RISK IDENTIFICATION AND ASSESSMENT FOR INVESTMENT DECISION MAKING IN SMALL HYDRO POWER PROJECTS OF UTTARAKHAND

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This Thesis I would like to Dedicate

My Husband

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

Neha Chhabra Roy

Sign:

Date:

Certificate

This is to certify that the thesis entitled “Risk Identification and Assessment for investment decision making in small hydro power projects of Uttarakhand” submitted by Neha Chhabra Roy to University of Petroleum & Energy Studies for the award of the degree of Doctor of Philosophy is a bona fide record of the research work carried out by her under our supervision and guidance. The content of the thesis, in full or parts have not been submitted to any other Institute or University for the award of any other degree or diploma.

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EXECUTIVE SUMMARY

With the fast growing economy and population, there has been a huge increase in energy demand in India. India ranks sixth in the world in total energy consumption. The rapid increase in use of energy has created a problem by defining a significant gap between energy production and consumption. Global declining of non-renewable energy brings future uncertainty in the energy supply to meet with an increase energy demand in India. To combat with future uncertainty in energy India has to meet with increased production of energy. However, given the raise of sustainable development concerns, there is the need to think about alternative sources of energy production, with a particular emphasis on renewable energy sources (RES) as India has a large amount of, supply of renewable energy resources.

Apart from the need to meet the increased energy consumption, there are several reasons for the growth of RES interest namely: the increase in fuel prices; the concern about protecting the environment of the impact of nefarious power generation through non-renewable sources (e.g., coal and oil); and the desire to reduce dependence on traditional energy sources (e.g. thermal). It is, therefore, imperative to develop new solutions for sustainable energy production combining economic development with environmental sustainability.

As in RES context, water resources is most economically viable solution as an alternative energy sources as India is monsoon dominated country. Water has been used for electricity production since early 70’s of the last century to ensure sustainable development and energy security. Although hydropower is a source of clean energy and renewable also, it has been neglected so far as this is not continued source of energy supply. The main obstacle is demotivation of investors, as SHP is low profit and risky project. As a result of the financial, economic and political climate of the country, the risk of the investment in renewable energy has increased. The unknown risks of small hydropower projects are discussed following a structural approach of identification of market, economical, technical, socio-economic and environmental risks.

A complete risk assessment procedure is likely to consist of five steps

1. Identification of the risk that is to be analyzed
2. A qualitative description of the problem and the risk – why it might occur, what you can do to reduce the risk, probability of the occurrence etc.
3. A quantitative analysis of the risk and the associated risk distribution options that is available to determine or find an optimal strategy for controlling and hereby solving the risk problem
4. Implementing the approved risk management strategy
5. Communicating the decision and its basis to various decision-makers.

Uttarakhand small hydro power project all risk variables are identified firstly from literature review and has been observed with the expert and officials of uttarakhand Small hydro power projects and investors, with average experience of 15-18 years in the form of semi structured interview. A total of 32 risk variables were found to be significant in Uttarakhand small hydro power projects such as generation, modeling techniques, terrorism, breakdown technical, operation & maintenance, electricity price, capital cost, clearances, machinery, tourist attraction, water quality, regulatory, interest rate, inflation, tax rate, employment, noise, precipitation, soil erosion, river flow, construction time, construction schedule, delay from suppliers, relocation, fund blockage, approvals, public.

Risk classification is another pertinent task as per this research, study area is decided only operational & construction stage small hydro power project. The classification of risks has been done based on responses of experts.

The essence of the traditional risk analysis approach is to give the decision-maker a mean by which he can look ahead to the totality of any future outcome. The advantage of using any risk analysis approach is the possibility of differentiating the feature of risk information in terms of outcome criteria such as Net Present Value (NPV), the Internal rate of Return (IRR) or the Benefit/Cost rate (B/C-Rate) by probability distributions (Hertz & Thomas, 1984).

In this study an assessment of investment related risks in small hydro power project in Uttarakhand state of India is evaluated using standard Monte Carlo simulation and Fuzzy logic approach. The main focus of this work is to analyse the importance of studying various risk parameters related to investment in small hydro power project-which is not a common investment practice performed in this particular area. Because of the stochastic nature of variables that compute NPV (net present value)/IRR (internal rate of return), it has some uncertainty which cause risk in investment decision. Apart from stochastic variables there are some external variables that are not stochastic by nature also influence on investment decision. Such external variables are identified based on literature reviews, expert interviews and field survey as follows: field geology, land use, environmental hazards, policy changes, social acceptance, etc. The relative importance of these factors are evaluated deterministically and ranked them accordingly.

Risks associated with operational & construction stage SHP investment are identified. These risk items serve as a checklist that cover possible risks associated with SHP investments in operational & Construction phase. Risk managers or investment decision makers can be informed and be able to recognize the risks associated with SHP investments.

Investment decision makers can predict the overall risk of the project investment entire as well as phase wise before start the investment. An overall risk index can be used as early indicators of project problems or potential difficulties. Evaluators can keep track to evaluate the current risk level with the progress of investments.

Moreover, it was assumed that if one project in the same phase if it is more risky so all the projects have similar risk. This myth is demolished with the help of this research where in the same stage two power projects in same geographical area contains different certainties reason behind this is variables considered for risk assessment varies in their relative importance in terms of severity and probability.

The greatest advantage of the applied method is that it quantifies all type of parametric and non-parametric risk factors with less computational complexity. Similarly the relative importance of all the risk factors was also identified. So even investors they get the idea that which factor is could be more problematic area as compare to others using tornado chart.

The risk managers can apply risk mitigation techniques based on those factors. Finally risk assessment was done computing Risk index values which show the phase specific risk which is not performed in this area so far. This estimation helps investors about the possibilities of risks in concerned projects. When dealing with the risk analysis problems, the predominance of new method has been showed: easier and more useful. Estimated Risk index further used for creating a new business model of investment is proposed to investors with less risk. Risk distribution for investors performed using Optimum portfolio and business models are discussed in chapter 6 which concludes this research.

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Moreover, it was assumed that the ‘‘weighting’’ assigned by each evaluator in the risk evaluation was the same, but the relative importance placed on certain factors by individual decision makers and experts could be widely different. Further research is needed to develop different ‘‘weightings’’ for different evaluators.

Risk distribution is the last analysis of this thesis. Risks are identified and assessed but for investors risk distribution is important task as to reduce the risk. Modern Portfolio theory and its foundations, the mean-variance model and the efficient frontier applied for investors of small hydro power project. The goal behind preparing an efficient and optimum portfolio for the investors of hydro power project to minimizes the risks of the investment and maximizes their return on that. Researcher hope to use the acquired knowledge on portfolio theory help investors to choose among different small hydro power projects and select the best one with estimated qualitative and quantitative risk analysis. Similarly using different concession agreements the investors can distribute their risk among private and public investors based on authority and power given to investors.

List of Symbols

α- Alpha

β- Beta

ω- Omega

σ- Sigma

ρ- Rho

p

N

P

Z

List of Abbreviations

ADB- Asian Development Banks

BCR- Benefit cost ratio

BOO- build own operate

BOT- Build Operate Transfer

BOOT- Build own operate transfer

BROT- build Rehabilitate operate transfer

BTO- Build transfer operate

CERC- Central Electricity Regulatory Commission

FL- Fuzzy Logic

HEP- Hydroelectric project

HT- Harmonious Tariff

IRR- Internal rate of Return

MCS-Monte Carlo Simulation

MNRE- Ministry of Non Renewable energy

MOEF- Ministry of Environment & Forestry

NPV-Net Present Value

PPA- Purchase Private Agreement

PPP- Public Private Partnership

RES- Renewable Energy Sources

SEB-state electricity Board

SHP-Small Hydro Power

UERC- Uttarakhand Electricity Regulatory Commission

UJVNL- Uttarakhand Jal Vidyut Nigam Limited

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CHAPTER 1

INTRODUCTION

The objective of this chapter is to host the research area and to sketch the research themes that lead the study. The research presented in this thesis is engrained within the current risk identification, assessment and distribution practices for risks in small hydro power sector literatures. It contributes to enhance the current practices used by investors with advance risk assessment theories and suggest better risk distribution methods to investors. Current literatures show that in Uttarakhand the investor's ignore risks in small hydro power projects.

1.0 Background of thesis

Hydropower represents use of water resources towards generation of pollution free and inflation free energy due to absence of fuel costs. Apart from the clean and cost economic nature of power, the other key advantage includes an inherent ability for instantaneous starting, stopping and load variations which helps in improving reliability of power system. Hydro power projects are generally categorized in three major segments i.e. small, medium and large hydro. Small hydro refers to hydroelectric projects with capacity generation less than 25 MW, which are typically canal based or run of the river type, while medium hydro refers to projects of greater than 25 MW and less than

100 MW are located on rivers and can be either of run of the river type or associated with large dams, whereas large hydro power projects have capacity more than 100 MW are located on rivers and associated with large dams.

A planned development of hydropower projects in India started only in the post independent era, with the first 50 years after independence seeing a hydro capacity addition of 21,644 MW, most of them being large hydro. Since the development was mainly in the Central sector and the State Electricity Boards (SEBs) were more or less tuned to the central planning system, relatively less importance was given to small projects.

1.1 Global view of Hydro Power Sector

India's potential of hydroelectricity ranked fourth following China, Brazil, and Canada. Whereas on the ground of installed capacity India ranked fifth because its utilization is only 18% of its potential (Flippani, 1988). Contrary Norway whose potential stands only one third of India's potential but installation exceed to 58% which creates benchmark for other countries. (Fig. 1.1).

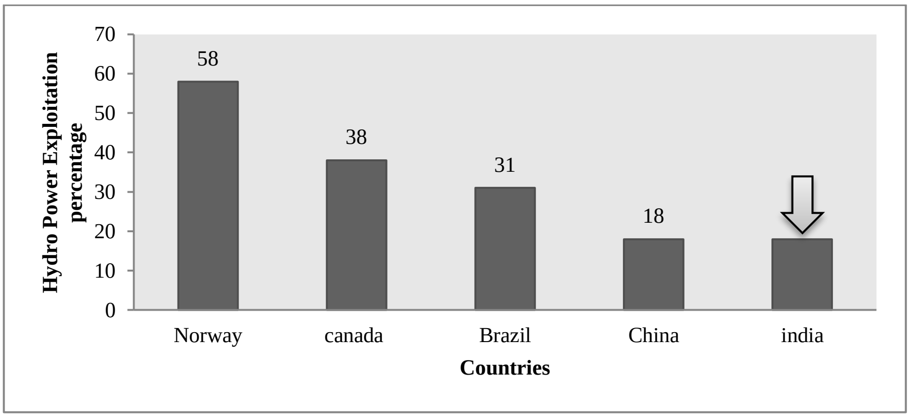


Figure 1.1: Percentage of Hydro Power Exploitation in Various Countries Percentage

In order to provide focused attention to small size projects, the subject of small hydro was brought under the purview of renewable energy. The decade of 90s saw a firm footing for the development of small hydro in India. Demonstration projects were supported throughout the country with new technical and engineering concepts to harness small, medium and high heads for SHP projects in hills as well as canals. Database of potential SHP sites on small rivers and canals was concurrently developed.

With the liberalized policy of the Government announced in 1995, there was a shift in the State Government policies to exploit small hydro potential through private sector participation. In view of the Electricity Act 2003 and National Electricity Policy 2005, 23 States announced policies to invite private sector to set up SHP projects. SHP projects are economically viable, environmentally benign and need a relatively shorter time for implementation and are less affected by the constraints or disadvantages associated with large hydro projects- namely deforestation and resettlement. The projects have potential to meet power requirements of remote and isolated areas where alternate sources of power are not available or are very expensive to use. These factors make small hydel as one of the most attractive renewable source of grid quality power generation. While Ministry of Power in Government of India deals with large hydro projects, the responsibility of small hydro development rests with Ministry of New and Renewable Energy (MNRE). Currently, most SHPs are supplying power to state utilities under long-term PPAs signed with state utilities. However, in the recent past a number of SHPs have opted to supply power under the merchant route or under the group captive route to harmonized tariff consumers where typically the realizations are linked to a mutually agreed discount to HT tariffs.

1.2 Indian Small Hydro Power sector

In five year plan the hydroelectricity is always considered to be prime motive of government to generate power from it, as in 10th five year plan government has targeted to harness 36000 MW, which will grow till 150000 Mw by the end of 14th five year plan around 2026-27(fig 1.2)

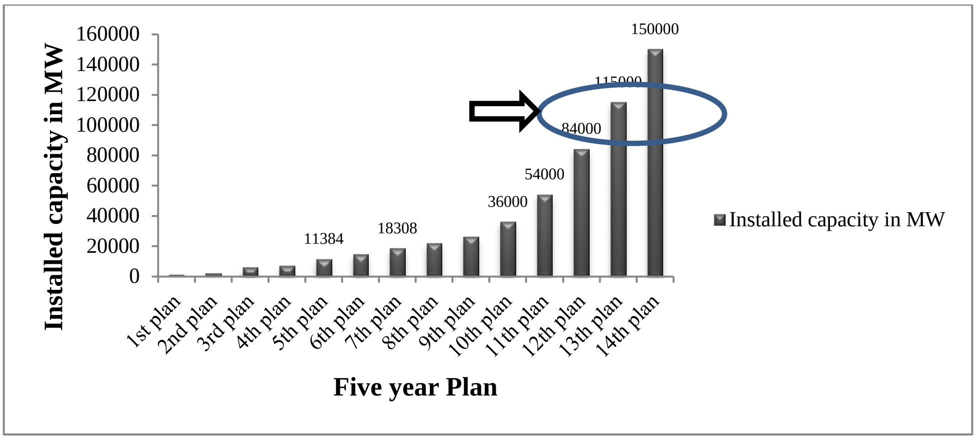


Figure 1.2: Hydroelectric Power Status with Five Year Plans

In order to provide focused attention to small size projects, the subject of small hydro was brought under the purview of renewable energy. Small hydro power sector in Indian context is defined as that hydro power project whose installation capacity is less than 25 MW. MNES is encouraging development of small hydro projects in the State sector as well as through private sector participation in various States.

