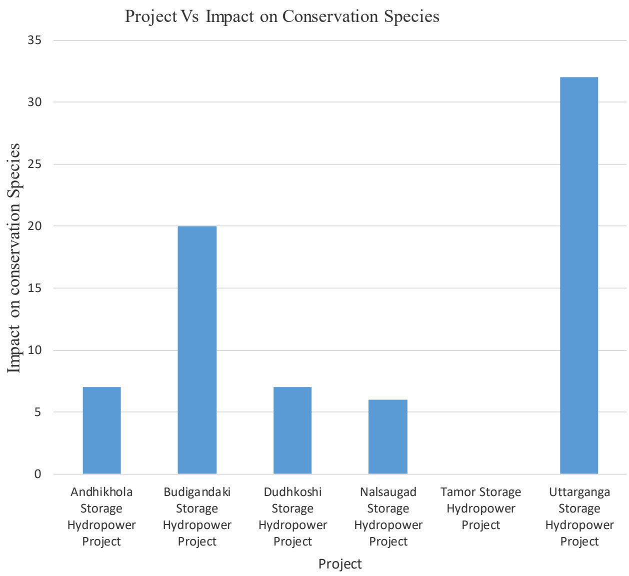

Figure 18.Project vs. Impact on conservation species

Uttar Ganga Storage Hydropower Project impact on larger nos of conservation species. This project impacts 34 conservation species. The data of Tamor Storage Hydropower project for the impact on conservation species is unavailable due to the reason that Tamor Storage Hydropower Project do not conducted the EIA study of its project.

Impact on Social Environment

Impact on Household

The impact on household is evaluated by the number of buildings located in project area. The number of buildings in the project area is taken from the EIA report of each project.

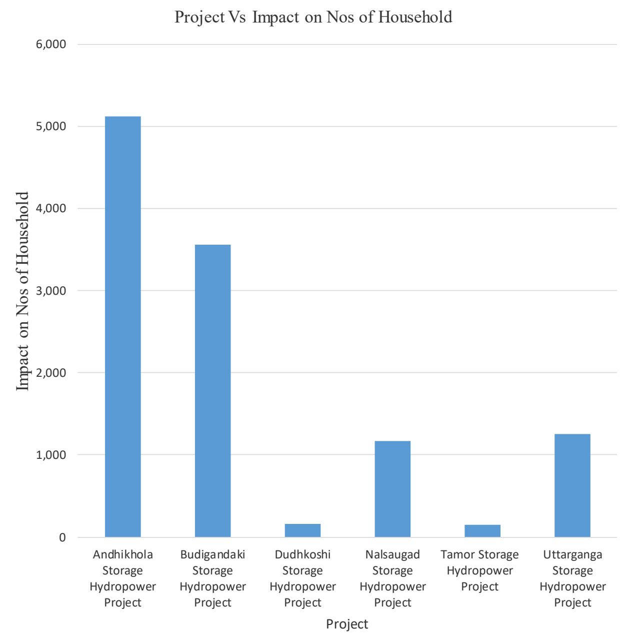

Figure 19.Project vs. Impact on Nos. of household

Five thousand one hundred twenty-one household will be affected by Adhikhola Storage Hydropower project. The Nos. of household inurned by Dudhkoshi Storage Hydropower project will be only one hundred sixty-four.

Impact on Agriculture

The impact on agricultural land is evaluated by the agricultural land area per unit output. The reason for using the area per unit output is the same as the evaluation of the impact on forest area.