Indian Small hydro power distribution region based among north, south, eastern, western & north eastern region distribution shows that major regions among small hydro power distribution is northern & north eastern region with 37% as mentioned in Fig1.3.

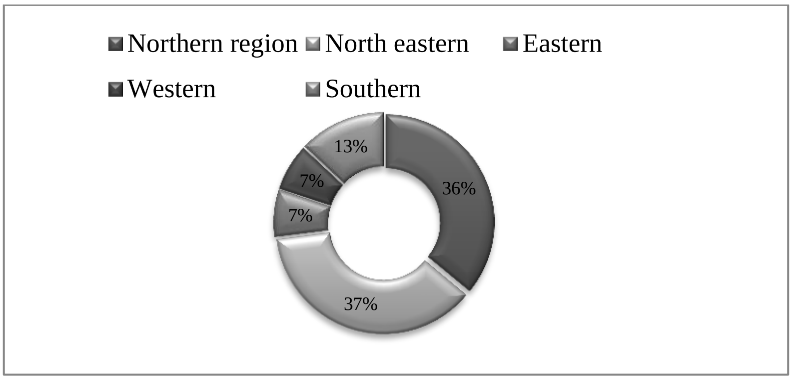


Figure 1.3: Indian SHP's Distribution Region Wise

In Northern region assessed potential for small hydro power projects is already 50.25%, developed proportion is 9.65%, under development stage is 3.53% and still 37% is balance which needs to be explored as shown in fig 1.4. Small hydro power project balance potential huge percentage indicates importance of this area which needs to be properly harnessed and make it useful for development of nation. Small hydro power project is renewable clean source of energy with low operational cost. Not only is this it also utilizing water resource for electricity generation so this is interesting area to explore.

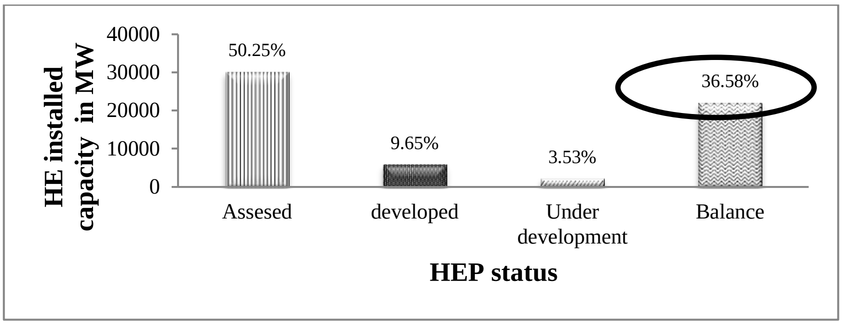


Figure 1.4: SHP’s Installed Capacity Potential in Northern Region

The major hydro power electricity generation states in India are Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Arunanchal Pradesh etc.

Installed capacity of Uttarakhand is more as compare to Himachal which is around 23% (fig. 1.5) so Uttarakhand is having more scope for harnessing the potential so it is to be chosen as a research area. (IEA Report, 2013)

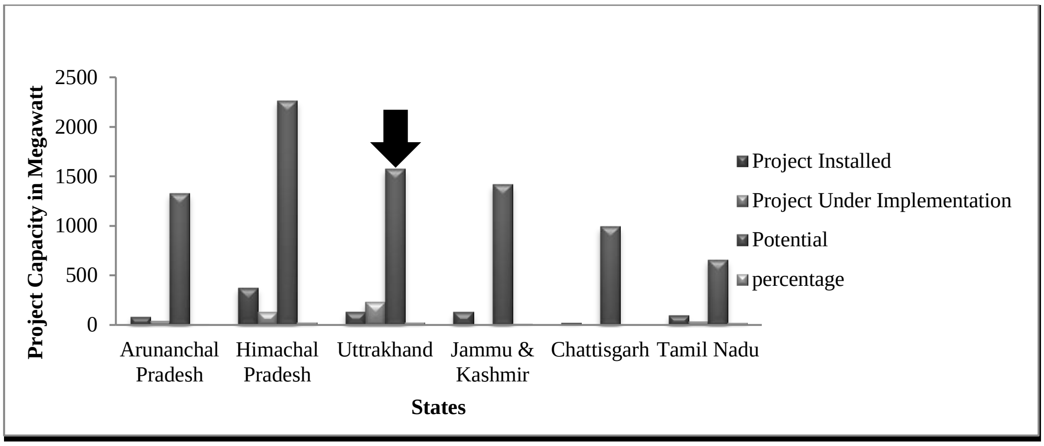


Figure 1.5: State Wise Estimated Small Hydro Power Potential of India as On 31-03-2013(In Mw)

1.3 Significance of Small Hydro power project

SHP schemes are mainly run- of- river with little or no reservoir impound. Although large as well as small hydropower are both clean source of energy compared to non-renewable fossil fuel energy; however, gigantic hydro projects built without regard to nature and man discredit hydropower and reduce its international social acceptance; small hydropower plants on the other hand can be extended in a sustainable environmentally - friendly and socially -compatible manner.

SHP provides decentralized development; therefore, most of the SHPs are located at remote areas, usually far from regional grid and therefore supply electricity to villages or small towns, cities, else otherwise the electricity supply are usually equipped with either diesel power or no supply at all. Some developing countries just started to construct SHP to replace diesel generating in rural areas to save foreign currency from importing diesel, therefore the installed capacity in many countries rises from few hundred KW to tens or hundreds of MW of electricity (Pejovic, Karney, Zhang, & Kumar, 2007).

SHP has low operational cost, easy maintenance and reliable power supply. Little environmental impact during construction, have social benefits like local economy development through promoting tourism in rural areas, irrigation, fisheries, etc. which stops rural people migration to cities.

Moreover, SHP is able to exploit energy from small river flow (river with catchment's area less than 500km^2), thereby, it actually enhances the potential of hydropower generation. Nevertheless investing in small hydro is not for ″fast money″ but for ″sustainable money″. But SHP project are highly capital intensive, so the main problem of developing small hydropower project is still its funding/financing, especially in its initial development stage. The main factor that stops financing in Uttarakhand is investment risk and the government policies and regulation for SHP development. As the growth rates of SHP observed during the past years both in terms of production and capacity have been rather disappointing compared to other developing countries . It was realized a tends to decrease the potential interest from investors in such projects. Moreover, in addition to the factors that influence the general economic activity, investments in renewable energy are affected by many other sources of risk. Thus, there is the need to identify which factors influence those investments and understand which are perceived as risk and uncertainty drivers in these projects in order to develop strategies that help mitigate those risks and to make this type of investment as safe as possible (Agrawal, 2012).

1.4 Small Hydro Power sector Uttarakhand

Uttaranchal Jal Vidyut Nigam Limited (UJVNL) was incorporated as a Company by the Government of Uttaranchal on 14th February 2001, under the Companies Act 1956. UJVNL manages hydropower generation at existing power stations, organizes development and promotion of new hydropower projects with the purpose of harnessing already identified and yet to be identified hydro power resources of the State of Uttaranchal.(Growth & Development Uttarakhand, 2012.) Uttaranchal is currently a net importer of electric power, but generates a seasonal surplus and plans to become a net exporter of power by 2015 by expanding its hydropower and high voltage transmission capacity. Total capacity expansion of 10,000 megawatts (MW) is planned through 2018(Hydro Power in Uttarakhand, 2012.). Currently 14 projects totaling 5,525 MW are under construction and expected to be commissioned by 2015. An additional 4,791 MW are under development, with expected commissioning dates after 2015, and another 9,090 MW are planned. Fig. 1.6 shows the projected annual and cumulative capacity additions from 2005 through 2018.

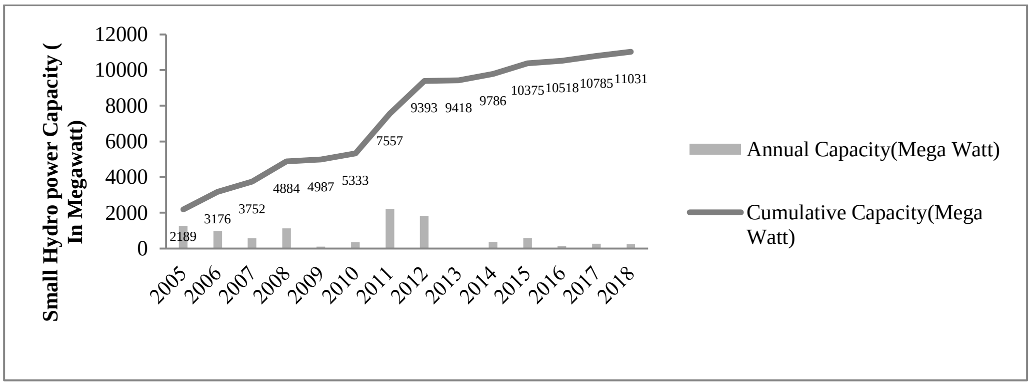


Figure 1.6: Planned Hydro Power Capacity Addition Till 2018

1.5 Investment Trend in small hydro power sector of Uttarakhand

Indian power scenario has major three constituent's thermal power, nuclear power and hydro power. In India the major participation of investment in power sector is from three different bodies Central Government, State Government & private participation. Table 1.1 clearly shows that in thermal sector capacity contribution in Indian power scenario is maximum; the role of hydro power sector comes next followed by nuclear sector. To attract large scale private investment, the Central Government has taken a sum of stages with the private sector to set up coal, gas or liquid based thermal, hydro, wind or solar projects with foreign equity participation up to 100% under the automatic route (Fig 1.7). An efficient investment for this sector is therefore essential task for the investors. Some of the changes originated by the government to create power sector investment attractive to private performers are introduction of open admittance, introduction of bidding competition, merchant power plant (no power purchase agreement, but risk should be borne by the developer)

Source/sector	Hydro	Thermal	Nuclear	Total	%AGE
Central Government	8,654	24840	3380	36,874	47%
State Government	3482	23301	-	26,783	34%
Private	3491	11552	-	15,043	19%

Table 1.1: Role of Central, state & private sectors in Power scenario in India

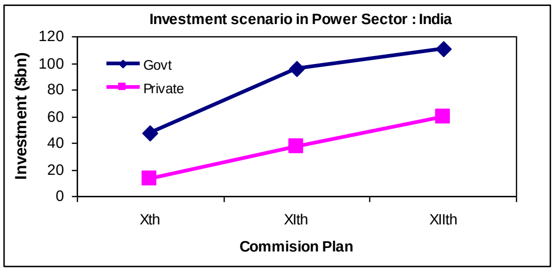


Figure 1.7: Investment in Power sector

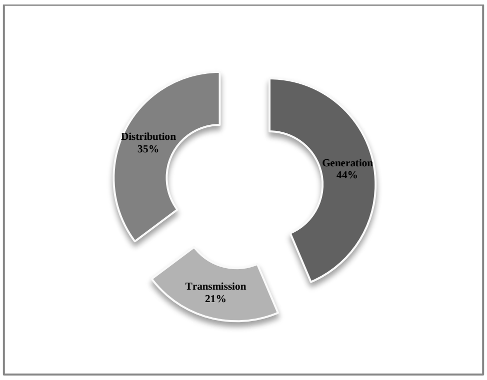


Figure 1.8: Distribution of SHP's Fund in Different stages

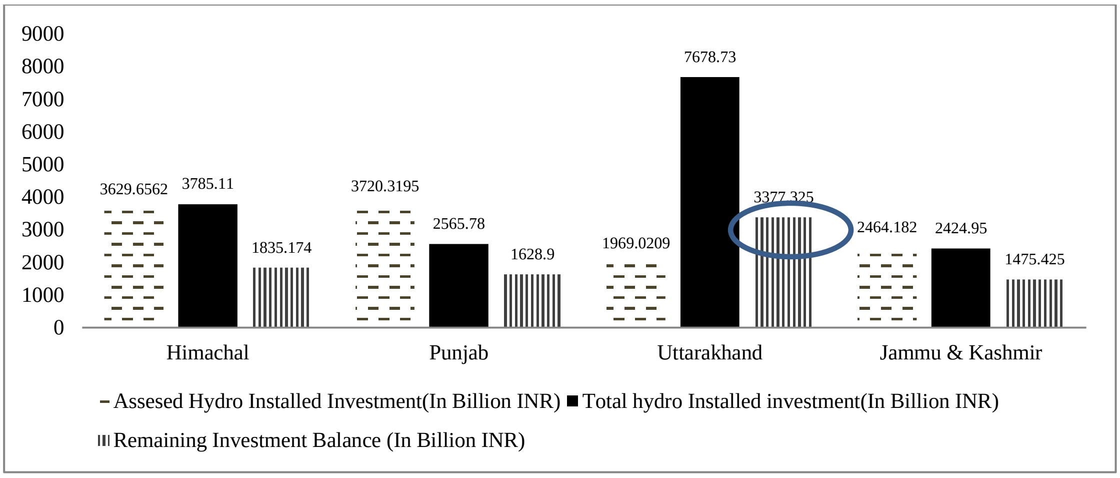


Figure 1.9: Northern Region Investment Potential in SHP's

The total investment potential and balance investment potential in uttarakahnd state is significantly high which makes this northern region as a source where huge investment potential persist. Investment trend in power sector based on five year planning commission report shows a constant rate of increase from private sector while the rate become little down after the XIth in the government sector, which reflects the increasing motivation of private partners in power sector business with time(Fig.1.9). The basic reason of such motivation is attributed to be new thinking in optimization of investment decision with the proper handling of risk/uncertainty of challenges associated with the area of interest (steyn,2006).

The central government & State government have developed workable and successful models for Public private partnership. At present India has 15 hydroelectric schemes with 1203 MW are in operation and 7 schemes with an installation of 2291 MW are under construction in private sectors. Further 73 schemes have been offered for development of hydro power sector by different states in the country. During 11th & 12th plan capacity addition through private sector would be around 23% & 24% respectively.

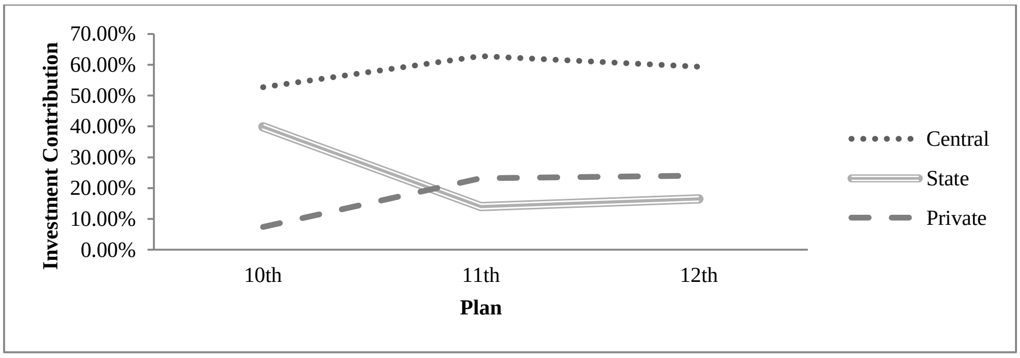


Figure 1.10: Central, State & Private Sector Contribution in HEP

Fig 1.10 shows the five year plan target to increase the potential around 150000 Mw by the end of 14th five year plan for that 50 lac crore is the fund requirement. The survey started and it cost around 5 lac crore. For each five year plan capacity addition the fund requirement is mentioned in fig1.11. For 11th five year plan the fund requirement is around 90000 crore where it increased till 175000 crore till 14th five year plan. The concept of public private partnership is supposed to announce for small hydroelectric power projects too.

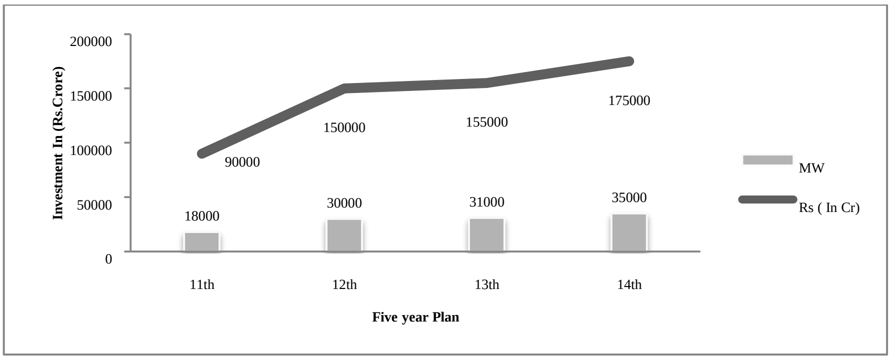


Figure 1.11: Investment projection Trend in HEP in India

Business Problem: Despite having huge investment Potential for small hydro power in the state of Uttarakhand, investors are not able to exploit it.

1.5.1 Investment Decision and investors perspective

- Proper investment decision-making is key to success for every investor in their efforts to keep pace with the competitive business environment.
- Risk plays a vital role, since investors are now directly exposed to the uncertain decision environment.
- The uncertainty (and risk) of an investment is increasing with the increased number of competing investors entering to market.
- The expected return on investment (ROI) of a decision quite often carries a high degree of uncertainty.

Researcher wants to create awareness to the investors from this study about the risks impact on their ROI and suggests suitable scenarios for investment.

1.6 Investment issues in power sector

The most serious issue facing hydro power sector is the fact that, despite the high power shortage that has continued over the past several years, there has been little progress in developing new power projects to meet power demand. Behind this is a negative spiral rooted in uttarakhand price regulation policy that keeps electricity prices. (Tohoku Electric Power Co., Inc., March (2010)

In particular, with regard to small-medium sized hydropower projects, many domestic private companies (particularly small and medium companies) from other industries flocked to the power sector in an investment boom in the midst of soaring economic growth, but with little know-how and experience in developing as well as unrealistic funding plans, in many cases construction had to be halted due to shortages of funds and the partially constructed waterway abandoned. Over the past 10 years of our consultation activities in Vietnam encountered numerous abandoned projects, but in fact of these there are many projects that could be restarted if the necessary technological support and funding could be provided. (Tohoku Electric Power Co., Inc., March (2010)

vann et al. (2013) infers that investment in hydro power remain limited in part of because of federal and nonfederal financial constraint, uncertainty in electricity generation, policy deregulations and price fluctuation. (Popovski, Gnjezda, Niederbacher, Naunov, & Milutinovic, 2000) concludes Considerable investment is needed to harness the potential of renewable energy and more efficiency energy use to reduce carbon emissions and provide energy essential for economic growth more investment required for economic growth. (Pejovic, Karney, Zhang, & Kumar, 2007b); (Kumar,R., 2006) mentioned investment in hydro power in Nepal is considered as best source for the development of women and children as well as societal development but major issue that faced my Nepal hydro power department is the policy deregulations. (Lundmark & Pettersson, 2007a) mention technical issues of modeling via proving that there is roughly a ten percent chance that the investment occurs in either t+5, t+10 and t+15, respectively in hydro power sector of Norway. (Ghosh & Kaur, 2002) highlights the two major challenges for hydro power investment as uncertainty and irreversibility he mentioned clearly that risk and uncertainty not highlighted in the modeling. (Zhang et al., 2010a) emphasis that a better investment model is always useful for investors as clarity about the risk and uncertainties mentioned. (Shahi, 2006) lukewarm response for investments in Indian power sector in last ten years has been the less reliability on hydro power DPR's, Environmental aspect, rehabilitation and resettlement issues, Dam security, construction time and creditworthiness of the sector. (Zhang et al., 2010b) Major challenges with this approach are input uncertainty and risk assessment. (Han, Kwak, & Yoo, 2008a) highlights on the infrastructure projects in electrical power industries have two important characteristics: one is taking much time and the other need of a big amount of capital. Therefore, a long time is needed for taking results from capital for performing any activity which needs large Investments. For this reason, it has a high risk for the investor. (Yang, 2007a) said that risks and uncertainties often compel investment in flexible power production technologies with short periods of ROI, brief construction times and the capacity to switch between fuels. (Filippini & Luchsinger, 2002) investments in the power sector in a regulated market and conclude that the possibilities to invest is better when electricity price is regulated, at least for projects requiring large capital investments per unit of output. The main problem for raising money for projects in the, small hydro power market is lack of investor confidence (Wiemann, 2011a).

Major Investment Issues in power Sector

- Cost variation occurs due to negligence of risk
- Better investment model give clarity to investors
- Reliability of detailed project report needs to be enhanced
- Create competitive environment for private investors
- Policy deregulations
- Risk ignorance
- DPRs need to enhanced
- Financing problem to investors

To sum-up all the above mentioned investment issues the conclusion drives to identify the various risks for the investors who have interest in investing but still they have lack of confidence of generating better profit to overcome this problem this research will help investors to invest in SHP's with more clarity and with less fear.

1.7 Motivation for the research

The private sector has been discover it enormously challenging to explain directing investment into new hydropower projects due to numerous issues that can compromise an otherwise functional project, such as social and environmental opposition, unwanted project risks, large upfront costs, long lead times and lower returns on investments, to name a few, as compared to other potential power projects.. In a privatized system, where new plants are mostly built on the build-operate-transfer (BOT) financing model, investors are readily drawn to the financing of thermal power plants (predominantly gas-fired) over hydro power plants due to their quick and relatively risk free construction periods, lower initial costs, less approval delay, and quicker returns on their investments.

More importantly, in attempting to privatize hydropower electricity, the public sector looks to passing on the risks involved in construction, operation and maintenance, to the private sector. This method has proven to be quite beneficial in less risky thermal power plant generation projects, however, hydropower presents a special case with a different set of risks that are unfavorable to the private investor, resulting in higher financing costs and ultimately the public sector bearing the costs. The reluctance on the part of private investors to assume all of the risks involved in hydropower finance is understandable, which leads to a more realistic probability of a public-private partnership, where the appropriate risks are shared and managed by both parties. Within the context noted above, this research intends to outline the major risks involved in the construction stage of small-scale hydropower projects, and the issues resulting from these risks in relation to private sector involvement and the need for appropriate risk-sharing in conjunction with the public sector and its institutions in order for hydropower to be financially viable. Hydropower projects face many of the same risks found in average thermal electricity generation development projects such as market risk, credit risk, simple construction and development risk, political risk, legal risk, force majeure risk, etc. However, hydropower is distinguished by geological and hydrological risks that are far greater than other power projects. These risks and mitigation measures will be discussed in the research.

Even though vast hydro power resources are available in the state and many projects are identified or already in the planning stage (under the heads of state, central and private market players) the realization of the projects lags behind the growing demand in the region. Due to various reasons that could be hydrology, geology, climate etc. Further most new projects are under the lead of private and Central Government companies which leaves only a minor share of their electricity to Uttarakhand. Under this consideration the planned projects of about 1850 MW are not going to close the current gap between the demand and the existing stations nor will this capacity be enough to serve the annual increase of demand. Similarly new generation capacity from central generating stations is also not expected to contribute considerably due to Uttrakhand's low share. Therefore any future capacity addition which provides electricity for Uttarakhand can be easily absorbed by the market by serving suppressed demand or replacing more expensive power imports.

Globally the potential of hydro power is harnessed more as compare to India, though India for hydro power potential comes under top five countries but harnessed potential is very less. The one of the influential issue comes with literature study as gap in the risks study as risk identification and assessment is missing. Uttarakhand is lagging in risk identification and their proper quantification and incorporation of all those identified risks into proper framework. This research helps to bridge the gap between, investor perception towards risk and it also give clarity about the various investment decision makers.

- Concern with the big loss in government revenue generation.
- Increase of energy demand, especially “clean energy”.
- Attract more investors.
- Promoting conductive conditions for private sector investment.

1.8 Research Question (RQ)

Central Research Question

What are the risks and how it can be assessed in SHP’s of Uttarakhand?

Research question Q1: What are the various investment risks during construction and operation stage of small hydro power projects of Uttarakhand?

Research question Q2: What is the assessment of identified risk in construction & operation stage of SHP’s of Uttarakhand?

Research question Q3: What is the risk distribution for investors in SHP’s of Uttarakhand?

1.9 Research objectives

The objective of the present research is to present a real valuation framework for analyzing a renewable energy investment, a hydroelectricity power generation in Uttarakhand, in a transition economy. The framework will quantify the major sources of risks on investment.

1. To identify investment risks during construction and operational stage SHP's of Uttarakhand.
2. To assess the identified risk impact in construction & operation phase SHP Projects of Uttarakhand.
3. To distribute investment risk for investors in SHP's of Uttarakhand.

1.10 Research Problem

What are the investment risk factors and how risk assessment & risk distribution can be applied for investors of Small Hydro power projects in Uttarakhand?

1.11 Chapter overview

The literature review in Chapter 2 draws on the academic literature on risks, risk identification, assessment and distribution current practices and investment decision-making based on risk assessment to highlight the gaps in the existing literature that the research questions presented above are drawn from. It is structured so that attention is focused on the source of each of the research questions in turn.

Chapter 3 outlines the methodology adopted in the research. The current study employs qualitative & quantitative methods for data collection and a combination of mechanisms for data analysis. The qualitative method of detailed literature review and semi-structure interviewing for risk identification followed on historical data analysis and structured questionnaire is used for the risk assessment processes. Parametric portfolio theory is employed to create optimum portfolio for investors of hydro power projects.

Each type of analysis is evaluated in terms of their suitability for the study of risk assessment investors decision-making.

Chapter 4 draws on the small hydro power sector literature to provide a brief description of the context of the current study that highlights the main challenges facing the small hydro power sector investors in the 21st century. Since the current study is located in the Uttarakhand, India. Firstly the investment risks of Uttarakhand small hydro power projects are examined and further classified phase specific as construction and operational stage. The assessment is further categorized based on qualitative and quantitative risk factors using Monte Carlo simulation and Fuzzy logic approach. Finally the portfolio theory is used for creating optimum portfolio for investors of hydro power projects of Uttarakhand. This study indicates the hidden risks in small hydro power projects and highlights how to make it useful for investors with available risks.

While Chapter 5 primarily draws on primary and secondary data sources, it is presented as a significant contribution to this thesis. It presents the first set of findings from the research interviews further the questionnaire survey response are used to assess risks using fuzzy logic approach. It draws on the interview data to provide available risks in small hydro power projects which impacts investor's decision-making. In particular, the qualitative risk factors which are not quantified are assessed in this chapter using fuzzy logic. The findings confirm the trend observed in previous quantitative research studies that there is a gap between current theories of risk assessment. Risks are quantified in different stages of SHP’s and then relative importance of each risk factor is estimated.

Chapter 6 uses the data presented in Chapters 5 in which risk was quantified for operational and construction stage is further used to distribute risks using optimum portfolio and concession agreement methods. Distribution of investor’s contribution in small hydro power projects is decided according to mean variance portfolio. With use of these concept decision analysis techniques in investor’s decision-making in hydro power project is enhanced. This methodology is used for risk distribution of investors either in two different projects or among different type of investor’s.

The final chapter, Chapter 7, brings together the information gathered for the thesis and provides the answers to the research questions posed in Chapter 1. It sets out the conclusions that can be drawn from the research. In particular, the implications of the results to the debate on available risk, their impact and their distribution in small hydro power projects. The limitations of the research presented in this thesis are discussed and this leads into the identification of areas for future research that arise from the current study.

CHAPTER 2

REVIEW OF LITERATURE

2.0 Introduction

The literature review cover under this research in major themes of small hydro power sector with admiration to investment potential, investment issues, risk identification, risk taxonomy, risk assessment, need of fuzzy logic for risk assessment, risk distribution. Seven dominant themes of the literatures have been undertaken in depth study of business problem. In alignment to objectives the pertinent themes have been funneled down to risk identification, assessment and distribution. The literature review concludes with Risk return trade-off and optimum risk distribution which proceed further for risk mitigation and management. Pertinent themes were considered for answering research questions raised in the Introduction chapter. It draws on the existing academic literature on risk assessment and investment decision making to best fill the gaps in this literature that the research questions presented in Chapter 1 are drawn from. The literature review is structured so that attention is fixated on the source of each of the two research questions sequentially.