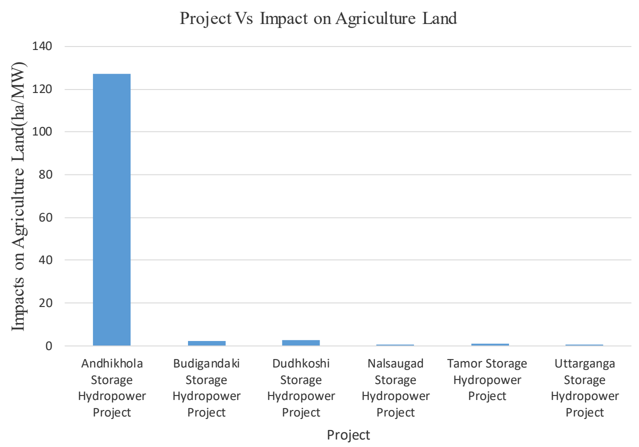

Figure 20.Project vs. Impact on agriculture land

Impact on the total area of agriculture land by Adhikhola Storage Hydropower project is 22869.689 hac whereas Uttar Ganga Storage Hydropower project impacts only 666.16 hac of agriculture land. Impact on agriculture land by Adhikhola Storage Hydropower project is highest and Impact on agriculture land by Uttar Ganga storage hydropower project is the lowest among other projects under study.

Impact on Ethnic Minorities

The impact on ethnic minority is evaluated by the number of affected ethnic minority.

For this evaluation, the ethnic minority is determined by the 84 caste groups.

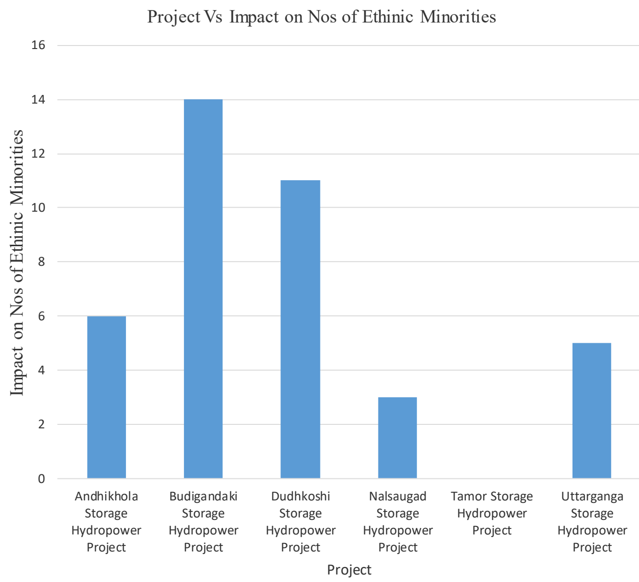

Figure 21.Project vs. Impact on Nos of ethnic minorities

Budigandaki Storage Hydropower project impacts 14 Nos. of ethnic minorities. The Nos. of ethnic minorities impacted by Tamor Storage Hydropower Project is not known.

Reliability of Resettlement Policy

The Project having Resettlement action plan to resettle the inundation household are evaluated with more importance. Dudhkoshi, Nalsaugad and Budigandaki Storage Hydropower Projects are the project having resettlement action plan among the study project.

Policy and Political

Storage hydropower projects are one of the political disputes between the various political parties. The change in policy by the government also effects the development of storage hydropower projects. The policy and political factors are mainly from the supply side. The government formulated the various existing policies based on its own view. The political situation also governs the development of hydropower. Four specific policy and political barriers are listed here for analysis. This sub factor has to be minimized. There are four policy and political sub factors considered.

- Changes in Policies

Frequently changes in the policies will affect the hydropower project. This sub factor has to be minimized. The project with holding generation license was given higher value of importance than the project with holding only survey license. The project having no license at all was given no marks. Tamour Storage Hydropower Project do not have licensee yet however all other projects under this study have survey license.

- Corruption

In developing countries, there is a high possibility of corruption and nepotism in various activities, which causes a delay in the public fund release process and leads to the misuse of public funds. This activity has to be minimized. The project having news about corruption on newspaper are less importantly noticed. News about corruption of Budigandaki Storage Hydropower Project was published on The Himalayan Times on August 30, 2019.

- Political Instability

In the case of Nepal, as there are divergent political mindsets at the central and local levels due to the constitution formation process, the government is not stable and the political leaders' commitment to hydropower development is weak. This sub factor has to be stable. The projects which lies in single province were given higher weightage and the projects which lies in more than one province were given least importance. Uttar Ganga Storage Hydropower Project is the only project among study project which lies in Gandaki province and Province No. 5.

Lack of Monitoring Authority

In the case of Nepal, monitoring authority is not active. Concerned authority has to be active and monitor all the project and accelerate the way out to reduce the energy crises. These activities has to be minimized by establishing a government monitoring unit. The projects which are donor funded and are under subsidiary company are given better importance. Nalsaugad Storage Hydropower Project is the only project among study project which is funded by JICA and is also the project under subsidiary company.