Investment decsion making is a process which organizations follow for better market share (S. M. H. Hosseini, Forouzbakhsh, & Rahimpoor, 2005a);

(Lundmark & Pettersson, 2007b), (Geetanjali Mittal, 2004). There are many investment related issues small hydro power sector investors come across as negligence of risks, improper assessment of identified risks, poor investment models, flaws in detailed project reports, competitive environment, policy deregulations. The authors (Kucukali,S.; 2011b) (Schwartz, 2012); (Pasha & Nasab, 2012); (Jayant Sathaye (USA), Oswaldo Lucon (Brazil), 2012a); (Pejovic et al., 2007a); (Zhang et al., 2010c); (Lundmark & Pettersson, 2007b); (Heggedal, Linnerud, & Fleten, 2011a); (Soni, 2011); (Zhang et al., 2010a); (S. M. H. Hosseini et al., 2005a) identified above mentioned issues during their study on Hydro power sector. Negligence of risk and improper assessment of risk are prime faces for investors of SHP's.

Authors (Deng, Su, Jiang, Xu, & Xu, 2010a); (Naik & Rathod, 2008a). (Walke, 2012a) in their study of risk identification defined Risk as outcome of an uncertainty whose impact is negative. Many risk factors were identified and analysed in different areas from time to time.(Pejovic et al., 2007); (F. Report, 2007); (Salling, 2005); (Parandin, Seidzadeh, & Hamedi, 2013). Globally many researches portray risk identification in various areas as infrastructure, construction, project. (Kucukali, 2011); (Saxena, 2006); (Maingi & Marsh, 2002); (Ghosh & Kaur, 2005).

Risk identification study start with global literature available on small hydroelectric power projects risks which further narrowed down to India and Uttarakhand. Few studies based on hydro power risk identification are also available. (Uhr, 2006); (Bhattacharyya, 2007); (Fleten & Heggedal, 2009). There are few authors who identified investment related risks in hydro power projects globally. (Heggedal & Linnerud, 2004); (Meeting, Ggf, Workshop, & Power, 2012a); (Fleten & Heggedal, 2009b). In Indian hydro power projects some of them have worked on investment related risks identification (Saxena, 2006b) but this area is not explored widely. The small hydro power projects are classified into different segments where investors are associated as pre construction, construction, operation and Renovation & Modernization ("Renovation and Modernization for Hydro Power Stations," 2001). Details of all these stages are explained in chapter 3. Investor risks, their impact and severity changes respect to phase. So far no study performed globally which highlights phase specific risk identification and risk assessment. (Nilsen & Aven, 2003);(Shang & Hessen, 2013).

In diverse projects risk identification as well as quantification or assessment was performed by authors (Harinarayana et al., 2006a); (Kolberg, 1990); (Wang, 2003) ;(Agrawal et al., 2003); (Chan, Chan, Asce, & Yeung, 2009); (Swainson & McGregor, 2008a). (Rode & Dean, 1982); (Geetanjali Mittal, 2004); (S. M. H. Hosseini et al., 2005a); (He, 2010a); (Yang, 2007b); (Zhang et al., 2010a); (Wittwer, 2009a); (Gains et al., 2002); (Jain, 2010); used some significant strategies for reduced risk using above assessment tools and move towards better investment decisions.

(Fleten, Fuss, Heggedal, Szolgayova, & Christian, 2010); (Harrison, Whittington, & Wallace, 2007); (Zhang et al., 2010a); (Kai & Tiong, 2008a); (Gains et al., 2002) applied Monte Carlo simulation for risk assessment in infrastructure projects and they found as one of the best methods available for estimating the uncertainty. The assessed uncertainties recognize the risks involved with these types of projects.

Fuzzy logic is another approach for risk assessment was used by (Kucukali, 2011) in small hydro power sector. (Cheung & Kaymak, 2008a); (Jenab & Ahi, 2010a); applied fuzzy logic only in the area of risk assessment in other areas. No studies so far come across in Indian context who has applied fuzzy logic as risk assessment tool for investment decision making in hydro or small hydro power sector.

Major risk factors were identified with reference to small hydro power projects such as price, market, river flow, operation & maintenance, climate, electricity prices, technology, clearances, environmental, socio-economic, interest rate etc. addressed by (Kucukali & Report, 2011a); (Ghosh & Kaur, 2005); (Berchmans, 2013a); (Zelenakova, Zvijakova, & Purcz, 2013a); (Pejovic et al., 2007a); (Knutsen & Poulsen, 2010a); (Heggedal & Linnerud, n.d.). There are some studies available which highlights important risk variables for Uttarakhand region for Ganga, Yamuna & Bhagirathi basin too as climate, policy, clearances, socioeconomic (Joshi, 2007a); (Indian Institute of Technology, 2007); (Bank, 2006).

Logically the literature review of Risk identification was followed by risk assessment which is equally important area for risk analysis (Gajewska & Ropel, 2011).This study has covered existing risk assessment practices observed globally as well as in uttarakhand in small hydro power projects,. Current practices of risk assessment shows that many theories for risk assessment are avialable globally as deterministic, probabilistic, stochastic and strategic approaches (Pasha & Nasab, 2012b); (Zhang et al., 2010a); (Fleten et al., 2010); (Khcherem & Bouri, 2009); (Angulo-fernández, Aguilar-lasserre, González-huerta, & Moras-sánchez, 2011); (Angulo-fernández et al., 2011); (Deng, Su, Jiang, Xu, & Xu, 2010b); (Dhillion, 2012); (Popovski et. al., 2000); (Planning commision, 2011); (Castaldi, Chastain, Windram, Ziatyk, & Sciences, 2003a); (Swainson & McGregor, 2008b); (Madlener & Ediger, 2004) .They applied various tools as NPV, IRR, LCC, CBA, scenario, sensitivity, Monte Carlo, fuzzy logic under different risk assessment theories

Once the risks are identified and assessed the risk distribution gives relief to investors as it transfer the risk of investor. Global literature on risk distribution has shown major three theories for risk distribution as portfolio theory; concession agreement & Extreme value theory. (Tongtao & Cunbin, 2014a); (Cheung & Kaymak, 2008b); (Bansal, 2012). Uttarakhand small hydro power projects does not follow risk distribution strategies as it is new practice suggested in this area hence no such literature was available for Uttarakhand.

Identified risk is applied in portfolio theory to aware investors about the optimum proportion of investment in different projects are the conclusive remark of this study. Many studies portray application of portfolio theory for creating optimum risk profile for investors from ages. (Tongtao & Cunbin, 2014b); (Zhang et al., 2010c).The application of optimum portfolio theory is not found in the area of small hydro power project investors so far globally.

India is 5th largest in potential of hydro power and preceding Norway and USA details are mentioned in chapter 3. These first world countries are harnessing hydro power more wisely. Current practices of Norway and

Canada show they apply proper risk assessment to attract more and more investors (Fleten, Juliussen, & Revdal, 2007a); (Kalantzopoulos, Hatzigeorgiou, & Spyridis, 2008). They also come across with major uncertainties as market, climate, policy and price (Fleten & Heggedal, 2009b);(He, 2010b);(Heggedal & Linnerud, 2008). They used advanced tools as Monte Carlo, Bayesian approach, decision tree for risk assessment and decision making.(Tuna, 2013);(Kalantzopoulos et al., 2008);(Lundmark & Pettersson, 2007).

India is rich in hydro power potential and investors are willing to invest still investment issue proper risk assessment arises. Possibility of risks, their impacts and severity changes with region but proper risk assessment is always useful to attract investors. All these demonstrate by the research reviews to work in this way will be helpful for small hydro power project of India as well. To fill the gap this research will put new light for risk assessment in small hydro power area of Uttarakhand.

Hence with detailed literature review of risk identification, assessment and distribution in small hydro power projects, it is concluded that there are no specific literatures available for risk distribution of Small Hydropower Project, particularly in Uttarakhand. On the other hand limited literature availability of risk identification and assessment for Uttarakhand region which included Ganga, Yamuna & Bhagirathi basins have been considered for this study.

2.1 Investment Decision Making

Executives do many things in addition to making decisions, but only managers make decisions. (Lundmark & Pettersson, 2007), thus the first managerial skill is to take effective decisions. (Noor-E-Alam & Doucette, 2010). Better investment decision making raise the market share of the sector (Zhang et al., 2010a). Therefore Investment decision making is a critical task for whole organization as business of the sector depends on right decisions. One wrong investment decision change scenario of organization (Chhabra & Mishra, 2011). Many factors and variables assimilate together for better investment decision (He, 2010b). Ignorance or negligence of factors may create trouble for company. As two important features in Infrastructure projects in electrical power industries are time and huge capital requirement if neglected change the profit of business (Nilsen & Aven, 2003b). Similarly many studies shows with ignorance of major or minor factor created destruction (Banerjee, 2006); (Knutsen & Poulsen, 2010b).

In chapter 1 major investment issues were highlighted in which risk is focus area. Risk is hidden behind every project which sometimes not noticeable clearly or sometimes deliberately avoided due to obsolete nature. It has been observed that every investment displays more or less risk (S. M. H. Hosseini et al., 2005). Therefore, much time is needed for taking right and effective decision. It was detected in small hydro power investor's opinion that change in business strategy will change the future level of ambiguity (Zhang et al., 2010a).

(Maingi & Marsh, 2002b) highlighted in his research on hydro power sector that 88% of respondents believe that their current risk structure is not suitable to meet future challenges. One of the vibrant reasons for risks in projects due to huge business competition and market economy (Möst & Keles, 2009). As a result, recent research in investment decision making is undergoing a paradigm shift with much integration of new techniques with existing methods to develop robust decision making processes. (Lundmark & Pettersson, 2007b)

2.2 Issues in Hydro Power Sector

Indian hydro power sector is one of the upcoming and flourishing areas in renewable energy. The contribution of power sector in Indian GDP is discussed in chapter 4 which is increasing. The investment in this area need to be enhanced .To attract more private investors Government of India is putting fruitful efforts. This sector is still under the umbrella of few investment issues that need to be explored, to find the reason why investors are not contributing effectively to expand the sector. The need for identifying investment issues in hydro power sector is raised.

(Fleten & Heggedal, 2009b); (Zhang et al., 2010a) Various investment issues addressed time to time noticed lukewarm response in power sector from last ten years. They mentioned that investments has been reduced due to less reliability on Hydro power reason behind this is environmental aspect, rehabilitation and resettlement issues, dam security, high construction time and creditworthiness of the sector. (Soni, 2002);

(Zhang et al., 2010a)(Heggedal & Linnerud, 2005); in his research on hydro power sector found that better investment model is always a challenge for investors. Targeted policy uncertainty that stop investors to invest in power sector. They concluded that the possibilities to invest in power projects are better when electricity prices are more regulated. The price regulation must be under control in hydro power project which require large capital investments.

(Pereira, Campodónico, & Kelman, 1998); (He, 2010b); (Maingi & Marsh, 2002b) Mentioned in their study that business fluctuations not permitting investors to retain with the sector. Business models keep on changing. Some government supports build own operate model; and few supports Build own transfer model, so flexibility abandoned in the mind of investors mentioned that it was also seen that Tariff regime for electricity, regulatory, legal, and governance frameworks keeps on changing and uncertainties arises because of that.

(S. M. H. Hosseini et al., 2005a); (Zhang et al., 2010a); (Pindyck, 1990a) mentioned that in hydro power dam construction is huge capital and time consumption project so investors are scared to invest. (Sørensen, 1974) shown that Investment in hydro power remain limited in part of because of federal and nonfederal financial constraint. (Madlener & Ediger, 2004); mentioned that flexibility arises in investment due to flexible power production technologies with short periods of return on investment, brief construction times and the capacity to switch between fuels. (Mittal, 2004); there is roughly a ten percent chance that the investment occurs in either t+5, t+10 and t+15, respectively in hydro power sector of Norway so construction schedule is creating a problem. (Kumar R., 2012). (Madlener & Wickart, 2006); mentioned that in hydro power dam construction is huge capital and time consumption project so investors are scared to invest. (Sørensen, 1974) shown that Investment in hydro power remain limited in part of because of federal and nonfederal financial constraint. (Hossain, 2007); mentioned that flexibility arises in investment due to flexible power production technologies with short periods of return on investment, brief construction times and the capacity to switch between fuels. (Arid, 2000) there is roughly a ten percent chance that the investment occurs in either t+5, t+10 and t+15, respectively in hydro power sector of Norway so construction schedule is creating a problem. Investment in Hydro power in Nepal is considered as best source for the development of women and children as well as societal development but major issue that faced my Nepal Hydro power department is the Policy Deregulations, found other challenge with hydro power projects are socio economic factors that create cost overrun.

(Schwartz, 2012); (Zhang et al., 2010); considered that Substantial investment is needed to harness the potential of renewable energy and more efficiency energy use to reduce carbon emissions and provide energy essential for economic growth, so the constraint are environmental and economy are major concern. (Girmay, 2006);Showed in his research that how Due to the lack of proper planning, proper implementation of those planning, lack of good understanding and wrong way of analysing the result, the development of hydropower is not fast enough as it restrict for further investment.

The various investment issues in small hydro power sector were highlighted by researchers in this section. Either it is policy, business, environment; or market but all creates dilemma in investors mind to go ahead or not. These all tributaries converged to one river called risk, which is either not identified or partly identified. Parallels if it is identified its assessment is not up to the mark. Resulting gives wrong picture to the existing investors so new investors think cautiously and out of that only 20% are converted rest change their mind and invest in some other area. This is not a good sign for power sector and Indian economy. To overcome this problem this study bridges the gap between investment decision making in small hydro power projects of Uttarakhand and proper risk assessment.

2.3 Risks

Risk is an integral part of any project weather big or small, hydro power project is large infrastructure project having huge capital investment and longer duration associated with it so the possibility of risk and uncertainties are also increased. Hence understanding of risk with its definition, nature and features is essential to know.

Many authors describe risks in one or other way as (Knutsen & Poulsen, 2010b) describes risks as a situation where probabilities cannot be objectively assigned and where all future contingencies may not be known. (Filippini & Luchsinger, 2002); (Jayant Sathaye (USA), Oswaldo Lucon (Brazil), 2012b) explained risk as uncertainty that occurs in future which needs to be coped so as to evade variation of penalties ranging from negative wonders to enduring loss. (Simu, 2002); (Júnior & Reid, 2010) well-defined Risk is "the likelihood of carrying about misfortune or loss" which also bears the same meaning as "threat, exposure, downside, jeopardy and uncertainty",

(Kristiansen, 2006.); (Salling, 2005) defined Uncertainty is intrinsic in all management supervisory but mostly relevant to the investor where the claims of their decisions are regularly very substantial for the organization. Even if risk may have both contrary and promising values according to this definition, risk-based methods are frequently focused on its negative outcomes.

(Harinarayana et al., 2006) defined Uncertainty is a rare state of nature categorized by the lack of any evidence connected to an anticipated outcome while (Heitsch & Römisch, 2007) Holmes (1998) stated that it is state of affairs where the investment decision maker can recognize each probable outcome, but does not have the required data to regulate the Chances of each possibilities. (Macmillan, F. 2000) defined risk is the commission of the probability and results of an uncertain happening. Even though the idea of "risk" is well-defined and come near inversely by different opinions, inside the background of construction projects, it is generally defined as the probability of occurrence of events that may positively or negatively affect the project's predefined objectives. (S. A. Hosseini, 2011) explained the intangible benefits are not included in this economic analysis of the project, but naturally a more desirable result will be obtained for the economic indices when taking these factors into account. Risks and uncertainties repeatedly force investors to become flexible in different modes of investments. (Yang;2007).

Above mentioned thoughts by many authors clarify that uncertainties which creates risk is somehow not good for investor's. Investor should consider risk impact and severity prior for moving further in the project. In this series risk management process starts this phenomenon where majorly risk identification and analysis is the focus area for this study.

2.3.1 Risk Management Process

This thesis give insight to better investment decision making for investors moving around risk, so before going towards investment decision making risk management process is the systematic process of identifying, analyzing, and responding to project risks, supporting the integration of RM processes with companies' routines and with project environments. (Walke, 2012b); (Deng et al., 2010b). RM as a systematic and formal process which should be conducted throughout the life of a large scale project which comprises of three phases, namely identifying, analyzing and responding to the project risks, (Angulo-fernández et al., 2011).

(Wang, 2003) described Risk Management process as a four-step systematic approach including risk classification, risk identification, risk assessment, and risk responses phases. The most effective approach toward the RM of large scale projects is the process consisting of the following five steps: 1) Risk Identification, 2) Risk Analysis, 3) Risk Evaluation, 4) Risk Response, and 5) Risk Monitoring,6) Risk Distribution H.Zhi, (1995) and (Bertani, 2012a).

(Edwards, 2009) mentioned the importance of the risk-related knowledge after the accomplishment of each Risk Management cycle. Six subsequent phases as the necessary steps for RM, namely 1) Establishment of the Context, 2) Risk Identification, 3) Risk Analysis, 4) Risk Response, 5) Risk Monitoring and Controlling, and 6) Capturing Risk Knowledge and distribution. In this way the Project Risk Management started from three to ended as six step process. (Han, Kwak, & Yoo, 2008b)

(Eybpoosh 2010) Found during his research that risk management systems are typically common in most of the huge capital infrastructure projects as hydro power project so following major phase's viz. risk identification, risk assessment and risk response. (Shang & Hossen, 2013b); (Participants, Ceo, & Crc, 2003) mentioned with reference to small hydro power projects that purpose of feasibility assessment and strategic decision making is important to identify the most probable risks at pre-construction stage and assesses it clearly so that investors become clearer about the impact of risks. Also, exhaustive identification of potential risks that may significantly affect project and corporate objectives will lead to proactive management decisions rather than corrective responses to raised problems. On the other hand, subsequent phases of risk management process (assessment, analysis and responding) are carried out based on the identified risk factors Al – Bahar and Crandall, (1990); Wang et al.,(2004)

Risk management practices will be beneficial for the companies only if the products of its initial stages (identification and assessment) are reliable and inclusive (Bajaj et al., 1997; Chapman, 1998).Risk identification and assessment phases are back bone of systematic risk management process (Crandall & Al-Bahar, 1990); (Simu, n.d.-b); (Kalantzopoulos et al., 2008); (Chaurasiya, Prasad, & Khare, 2013a);(Berchmans, 2013a).

2.4 Risk Identification & Taxonomy

In the previous section of risk management process, risk identification and classification is the first and major step to proceed further. With due course of time many authors identified risks in various projects using primary or secondary sources of data.This section focus on risk identified with many projects and areas using methodologies are discussed. In paragraph 2.4.1.2 the specific risk for small hydro power projects are identified.

Moving further (Madlener & Wickart, 2006) proposed an updating approach for identification of a limited number of most critical project-specific risks which are obtained referring to large amount of data available. These project-specific identified risks will be used as the inputs for their developed risk assessment methodology.

Leung et. al.(1998) Risk identification model explaining the causality among each risk factor and its possible consequences, a knowledge-based risk identification system is then established employing some If-Then rules acquired from expert knowledge.

(Castaldi et al., 2003a) identified different project stakeholders' risk factors throughout the life cycle of the project using questionnaire survey. They claim that risk factors of construction projects are not one-time happening events and should be studied through whole phases.

(Maingi & Marsh, 2002b); have identified the most important risk factors leading to cost and time overruns in Indonesian construction industry through expert interviews. They propose the identified list of risk groups comprising of most important individual risks to be considered during risk assessment process in construction projects conducted in Indonesia.

(Chaurasiya, Prasad, & Khare, 2013b);(Zhang et al., 2010a) proposed knowledge-based approach for identification of possible risks associated with a new large infrastructure project by means of two types of knowledge structures, namely a reusable document comprising of stored past experiences, and rule sets defined for reasoning and similarities used in determination of project attributes and characteristics of the environment.

Once the risk identified the next step to decside the taxonomy with some basis so that management of risk must be simple.In this series the section shows classification done by researchers during their studies. (Pejovic et al., 2007b) in his studies classified individual risk factors according to their initial sources, namely external and internal risks, and assessed considering their likelihood and impact degrees.(Deng et al., 2010b) followed structured risk management process for small hydro power projects as the risks are categorized in business, strategic and operational. (Ralph et al., 2000a) identified several global risk factors affecting cost performance of construction projects.

(Wang, 2003) identified critical risk factors affecting construction projects in developing countries, classified them under three main levels, ranked them, and proposed some response strategies to cope with these identified risks. (Assistance, 2003)Taxonomy of possible risk factors for infrastructure projects with the aim of facilitating risk identification at the planning phase. He introduced 15 risk headings which may cause 96 potential problems in terms of quality, quantity, schedule and cost.

(Mcveigh & Cohen, 2007) in his study identified risk in hydro power projects and they suggested claiming global risk factors to be the most critical ones in international projects, they classified potential risks under the headings of "organization-specific" (internal environment), "global", and "acts of God" (external environments).

In other study in the same area (Pereira et al., 1998) an outcome of a project-specific updatable risk register is developed comprising of a list of probable risks under diverse categories. He mentioned "process", "physical", "socio-economic” and “organizational” factors to be the most dominant risk areas in infrastructure projects.

Like above the risk identification and classification was performed in several research areas. This thesis identifies investment risk in small hydro power project in next section. The further classification of identified risk which are mutually exclusive is given in detail in chapter 4.

2.4.1 Risk Identification in Small Hydro Power Projects

In this section globally addressed small hydro power risks are explored. Although global studies shows that few authors only worked on investment related risk which explore types of significant risks faced by investors during investment in small hydro power projects. So far no study which explores investment related risks in junctures of small hydro power sector so this learning even fills this gap.

In this series various risk factors are explained by authors as (Harrison, Whittington, Gundry, & Management, 2004), presented very crucial unsystematic Climatic risk impacts on the electrical system as well as shows the investment performance of hydroelectric plant with climate impact using empirical method to enable analysis of the impact.(Fleten, Juliussen, & Revdal, 2007b) also addressed climatic risk in Norway hydroelectric power project. (Kucukali,S., 2011) mentioned various external factors such as site geology, grid connection, and environmental issues in the Construction of river type hydropower plants. A fresh look at the environmental impacts of dams on an ecologically diverse and partially protected river in China found that small dams can pose a greater threat to ecosystems and natural landscapes than large dams, (Zelenakova, Zvijakova, & Purcz, 2013b). (Maingi & Marsh, 2002b) addressing risk factors river flow and river precipitation which impact the environment as well as it is impacting machinery of hydroelectric project as well. Forest clearance is sometime requirement in the case of dam construction in that case forest is removed for those clearances are required from ministry of environment and forestry. This activity misbalanced the ecology of the system addressed by (Girmay, 2006b)

(Bazmi & Zahedi, 2011) mentioned technological impacts related with construction duration which change capital investment, investment timing and technology choice are of principal interest to not only to policy makers but also to the various market participants. (Fleten et al., 2010) mentioned that investment decision is affected by factors influencing the cash flows of the project in which Operation and maintenance cost is one of them. They found O&M cost increased to double from estimated as per DPR, reason behind that is obsolete technology. This factor is one of the major factor in hydroelectric power project as it is long run project where O&M is keep on increasing.(Uhr, 2006b).(Madlener & Ediger, 2004) in his study on Dam of hydroelectric power projects the breakdown in machinery impacts the operational stage of project which creates cost overrun. He also mentions regular cash flow for preventive maintenance, if increased create cost overrun.

(Kesharwani, 2006) mentioned problem of construction, climate, policy particularly for Ganga, Yamuna & Bhagirathi basin small-hydro, where he mentioned incompatible approaches to the design opposed to large installations. The design at Bajina Basta was a large one and the error was caught due to the review process. Such a process is thus encouraged for smaller installations, perhaps with the aid of codes or guidelines for standard, contemporary or replicable design. Head of dam and delay from suppliers will change in river type small hydro power plant will impact directly on investor's revenue, (Schaefli, Hingray, & Musy, 2007).

(Swider & Weber, 2009); (Wong & Kelley, 2010a); (Tongtao & Cunbin, 2014b) proved the relationship between price volatility and the probability of investment in hydro power sector investment. (Naik & Rathod, 2008b); Takizawa, et al (2004) identified price uncertainty and generation of electricity in the power sector in a regulated market and concludes that the possibilities to invest is better when electricity price is regulated, at least for projects requiring large capital investments per unit of output such as small hydro power. (Pindyck, 1990b); (International EnergyAgency, 2003) shown market uncertainty impact on Investment and sunk costs associated to disinvestment. In their analysis, demand uncertainty is modeled using a stochastic process on output price, deemed to be acted by random shocks. (Zhang et al., 2010d); (Lundmark & Pettersson, 2007b), mentioned market risk is one of the predominant risks in small hydro power sector industry. The variation in electricity generation also a dominant risk factor which impacts revenue that generates on generated electricity sale, (He, 2010b). Modeling techniques for investment evaluation if based on older version work as hidden risk factor. (Kalantzopoulos et al., 2008)

(Wittwer, 2009b) identified socio economic and environmental risks are one of the most influential factors before construction of small hydro power projects. Dam is required so there are problems as relocation and rehabilitation cost affects investor’s profit.(Bhanu, 2011)(Hossain, n.d.-b) mentioned that Dr Roy Laifungbam, the chief of the Imphal based Center for Organization, Research and Education, noted that the Tipaimukh dam would cause a disaster in Manipur while parts of Assam, particularly its Kachar district would also be affected while it would also have a marginal negative impact on Mizoram.

(Hossain, 2006) In his study described rehabilitation and resettlement cost associated with Tipaimukh dam in Bangladesh which increase investment cost. Considering the current socio economic scenarios of Uttarakhand here, the investors are dominated by farmers and other local landowners in this particular region near to hydro power dam in Uttarakhand in Ganga & Yamuna Basin ((Kesharwani, 2006). Many socio economic and environmental risk factors as water quality, soil erosion, employment, flora and fauna, noise pollution, tourist attraction, are discussed by (Kucukali,S., 2011a) which impact small hydroelectric power projects investors. The company which owns the power plant will rent the right to use the river from the company which owns the river. While the river is most often fully controlled by local landowners, the power plant may be owned, fully or partly, by a professional investor. In circumstances where the power plant is fully owned by a group of local landowners, the power plant and the river may be organized in one company. Although considering these differences in organization have only minor impacts on the net cash flows to the investor and will therefore use the same cash flow setup for all investors irrespective of organizational form. However, professional and non-professional investors may differ with respect to preferences and risk attitudes,(Joshi, 2007b); (Lamech, Saeed, Energy, & Board, 2003). Clearances from Ministry of Environment & forestry (MOEF), Pollution control board, central electricity authority and central water commission are the requirement before the construction of small hydro power plants. (Berchmans, 2013). High court and Supreme Court stays for hydro power construction is one of the major impacts on investor's perception towards investment (Pejovic et al., 2007).

In order to construct a hydropower plant the investor must hold a license issued by the government of the state/country. A license holder has the permission to start constructing a power plant within a particular time period (e.g. five years in case of Norway, 10 years in case of USA)(Zhang et al., 2010) at which time the license expires. Investments do not start immediate after the license agreement. Time required spending for other objectives before the investment decision is made. Such as making agreements between the developer and landowners, updating the cost estimate to reflect changes in the license conditions, and the results of any new water flow measurements, undertaking precautionary measurements to avoid landslides, earthquake related hazards; cost quality assurance; making the final choice of development layout, securing project funding and making sales agreements for delivering the power to the grid and revise the investment budget accordingly. (Ikonnikova, 2011) after receiving the responses from authorized body, the decision is made whether to invest or to postpone the investment decision.

In a PPP arrangement, the private sector is responsible for not only constructing the asset, but also for the long-term operation and maintenance, and possibly financing, of the asset. (Chicago Press, 2008)Fundamental to the development of a successful partnership is agreement on the long-term objectives and contractual responsibilities of each of the partners and also the allocation of risk to the party best able to manage that specific risk. This arrangement leaves the local authorities free to plan resources and monitor services, rather than directly provide them. To date 105 projects have been approved to proceed under a PPP arrangement and are at different stages of development. There are a further 74 projects which have been identified as potential PPP projects. (Chaklader & Aggarwal, 2010); (PWC report 2011) In its November 2001 *"Framework for Public Private Partnerships",* the government restated its commitment to developing the Public Private Partnership (PPP) approach for the provision of public infrastructure and services. While most of the PPP projects envisaged under the National Development Plan (NDP) will be for major infrastructural requirements covered by mainstream investment programmes, there is considerable potential for developing PPP's in other areas, including alternative energy generation, for which there is no specific NDP investment programme.