Uncertainties

With all types of technologies, the market can notice the risks and uncertainties, such as those posed by natural disasters, technical failures, conflict & controversial, political instability/ riots. There are four uncertainties sub factors considered.

- Natural Hazard

Natural events such as earthquake, flood which is not in control of human beings will also affect the storage hydropower project when will be moved in construction Stage. This results the time and cost overrun of the project. These activities have to be minimized by taking precaution. The projects having presence of active landslides are given relatively low weightage. Adhikhola, Budigandaki and Nalsaugad Storage Hydropower Project have presence of active landslide in their dam site area.

- Inundation

The projects which inundate other small projects are given less importance. Tamour Storage Hydropower Project inundates Lower Hewa Hydroelectric Project and Kabeli-A Hydroelectric Project whereas Adhikhola Storage Hydropower Project inundates the 9 MW Adhikhola Hydropower Project.

- Unforeseen Site Condition

Any conditions such cannot be estimated and occurs suddenly which is not in control of human beings will also affect the hydroproject. This results the time and cost overrun of the project. These activities have to be minimized by taking precaution. This criterion is not quantized by the researcher.

Table 3.Respondents from Adhikhola Storage hydropower projects

S. No.	Name of Project	Institution Holding license	Capacity of Project (MW)	Location	Rank
1.	Dudhkoshi Storage Hydropower Project	NEA	300	Khotang/ Okhaldhunga	3
2.	Tamor Storage Hydropower Project	NEA	762	Terhathum/ panchthar	2
3.	Uttar Ganga Storage Hydropower Project	NEA	828	Baglung	1
4.	Adhikhola Storage Hydropower Project	NEA	180	Syangha	4
5.	Budigandaki Storage Hydropower Project	MOE, Water Resource and Irrigation	1200	Dhading/Gorkha	6
6.	Nalsaugad Storage Hydropower Project	GEN, Company	410	Jajarkot	5

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- Unpredictable Weather

Weather cannot be easily forecasted which is not in control of human beings will also affect the construction project. This results the time and cost overrun of the project. This criterion is not quantized by the researcher.

- Respondents View on Alternatives/ Projects

The respondent was taken from each study projects. The format of form to fill the rank was developed and respondent were asked to fill that form.

Table 4.Respondents from Budigandaki Storage hydropower projects

S. No.	Name of Project	Institution Holding license	Capacity of Project (MW)	Location	Rank
1	Dudhkoshi Storage Hydropower Project	NEA	300	Khotang/Okhaldhunga	2
2	Tamor Storage Hydropower Project	NEA	762	Terhathum/panchthar	3
3	Uttar Ganga Storage Hydropower Project	NEA	828	Baglung	4
4	Adhikhola Storage Hydropower Project	NEA	180	Syangha	6
5	Budigandaki Storage Hydropower Project	MOE, Water Resource and Irrigation	1200	Dhading/ Gorkha	1
6	Nalsaugad Storage Hydropower Project	GEN, Company	410	Jajarkot	5

Table 5.Respondent view from Dudhkoshi Storage hydropower projects

S. No.	Name of Project	Institution Holding license	Capacity of Project (MW)	Location	Rank
1	Dudhkoshi Storage Hydropower Project	NEA	300	Khotang/ Okhaldhunga	2
2	Tamor Storage Hydropower Project	NEA	762	Terhathum/ panchthar	1
3	Uttar Ganga Storage Hydropower Project	NEA	828	Baglung	3
4	Adhikhola Storage Hydropower Project	NEA	180	Syangha	6
5	Budigandaki Storage Hydropower Project	MOE, Water Resource and Irrigation	1200	Dhading/ Gorkha	5
6	Nalsaugad Storage Hydropower Project	GEN, Company	410	Jajarkot	4