A more complex mix of public and private structures in order to balance public and private benefits and a range of risks. The Nam Theun two project's complex private-public partnership involved more than 30 parties, with explicit allocation of risks across Nam Theun Power Company equity holders, project sponsors, and private participants, as well as the Government of Laos and the WBG. (Vespucci, Maggioni, Bertocchi, & Innorta, 2010); (Hydropower partnership report 2013)

(Wang, 2003); considered electricity supply industry reforms unfold the resultant deregulation brings in several market regulatory and trade related risks on the investment area. (Castaldi et al., 2003a); (Fleten et al., 2010); (Kai & Tiong, 2008b) applied policies and regulatory factors like carbon emission trading schemes and cross subsidies of renewable energy production schemes may bring along additional risk to investors that makes investors demand a higher rate of return on their investments, which again leads to a slower investment rate in emission-reducing technology.

Liquidity risk arises in infrastructure projects basically due to credit risk and market risk in investment decision, (Tongtao & Cunbin, 2014b); (Monetary Authority of Singapore; 2013). Small hydro power projects that performance and breakdown will impacts directly on investors' profit, Exert ambassador group (Jul 2013).UJVNL officials discussed risk factors for Ganga & Yamuna basin risk factors of innovation and force majeure impacts profit of investors. In other cases, there may be non-economic factors delaying the time of the decision. This may include, for instance, complaints filed by the license owners or other stakeholders, problems with access to the grid and problems with securing adequate funding, (Bhattacharyya, 2007b).

The delays for non-economic reasons are not misinterpreted as the result of economically rational investors balancing the value of immediate investment against the value of putting the project on hold and see how the market conditions and policies evolve,(Naik & Rathod, 2008b). Irreversibility of investment and sunk costs associated to disinvestment; in their analysis, demand uncertainty is modeled using a stochastic process on output price, deemed to be acted by random shocks, (Yang, 2007b). Strategies for reducing risk and uncertainty include collecting additional information before making a decision, (Cheung & Kaymak, 2008a); (Ralph et al., 2000b); (Wiemann, 2011b).

(Knutsen & Poulsen, 2010b); mentioned the impact of sources of finance, exchange rate risk, interest rate, tax rate. In hydro power sector investment has seen in the form of foreign direct investment so purchasing power of two currencies affects today's exchange rate of two currencies which affect investment directly. (Zhang et al., 2010b), showed the impact of project management risk due to human errors and technological defects in small hydro projects. (Fleten et al., 2007b) mentioned currency risk is greater for shorter term investments, which do not have time to level off like longer term foreign investments. The main factors deciding the annual cash flows are the revenues from the electricity price and potentially the support scheme, the operational and maintenance costs, the income tax, the resource tax and the property fee.

Globally risk taxonomy is based on tangibility, area specific, phase specific etc. but in this research the risks are classified primarily based on behavior of risk. First classification shows linguistic and nonlinguistic behavior of variables and another classification based on macro factors as technological, legal, financial, socio-economic, environmental, business, strategic i.e. some sub factors are also which goes in each category which addressed in detail in chapter 4.

2.5 Risk Assessment

Risk Assessment is processor of risk management. Without proper risk assessment, risk mitigation strategies are not possible. Though risk assessment is the part of risk management process but risk assessment itself is big process. Proper treatment of identified risk is possible through true assessment.

There are certain question arised in resercher mind while going through this section:

1. How identified risk and risk assessment are corelated?
2. What are the various risk assessment models?
3. Whether to choose the same technique or different for qualitative and quantitaive risk?

In order to realize the concept global study for risk assessment is performed that how authors apply risk assessment in their studies? Crandall & Al-Bahar, (1990) assessed risk using Monte Carlo simulation in his study. Cano & Cruz, (2002) in his development of project and organization-specific risk management process, they proposed a “project uncertainty management” (PUMA) including a generic PRM process from the view point of project owner and consultant. Supporting the application of a systematic risk management process.

Sanchez, (2005) listed of most critical risk factors affecting cost performance of infrastructure projects in Germany, and developed a Neural-Risk Assessment System to quantify the money value of the identified risks’ impacts.

Choi et al. (2004) done risk assessment of underground construction projects, their presented assessment process starts with identification of most critical risk events based on collected risk-related data and information. A probabilistic fuzzy-based approach is recommended for evaluation and assessment of these identified events.

Hastak & Shaked, (2000) developed ICRAM-1 model (International Construction Risk Assessment Model) is another systematic approach toward the assessment of potential risk factors in international projects. They categorized 73 tangible and intangible risk indicators under three interrelated levels, namely “macro environment”, “construction market” and “project” levels.

Tah and Carr, (2000) hierarchical risk breakdown structure in order to classify diverse risks (categorized as external and internal) that may affect construction projects. Three attributes of each risk, called “risk factors”, “risks” and “consequences” are assumed to be causally dependent, and is assessed using a structured fuzzy risk rating approach.

Dikmen et al. (2007) applied Fuzzy risk rating approach to qualitatively assess the risk of cost overrun in the bidding stage of international projects by taking into account of interrelations between various risk factors and impact of project-related factors as well as contract conditions on the risk level of projects, in order for development of a fuzzy decision making framework.

The researcher has designed a risk model named “stochastic Risk assessment System” (SRAS) comprising of main phases of risk management process. For the purpose of identification, researcher classified risks in accordance with their natures and potential outcomes. They also offered fuzzy logic Monte Carlo simulation methods as approaches for analysis and evaluation phases.

2.5.1 Global Evolution of Risks Assessment & Investment Decision

Firstly this section gives brief evolution risk assessment theories and secondly how these theories are addressing investment. To start with (Mittal, G., 2001) present the Hydroelectric power project has no salvage value option, so decision cannot be reversible once invested. It is characterized by high front-end capital investment and low operational cost.

Neo classical approach of investment decision follows cash flow change in a deterministic way over time. It is also known as NPV method. It reduces financial and economic constraints leading to a single value (NPV) for decision making. It does not incorporate the risk of uncertainty to the future cash flow (Heggedal & Linnerud, 2006); Ingersoll & Ross, 1992; Munn, 2002). Merit of this method to analyze financial feasibility without considering the discount rate as in NPV.

(Bloom, Bond, & Van Reenen, 2007); Fritz (1984) highlighted LCC is variation of NPV method, is the present value sum of all the costs related to capital, operation, debt service, maintenance over the entire project life. This method is popular in project where high front-end capital cost vs. high operational cost (e.g. Hydro power project). This is more attractive than NPV as in NPV only one life cycle of cash flow used whereas here time period of cash flow is lesser as it design more than one life (Munn, 2002;(Heitsch & Römisch, 2007b)).

CBA estimates equivalent economic worth of a project costs and benefits to determine financial and economic feasibility. It addresses time value of money, which implies that the dollar spent today, is not the same as the dollar spend tomorrow, (Angulo-fernández et al, 2011; Fuquitt, 1999; Morimotto, 2001; Shibl, 1971). All variables are not quantifiable in this approach. (e.g.Bakun Dam Malaysia) All costs & benefit cannot be anticipated future uncertainty cannot be accounted for (eg. In Bakun Dam decommissioning related with NPV).

Probabilistic inputs for CBA, thereby address future uncertainty. Hence capture more information about project feasibility than using single NPV, Gives information about project risk, and partially this is reversible decision in worse case situation, (I, 2007)Morimotto & Hopes (2002). DTA is useful tool for strategic decision making in the presence of uncertainty (considering the uncertainty). It can take sequential feasibility test and decision as opposed to NPV analysis focused on initial accept or reject. The major flaw is with increasing number of paths decisions increase in geometric progression which yield big analytical challenge in choosing the right decision. In addition choice of appropriate discount rate is also question to the subject, (Zhang et al., 2010a); deNeufville(1990).

Popular technique for examining the effect of uncertain inputs is sensitivity analysis, where a given output is calculated for various input, used a more sophisticated approach within the framework of sensitivity analysis is to characterize scenario as most likely hood, pessimistic and optimistic. Such scenarios can also be assigned explicit probabilities and be represented as decision trees analysis, (Castaldi et al., 2003a); Watkins, Kirby &Lawrey (1984) (Castaldi et al., 2003a); Morgan & Hennon (1992).(Kalantzopoulos et al., 2008) Spinney & Watkins (1996)

A footwear industry shows 5.67% increase of accuracy compared to sensitivity analyses when validated with a case of footwear industry in Kanpur city, India, Chhabra (2011). A more comprehensive technique is to characterize the uncertainty in model outputs by assigning probability distributions to inputs, and to simulate the output distribution by repeated sampling: the Monte Carlo Approach, Spinney & Watkins(1996);Williams et al.(2005); (Zhang et al., 2010a)Devgun & Williams (2005).

Scenario analyses yield discrete output instead of probabilistic range derived from Monte Carlo simulation, and some policy makers prefer to that discrete output as this has more practical use, (Firestone, Fenner-crisp, Chang, & Callahan, 1997); (Rode & Dean, n.d.); (Kalantzopoulos et al., 2008)Williams 2002a; 2002b; 2003; 2004. Main advantage of Monte Carlo simulation than other stochastic approach is as other stochastic simulation are not aware of large inherent stochastic uncertainty or risk, embodied within the results of analyses, Williams (2000).Provides a nice analysis of the case in which the cash flows of a project change in a known and deterministic fashion when it is delayed. He shows that the optimal rule is to undertake the project at the future time that maximizes the current NPV, Marglin (1967).

Irreversible investments with benefits and initial outlays that both follow diffusion processes. They apply option-pricing techniques to show that the project is undertaken when the NPV is sufficiently high, (Mcleish, 2004)

McDonald and Siegel (1986). Option-pricing techniques, models the flow of information on cash flows to find the optimal delay policy, (Bertani, 2012b) Bernanke(1983). The evaluation of re- source development problems in which the project explicitly contains an option to undertake investment after uncertainty, Brennan and Schwartz(1985)&Ekern(1988). (Zhang et al., 2010e)Titman's (1985) use of option-pricing, flow of information on cash flow techniques to show the development delay for a real estate project. Even for the simplest projects with deterministic cash flows, interest rate uncertainty has a significant effect on investment, Ingersoll & Ross (1992).

First order simple investment model with stochastic interest rate. The model assumes no uncertainty as to the amount or timing of this return. No additional resources or expenditures apart from the commitment of I are required either to maintain rights to the investment before the commitment is made or to sustain the project during the time t through t + T and assure its payoff, (Fleten et al., 2007b)Cox, Ingersoll, and Ross (1985). The effect of changes of interest rate & uncertainty of the timing of investment decision using stochastic method. Apart from valuing the option to invest here they consider the effect of interest rate uncertainty of return, in a scenario of dynamic economy rather static in previous investment decision model, Ingersoll & Ross (1992).

Advanced Real Option strategic approach and highlighted the decommissioning of firm's market under uncertainty, Myers (1997); Otto (2007). This is based upon option-pricing theory. ROV has three decision choices: 1. commit & invest now 2.Do not commit now 3.Pay for an opportunity to teach over time before committing in future, Black & Scholes

(1973). Major challenges with ROV: Entrepreneurs are sometimes faced with a difficult choice, whether to pursue risky projects that offer a below-target rate of return but could create valuable strategic opportunities later, or to stick with less risky and more immediately profitable ventures, Otto (1998); (2007).

Strategic approach based upon objective function maximization and solution for optimal time of investment through dynamic programming method, Madlener, (Kumbaroglu, Edgier;2004). The objective function can be used either DCF or ROV. A dynamic programming approach is adopted and the timing of the irreversible investment formulated as an optimal stopping problem, (Karatzas & Shreve;1991). Major challenges with this approach are input uncertainty and risk assessment, Madlener, (Kumbaroglu, Ediger;2004). Soni (2007) in his standard approach practice in Indian power sector are DCF, PECV, NAV, EBITDA, Replacement Cost Method as per the recommendation of disinvestment commission, govt. of India. However, none of these account for uncertainty or risk to the future NPV.

Decision making scenario analysis is used in Indian hydel power sector considering the case of IRR, ROE,NI(Net Income after tax),CR(current ratio),DC(debt coverage).GIZ International service (2012) Decision making in investment decision using scenario analysis considering the profitability indicators as NPV and IRR, Lintz (1998)

(Raje & Mujumdar; 2009) used Econometric Linear model to address climate and policy risk in hydro power sector whereas (Fleten et al., 2009) addressed Climate and policy risk and modeled in real option stochastic model. T. Nilsen applied Bayesian approach to incorporate flow or climate risk is modeled in small hydro power sector. Aven(2001) also consider Climate and market risk using real option analysis linear model for hydro power sector. (Haugstad et al.; 2006) quantified the impact of discount rate which is market risk is analyzed with the help of fuzzy logic approach a nonlinear model.

(Hansen;1998) applied two period model using deterministic dual life modeling technique Inflow risk raised due to technological risk. Lucia & (Schwartz; 2002) quantified Market risks with two stage period linear model. (Gjermundsen et al.; 2002). Quantified flow and precipitation hydro power risk using nonlinear Probabilistic Resampling. Alam and Doucette showed that policy plays an important role which will impact on investment decision using Dynamic Stochastic modeling. (Aichinger et al.; 2011) identified and quantified Power blackout risk Using Real Option analysis. T. Key (EPRI) 2013 in Electric power research institute highlights the scenario analysis for investment risk as market and policy risk modulation using Scenario analysis.

Risks and uncertainties often compel investment in flexible power production technologies with short periods of return on investment, brief construction times and the capacity to switch between fuels. Used Real option analysis nonlinear, (Yang and Blyth; 2007).(Takizawa, et al; 2004) used Dynamic programming modeling using nonlinear techniques for the Investments in the power sector using price and market uncertainty.

This section explained the investment decision taken by decision makers globally assessed with and without consideration of Risk. It is also essential to know about the current practice of investment decision in study area.

2.5.2 Current Practice of Risks Assessment in Uttarakhand

Most of the investment decisions are made by tariff calculation technique in Uttarakhand SHP's of Ganga, Yamuna & Bhagirathi basins (DPR Shobla, 2005); (DPR, 2002); (DPR, 2007) (DPR, 2008). But in tariff calculation technique, the model is not considered risk adjusted cash flows. However, in few projects (Galogi (Bhagirathi), Mohammadpur (Ganga) & Pathri (Ganga)) are also evaluated and supported by standard financial indicators such as Net present value (NPV); internal rate of Return (IRR); profitability Index (PI) & payback period (PBP). But even in these methods also nowhere risk adjustment is considered for financial indicator assessment. Though Sensitivity analysis is also applied in Chibro hydroelectric power project but that is not gives a clear picture to investors.

Currently, river discharge observations are not made available; dimension of hydrological and atmospheric data of all identified sites in Ganga, Yamuna & Bhagirathi basins are not done, (Joshi, 2007a). Uncertainty about price levels may also reduce the investment incentives. (Jal & Nigam, 2010). The immaterial benefits are not included in this financial analysis of the project, but logically a more required result will be attained for the economic files once taking these factors into account. (Pasha & Nasab, 2012b) investments in the power sector in a regulated market and conclude that the possibilities to invest is better when electricity price is regulated, at least for projects requiring large capital investments per unit of output. Strategies for reducing risk and uncertainty include gathering additional evidence before making a choice**.**

Conclusively, from the current practices it is assumed that Uttarakhand with large potential for hydroelectric power cannot target more investors as is the area ignorance of risk factors is major problem which needs to be focused. Thus better risk identification and assessment give precision to investors about their investment.

2.5.3 Subjective Risk Assessment Theories

Risk assessment is an important step of risk management process. Risk assessment various theories for investment decision making are distributed in deterministic, probabilistic, stochastic and strategic. Inside strategic approach subjective risk assessment theories are available as strategic approach is an advance approach so more acceptable as it considers maximum risk factors in it. In subjective risk assessment category major two theories are available one is real option theory and other is fuzzy logic theory.

Ever since these theories are applied in different areas with time to time but in India especially in small hydro power project risk assessment is not performed using subjective risk assessment theories. Under real option theory Irreversible investments with benefits and initial outlays that both follow diffusion processes, for risk assessment option-pricing techniques to show that the project is undertaken when the NPV is sufficiently high with all risk variables, (Mcleish, 2004); (McDonald and Siegel; 1986). Option-pricing techniques, models the flow of information on cash flows to find the optimal delay policy which is risk, (Bertani, 2012); (Bernanke; 1983). The evaluation of re- source development problems in which the project explicitly contains an option to undertake investment after uncertainty, (Zhang et al., 2010e). (Titman's;1985) use of option-pricing, flow of information on cash flow techniques to show the development delay for a real estate project. Even for the simplest projects with deterministic cash flows, interest rate uncertainty has a significant effect on investment, (Ingersoll & Ross ;1992).

The effect of changes of interest rate & uncertainty of the timing of investment decision using strategic risk assessment method. Apart from valuing the option to invest here they consider the effect of interest rate uncertainty of return, in a scenario of dynamic economy rather static in previous investment decision model, (Ingersoll & Ross ;1992). Major challenges with Real Option Theory: Entrepreneurs are sometimes faced with a difficult choice, whether to pursue risky projects that offer a below-target rate of return but could create valuable strategic opportunities later, or to stick with less risky and more immediately profitable ventures, (Otto ;1998).

To attain fast and less mechanical precise decisions in the credit evaluation process, computerized fuzzy logic risk assessment systems considered to be best. (Lahsasna ;2009) made and examined the correctness and clearness of a credit-scoring model using German and Australian data sets and two fuzzy model types. The proposed method permits operators to apply Fuzzy logic is one of the planned and stochastic approach in which strategically both qualitative and quantitative risk factors are assessed under one tool. (Matsatsinis at el. ;2003) found that sometimes the systematic cravings among the variables of a process or system are new or not so easy to interpret so, they used fuzzy logic to frame the needs between the factors in the context of taxonomy analysis for a business failures model. (Cherubini and

Lunga;2001) founded that in pricing of contingent claims, the probability measure applied are not too precise, and so they applied a class of fuzzy procedures for uncertainties. They performed this method to quantify liquidity risk for pricing an asset in illiquid markets.

(Heggedal, Linnerud, & Fleten, 2011b)(Lin at el.; 2008) presented a hybrid model for risk assessment and predicting the existence of currency crises by using the neuro fuzzy modeling approach. They integrate the learning ability of neural networks with the corollary mechanism of fuzzy logic to expose the causal relationships among the variables. So both the theories has been applied globally used for subjective risk assessment as real option theory limitation of dynamism of data which stop the investors towards more complicacy so fuzzy logic theory is applied for subjective risk assessment which authenticate this theory in this area.

2.5.4 Monte Carlo simulation for Risk Assessment

The proposed method for the present research involves the use of a Monte Carlo simulation tool to portray the stochastic process underlying the risk adjusted cash flows, thus enabling the clarity to investors because it incorporate the impact of many types of uncertainty as discussed i.e. average capacity, river flow, average energy, capital cost etc.. The growth of a computer simulation model to be used for an assessment starts with a typical cash flow forecast. A cash flow forecast states the net income from the project over the expected useful life of the project, the larger the difference between the costs and the revenues, the greater the net operating income and value of the asset. All the variables that help to determine the costs and revenues of a project should be included in the detailed analysis, as well as all relationships among those variables.

After the basic model is constructed, various types of risks can be added as economic (per unit electricity cost & price), political (agreement between government and investors), (Fleten et.al. 2009) natural hazards (fluctuation of river water supply to the reservoir), (Maingi & Marsh, 2002b),(Pathak, 2010) Filippini, (Banfi & Luchsinger; 2002) and technical (turbine operations, head, operations and maintenance cost), (Mittal, 2004), capital cost.

Monte Carlo Simulation is one of the appraised tools used in various sectors as dam construction, steel plants, garment industry etc. many authors they used Monte Carlo simulation in areas like, risk assessment, appraisal, economic analysis, engineering economics In this study use of Monte Carlo is applied in the area of risk assessment. The various studies which apply Monte Carlo as a tool is mentioned in this section.

(Kalantzopoulos et al., 2008)Monte Carlo simulation, in risk analysis and presents an extended review of studies, using either statistical techniques in general, or specifically Monte Carlo simulation in risk analysis. He constructed a model of a Monte Carlo simulation for the appraisal of a potential investment with uncertain annual revenues and Costs. The results obtained show that Monte Carlo simulation can prove a valuable technique in the decision making for the evaluation of a potential investment.

In the early 80's, (Coats and Chesser;1982) used Monte Carlo on financial statement analyses in order to produce useful statistical measures, such as probabilities of occurrence, confidence intervals and standard deviations. Later on, (Seila and Banks;1990) simulated financial risk with Monte Carlo techniques, by exploring the probability distribution of the NPV of a project as a function of the unknown random input variables.

Alloway with a Monte Carlo simulation example, where the objective was to determine the expected present worth for an alternative investment when several cash flows were uncertain.

The present worth of the project was determined as a function of variable elements, including life, salvage, annual savings and expenses, whose values were based on the random numbers generated in the fourth region of the model. The results of the simulation were evaluated graphically using a bar chart which gives a better impression of the present worth's distribution than the summary statistics. Alloway also experimented with the use of add-in software, such as @RISK, in order to simplify the initial simulation model.

(Coates and Kuhl; 2003), in a more recent paper, provided three simple examples demonstrating engineering economy problems with stochastic input variables can be modeled using widely available industrial simulation software. The probability descriptions of the random input variables, along with Monte Carlo techniques, provided a practical method of finding the distribution of the desired output variables, using simulation packages that can handle great amount of sampling data and have capabilities of good output report.

In a case they demonstrated the calculation of the future worth of an annual series of payments, represented by the NPV, where the interest rate varies from year to year. They assumed a stock market investment for the entire time period of the payments, with a stable long-term average return but individual annually returns normally distributed with a given standard deviation. The interest rates were selected via Monte Carlo sampling from the distributions.

The another example attempted to model the risk in the appraisal of an investment project, having uncertain, mutually independent, normally distributed, annual cash flows, as in (Hillier's;1963) initial example.

In their final example, Coates and Kuhl compared two mutually exclusive, alternative projects with different net expected cash flows, normal cash flow distributions and interest rate distributions like the one described in their second example. The comparison between the two projects was based on the difference in the expected Net Present Values of their investments. They applied a simulation model on each alternative project, as the one described in the previous paragraph, obtained independent observations of the NPV for each one and as a result they constructed a confidence interval of the difference between the population means.

(Perry;2006) presented an overview of the Design for Six Sigma process (a methodology that spans the entire product commercialization process from business idea development to initial product sales), utilizing specific applications of Monte Carlo simulation using Crystal Ball® software. Among others, he demonstrated how Monte Carlo simulation along with product optimization techniques could be applied in business financial value analysis. Doing so, he presented a case study example of a new product design project. Once the primary variables of the initial financial analysis (sales volume, unit price, raw material unit cost, operating/other cost per unit etc) and their distribution assumptions (distribution type, mean value or standard deviation) were defined, a traditional financial analysis was carried out in order to determine the expected value of the project's NPV. Having executed a Monte Carlo simulation and according to the distribution type of the estimated values, it was obvious that, although the project was expected to produce a positive NPV, it was not statistically certain. In this example, the simulation results indicated that there was a 20% chance of a negative NPV of the project, a possibility that should be taken under serious consideration despite of the positive expected NPV. is in the area of risk assessment.

The benefits of the simulation approach have been predictable by many appraisal industries (e.g., Appraisal Institute, 1996; Li, 2000). Gain (1990) goes as far as category the simulation approach "one of the best methods available for estimating the value of income-producing properties." Adding doubt into an assessment harvests a result that covertly recognizes the risks involved with these types of projects.

2.5.5 Fuzzy Logic for Risk Assessment

Fuzzy logic can be performed in three major stages, namely fuzzification, inference and/or defuzzification, (Cheung & Kaymak, 2008a). Ever since from physical to social science there has been much literature, covering both academic research and practical implementation in almost every area that gives contribution to this new field. The literature review here focuses on areas related—directly or indirectly—to risk assessment and investment decision making. The application is quite expanded. It might be a substitute of classical sets with fuzzy sets, a complete application of a fuzzy logic system or a hybrid model that includes a fuzzy logic model. The purpose is to familiarize a wide range of possible areas of fuzzy logic and is by no means envisioned to be extensive.

To attain fast and less mechanical precise decisions in the credit evaluation process, computerized credit risk assessment systems considered to be best. (Lahsasna;2009) made and examined the correctness and clearness of a credit-scoring model using German and Australian credit data sets and two fuzzy model types. The proposed method permits operators to apply Fuzzy logic is one of the planned and stochastic approach in which strategically both qualitative and quantitative risk factors are assessed under one tool.

(Matsatsinis at el.; (2003) found that sometimes the systematic cravings among the variables of a process or system are new or not so easy to interpret so, they used fuzzy logic to frame the needs between the factors in the context of taxonomy analysis for a business failures model. Leveraging the results on taxonomy difficulties with admiration to financial and credit risk analysis, Li at el. (2011) used a fuzzy linear programming classification method with soft constraints to analyze credit cardholders' behavior.

(Cherubini and Lunga; 2001) founded that in pricing of contingent claims, the probability measure applied are not too precise, and so they applied a class of fuzzy procedures for uncertainties. They performed this method to quantify liquidity risk for pricing an asset in illiquid markets. (Horgby;1999) introduced practices of fuzzy corollary in economics, taking cases, he highlighted the way to assume material that is, by nature, fuzzy, and concluded from a set of fuzzy "if-then" directions. (Caleiro;2003) examined an exciting study analyzing how subjectivity like consumer believe can be approached by objectivity of economic measures such as the unemployment rate using this logic. (Blavatksyy;2011) studied risk dislike when results may not be computable in financial terms and individuals have fuzzy likings over lotteries, i.e., inclinations over lotteries are stated in a probabilistic manner.

(Ng at el.; 2002) recognized a fuzzy membership function of procurement selection criteria through an experimental study in Australia recognizing that frequent selection criteria— such as speed, complexity, flexibility, responsibility, quality level, risk allocation and price competition—are fuzzy in nature. (Xu at el. ;2011) prolonged this approach by emerging a practical risk assessment model for public-private partnership attaining projects where the vital risks factors are recognized using the Delphi survey technique and fuzzy set theory.

(Oliveira and Silva; 2004) considered qualitative factors as environmental regulation in which the relation between regulations and pollution-generating processes are exhibited using a fuzzy logic approach. To help effective decision-making, this study goal is to provide a judicious indulgent of the difficulty in connections, which caused costly regulation, exploitation and extreme pollution.

(Sun and van Kooten; 2005) applied fuzzy logic to depending estimate of environmental facilities and public goods using a fuzzy random utility maximization (FRUM) framework. They conducted an empirical study to measure the prompted residents' willingness to pay for enhanced forest conservation using Swedish data.

(Cai at el. ;2009) established a fuzzy-random interval programming (FRIP) model for identifying optimal policies in the planning of energy management systems under numerous uncertainties caused by economic, environmental and political factors. Their FRIP model was constructed by integrating interval linear programming, fuzzy-stochastic programming and mixed integer linear programming to deal with uncertainties presented as interval values.

(Madlener & Ediger, 2004),(Tucha and Brem ;2006) proposed a quantitative approach to analyze functions and risk patterns in international transfer prices using the fuzzy framework. Dow and (Ghosh & Kaur, 2009) studied the notional demand for money using a fuzzy logic framework. They incorporate different opinions and recognize that expectations may differ when the environment of the difficulty prevents an accurate and absolute description of the basic variables.