Table 6.Respondent view from Nalsinghaud Storage hydropower projects

S. No.	Name of Project	Institution Holding license	Capacity of Project (MW)	Location	Rank
1	Dudhkoshi Storage Hydropower Project	NEA	300	Khotang/Okhaldhunga	2
2	Tamor Storage Hydropower Project	NEA	762	Terhathum/panchthar	4
3	Uttar Ganga Storage Hydropower Project	NEA	828	Baglung	3

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4	Adhikhola Storage Hydropower Project	NEA	180	Syangha	6
5	Budigandaki Storage Hydropower Project	MOE, Water Resource and Irrigation	1200	Dhading/Gorkha	5
6	Nalsaugad Storage Hydropower Project	GEN, Company	410	Jajarkot	1

Table 7.Respondent view from Tamour storage hydropower project

S. No.	Name of Project	Institution Holding license	Capacity of Project (MW)	Location	Rank
1	Dudhkoshi Storage Hydropower Project	NEA	300	Khotang/Okhaldhunga	3
2	Tamor Storage Hydropower Project	NEA	762	Terhathum/panchthar	1
3	Uttar Ganga Storage Hydropower Project	NEA	828	Baglung	4
4	Adhikhola Storage Hydropower Project	NEA	180	Syangha	2
5	Budigandaki Storage Hydropower Project	MOE, Water Resource and Irrigation	1200	Dhading/Gorkha	6
6	Nalsaugad Storage Hydropower Project	GEN, Company	410	Jajarkot	5

Table 8.Respondent view from Uttar Gangastorage hydropower project

S. No.	Name of Project	Institution holding license	Capacity of Project (MW)	Location	Rank
1	Dudhkoshi Storage Hydropower Project	NEA	300	Khotang/Okhaldhunga	3
2	Tamor Storage Hydropower Project	NEA	762	Terhathum/Panchthar	2
3	Uttar Ganga Storage Hydropower Project	NEA	828	Baglung	1
4	Adhikhola Storage Hydropower Project	NEA	180	Syangha	6
5	Budigandaki Storage Hydropower Project	MOE, Water Resource and Irrigation	1200	Dhading/Gorkha	5
6	Nalsaugad Storage Hydropower Project	GEN, Company	410	Jajarkot	4

Conclusion

Present Scenario of Storage Hydropower Projects

The present scenario of storage hydropower projects under our research is that all the projects are under study. The projects under the research do not have construction license. Budigandaki Storage Hydropower Project is the only project which have completed its Detail Project Report (DPR). Dudhkoshi and Nalsaugad Storage Hydropower Project are ongoing DPR till date. Uttar Ganga and Tamour Storage Hydropower Projects have completed feasibility study and Adhikhola Storage Hydropower Project is still ongoing feasibility study. Tamour Storage Hydropower Project is the only project among the study project which have completed its feasibility study without issuing license. None of the project under our study have found investor except Nalsaugad Storage Hydropower Project. This present scenario of all these Storage Hydropower Project indicates that we still have to wait more than a decade to have them in operation mode.

Prioritization of Storage Hydropower Projects under Study in Nepal

The factors and sub-factors and Co-factors considered in the study model deserves its full value in the decision-making process. In accordance to the result of the study, the first priority is gained by the Nalsaugad Storage Hydropower Project, second by Dudhkoshi Storage Hydropower Project, thirdly by Uttar Ganga Storage Hydropower Project and Fourth by Tamor Storage Hydropower Project, fifth by Budigandaki Storage Hydropower Project and sixth by Adhikhola Storage Hydropower Project.

Similarly, if technical factor, financial factor, impact on environment, policy and political, uncertainties and respondents are taken into consideration alone Dudhkoshi stands first on technical and impact on environmental factor whereas Nalsaugad stands first on financial factor, policy and political factor, uncertainties and respondents' factor. The ranking of the project can be changed in future which is shown by sensitivity analysis of the projects with respect to factors.

Recommendations

- Recommendation of this research are as follows
- Outcomes of this research can be guideline for government agencies for further implementation
- The optimum thrust can be put on the first prioritized project i.e. Nalsaugad Storage Hydropower Project
- Authority should be given to project manager to run the project effectively as the result depicts in this research
- The research will help to know the location for the development of other infrastructures like roads, sub-station, and transmission lines

The result of this research can be used by ministry of finance for allocating budget among study projects.

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