(Heggedal et al., 2011b), (Lin at el.;2008) presented a hybrid model for predicting the existence of currency crises by using the neuro fuzzy modeling approach. They integrate the learning ability of neural networks with the corollary mechanism of fuzzy logic to expose the causal relationships among the variables. (Leon and Machado; 2011) proposed an index built using a fuzzy-logic-based inference system to conduct a comprehensive relative assessment of a financial institution's systematic importance. The proposed index uses some key importance indicators of the institution's size, its connectedness and substitutability. Expert knowledge is used for combining those indicators.

(Caetano and Caleiro; 2005) studied how corruption influences decisions concerning direct, foreign investment with a fuzzy logic approach recognizing that a certain level of perceived corruption can be subject to different subjective evaluations by investors. (Brochado and Martins;2005) studied cross-country variation in political indicators and their association with the level of economic, human and gender-specific development indicators using a fuzzy k-means classification algorithm. The aim was to enhance the understanding of the heterogeneity of behaviors with respect to political indicators. (Sveshnikov and Bocharnikov; 2009) developed a model to study the international politico-economic risk where contradictory and opposing views of countries concerning decisions on political, economic, internal and international issues are combined together using fuzzy measures and integrals. They conducted an empirical study to estimate the politico-economic risk of Ukraine.

(Magni et al.; 2006) studied an alternative method of firm estimation based on fuzzy logic and expert opinion. In this study, the cash flow are discounted for quantitative and qualitative variables, e.g., financial, strategic and business sectors, and also their shared combination via “if-then” rules used to rate and rank firms, in addition to assess the impact of managers’ decisions on worth-establishment and the quality of business authority. (Smimou;2006) conducted an pragmatic study for the Canadian commodities futures market within the capital asset pricing model (CAPM) context using a fuzzy reversion method. Smimou providing a relative analysis to display the dominance of the applications of a fuzzy approach to capturing the risk premium in commodity futures over other methods. (Giovanis;2009) protracted the fuzzy regression context to generalized autoregressive conditional heteroskedasticity (GARCH) modeling and studied the day-of-the-week effect on four major stock exchanges. The principal motivation was to incorporate nonlinearities in finance and evade the use of binary taxonomy in this context. (Su and Fen; 2011) constructed a trading strategy using a risk-controllable fuzzy inference system built on structural equation modeling, and they confirmed that it outperforms the buy-and-hold strategy.

The fuzzy logic method was chosen over Monte Carlo simulation because of its capacity for modeling the unimportance in the associated problem, facility to work with less cost and simple application, high automated aptitude, ability to solve different problems with the help of knowledge of the prototype within the background of the principles defined in model, ability to make changes in layout, have capacity for solving the partially completed problems, and use of spontaneous methods instead of a fixed procedure.

This study makes risk assessment for taking investment decision, unlike in diagnosis. Because of that, the motives for taking fuzzy logic with disparity to other models are stuck due to less flexibility in construction of other models, process with exact data, and creation of precise results. There are some general characteristics about fuzzy logic are as this method is theoretically simple to understand and is a more spontaneous approach. The measured concepts behind fuzzy reasoning are very simple, flexible, easygoing with rough data. It can model nonlinear functions of random difficulty; can be built on top of the experience of experts and more important fuzzy logic is based on linguistic description. Because fuzzy logic is built on the structures of qualitative explanation used in everyday language, fuzzy logic is easy to use.

The resulting declaration is perhaps the most important one and justifies more conversation. Ordinary language, which is used in daily life by normal people, has been structured by thousands of years of history to be suitable and efficient. Verdicts written in regular language signify an achievement of efficient statement.

2.5.6 Significance of Fuzzy Logic theory for risk Assessment

Fuzzy logic can be performed in three major stages, namely fuzzification, inference and/or defuzzification, (Cheung & Kaymak, 2008a). Ever since from physical to social science there has been much literature, covering both academic research and practical implementation in almost every area that gives contribution to this new field.

Construction of SHP plants involves uncertainties because of various external factors such as site geology, grid connection and environmental issues. These factors increase the construction costs and duration. For example, in one of the SHP plants, Kulp IV in Turkey, the cost of civil works increased twofold because of unpredicted geologic structure at the tunneling site. In another example, the judges have ruled against hydroelectric power plants in 33 completed cases in Turkey, issuing a stay of execution decision or canceling the construction altogether because of the environmental issues. Besides, a hydropower scheme on the Malagarasi River in Tanzania was initially approved for grant funding, but was subsequently rejected because of the identification of potentially significant biodiversity impacts, which had not been adequately addressed in Environmental Impact Assessment (EIA) report (Hovland, 2010).

In the literature there are several studies considering risk analysis in construction projects (Zavadskas et al., 2010). However, risk analysis in renewable energy projects, especially for hydro- power plants, is very limited. In classical project risk analysis techniques, risk rating values are calculated by multiplying impact and probability values, but direct analysis of these linguistic factors is often neglected (Dikmen et al., 2007). Most existing risk analysis models, such as Monte Carlo simulation and tornado chart, are based on quantitative techniques, which require numerical data. (Kangari and Riggs; 1989) note that probabilistic models suffer from detailed quantitative information, which is not normally available in the real construction world. However, much of the information related to risk analysis is not numerical (Mustafa and Al-Bahar, 1991). Rather, this information is expressed as words or sentences in a natural language. These conceptual factors can be expressed in linguistic terms, so-called fuzzy information (Kucukali and Baris, 2010). Uncertainty factors such as ''poor geology'' or ''unstable policy'' fall into this category. The aim of this research is to introduce a new approach for hydropower projects risk assessment through the fuzzy logic concept. The methodology addressed the decision circumstances at a preliminary phase of an investor that investigates the risk of alternative potential hydro projects in order to decide which ones to undertake.

2.6 Risk Distribution

Risk distribution is the important area in risk management process as risk which are uncontrollable needs to be reduced using risk distribution (Zhang et al., 2010). Risk distribution theories used globally mentioned in next section in detail.

2.6.1 Risk Distribution Theories

After risk assessment, investor has to bear the some risks which are under uncontrollable category. There are some situations in which investors can distribute their risks with transfer of risk among investors or even in projects too. Globally for risk distribution three major models are considered as portfolio theory using Mean variance approach (MVA), concession agreement of public private partnership (PPP) Model & Extreme value theory (EVT).

Globally these models are used in different projects as stock market, infrastructure projects and capital market too. In recent years there has been an increasing application of the MVA approach to electricity planning in many countries such as Ireland (McLoughlin, Basilian 2006), Italy (Arnesano et al 2012) and Japan (Bhattacharya, 2010). In fact, the mean-variance model can be used to estimate optimal portfolios of electricity generation both for a company and for a country (Ferreira, Cunha 2011). As emphasized by Awerbuch (2003), energy planning is no different than investing in financial securities, where efficient portfolios are widely used by investors to manage risk and improve performance. Thus, energy planning should be focused to develop portfolios with efficient production than on finding alternatives with lower cost of production, because, at any given time, certain alternatives may have high costs and others may have lower costs. However, over time, a favorable combination of alternatives may facilitate minimizing the overall cost of production compared to the risk (Awerbuch, 2003).

Major limitation with Extreme value Approach described enables analysts to simulate and model dependent on hydro power risks with historical performance. This enables analysts to isolate the dependence structure of the portfolio from the description of the individual indices a compelling alternative to the traditional assumption of jointly-normal portfolio returns.

The value of modeling risk using EVT extends to many different applications. In addition to measuring VaR and estimating potential damage, these techniques can be used by insurers to assess the likelihood of any number of natural disasters. They can also help organizations ensure compliance with the Basel Accords and other regulatory mandates that require institutions to quantify market risk and retain sufficient capital to protect against unanticipated losses. Portfolio theory does not work on historical data set and here mandate condition of normal distribution data availability of all historical data is also not fulfilled as some risk factors have uniform distribution too so EVT is not applicable in this case.

The portfolio modeling tool factors in a number of key inputs such as current returns, growth expectations and cross-correlations among existing business units, acquisition targets and investment opportunities. The quantitative risk metrics developed during the risk assessment are the most important of these inputs, as they provide the basis for including risk into capital allocation decisions. In this thesis, the awareness underlying the MVA approach is applied to the selection of portfolios of small hydro power projects. By including as a decision variable the risk of portfolio, this approach allows policy makers or private investor integrating the three main objectives of energy policy in a quantifiable manner (McLoughlin, Basilian 2006): Energy at competitive prices; security of energy supply; mitigation of environmental impacts.

In recent years there has been an increasing application of the MVA approach to electricity planning in many countries such as Ireland (McLoughlin, Basilian 2006), Italy (Arnesano et al. 2012) and Japan (Bhattacharya, 2010). In fact, the mean-variance model can be used to estimate optimal portfolios of electricity generation both for a company and for a country (Ferreira, Cunha 2011). As emphasized by (Awerbuch; 2003), energy planning is no different than investing in financial securities, where efficient portfolios are widely used by investors to manage risk and improve performance. Thus, energy planning should be focused to develop portfolios with efficient production than on finding alternatives with lower cost of production, because, at any given time, certain alternatives may have high costs and others may have lower costs. However, over time, a favorable combination of alternatives may facilitate minimizing the overall cost of production compared to the risk (Awerbuch, 2003).

Apart from the fact that it can find the optimal portfolio, the application of MVA allows analyzing the impact of the inclusion of renewable technologies (RES) in the scenario of generating sources of electricity. In particular, the MVATP allows a better assessment of the risk associated with the different technologies. Moreover, it allows, also, illustrating the trade-off between production costs and risk, which means that it is not possible to achieve a lower cost of production of electricity, without assuming higher levels of risk (Ferreira, Cunha 2011).

Awerbuch (2003), in the analysis of power (or energy) systems, was able to model a combination of political, environmental and technological aspects. The inclusion of this aspects and, particularly, environmental concerns, has demonstrated that producing electricity through renewables is a strategy conducive to positive effects on the environment. In fact, (Awerbuch;2003) demonstrated that the introduction of RES technologies (as wind, solar and hydro) in the energy portfolio, significantly reduces the total cost of energy and the production risk, since solar and photovoltaic technologies are risk-free, since its operation is not correlated with the change in the price of fuel (Arnesano et al 2012).

This thesis applies the mean variance approach for optimum portfolio preparation using different types of small hydro power projects.

2.6.2 Significance of Portfolio theory & PPP model for risk distribution

The application of MVA allows analyzing the impact of the inclusion of renewable technologies (RES) in the scenario of generating sources of electricity. In particular, the MVATP allows a better assessment of the risk associated with the different technologies. Moreover, it allows, also, illustrating the trade-off between production costs and risk, which means that it is not possible to achieve a lower cost of production of electricity, without assuming higher levels of risk, in other words it create better risk return tradeoff.

Privatization is the transfer of ownership of assets from the public to private sector or application of private capital to fund investment in the facilities, equipment's and systems in which risk is distributed between public and private investors so it is upcoming demand of future scenario. With proper risk quantification using different business models or concession agreements if activities of the projects are segregated between public and private investors than the risk is also distributed so it is one of the simple and useful strategies for risk distribution.

2.7 Research Gap

The above literature review gives roadmap to reach to research questions raised in chapter 1; this section highlights the gap in literature study found so far. Current practices in small hydro power projects shows that investors want to invest but due to some major reasons they sometime withdraw their opinion or sometimes the investors are not so happy with their returns. The major reason behind this deviation is less clarity about future prospects, and unawareness about the severity of the risks if it persists and whether it is possible to mitigate it or not.

Considering the above mentioned phenomenon in mind these study major themes would find the gap in several areas as investment related risks are not identified and assessed so far in small hydro power projects of uttarakhand. Secondly the stage specific risk as operation & construction phase risks are also not identified so far. The assessment of risk with current practices of uttarakhand shows obsolete methods no advance tools for risk assessment enhancement has used in this area globally. In small hydro power projects various risk assessment tools and models are not gathered together which is the thrust area and which gives ease to industry as well as researchers to make it generic. A stochastic Monte Carlo simulation approach and strategic fuzzy logic approach is not applied for risk assessment in small hydro power projects so far in India. This thesis concludes with major research gap that investors they cannot make the use of identified assessed risks, and even they have no certainty about their capital investment distribution so that they get better risk and return tradeoff.

2.7.1 Major gaps

- Investment risk in construction and operation stage in SHP's of Uttarakhand has not been identified.

- Subjective risk assessment in Construction & operation stage SHP's, in Uttarakhand has not been done.

- Investment Risk Distribution for investor's is lacking in SHP's of Uttarakhand.

2.8 Summary

In seeking to explore the optimum investment scenario in small hydro power sector, the literature review for the current study has examined the academic literature on investment risk identification and assessment for small hydro power projects and makes use of it for better investment model. The source of each of the two research questions proposed in Chapter 1 was explored and advanced for empirical testing using modern tools and techniques.

CHAPTER 3

RESEARCH METHODOLOGY

3.0 Introduction

This study contributes to the current debate in the risk assessment and distribution theory literature by investigating the value of the application of investment decision analysis in small hydro power projects. Set in the context constructional and operational stage small hydro power projects of Uttarakhand state, are considered. This research has three specific objectives that were first set out in chapter 1. The research aims firstly to identify leading risks for construction and operational stage Small Hydro Power Project investors of Uttarakhand. Secondly, to assess the impact of all identified risk and lastly to distribute the assessed risk for investor's.

This chapter analyses the way in which the researcher answered these two research questions by evaluating the methodological approach and research methods that were used to inform the study. The choice of the small hydro power sector as the context for the current study has already been justified in the preceding chapter 1 hence it will be taken as given here. Directions for future research will not be discussed in this chapter but future prospects will be proposed in Chapter 7.

The chapter aims to design the coordinated and vigorous flows between research objectives and methodology that has been the individualities of several recent concepts. The characteristics of the research have been the development of the researcher as an academic researcher. In this regard, the papers and presentations that have been prepared during the course of the current study are shown in Appendix A7. This study creates paradigm shift in risk assessment practices. Applying advanced methodology present big picture to investors in concerned area.

3.1 Adopting an Appropriate Methodological Framework

There are three perspectives that can be used to create taxonomy for research that is accomplished (Ullmann, 1965);(Kumar 1999): based on the proposal of the research study, the objective in commission the research and the kind of information used. Fig.4.1 shows the classification for research type.

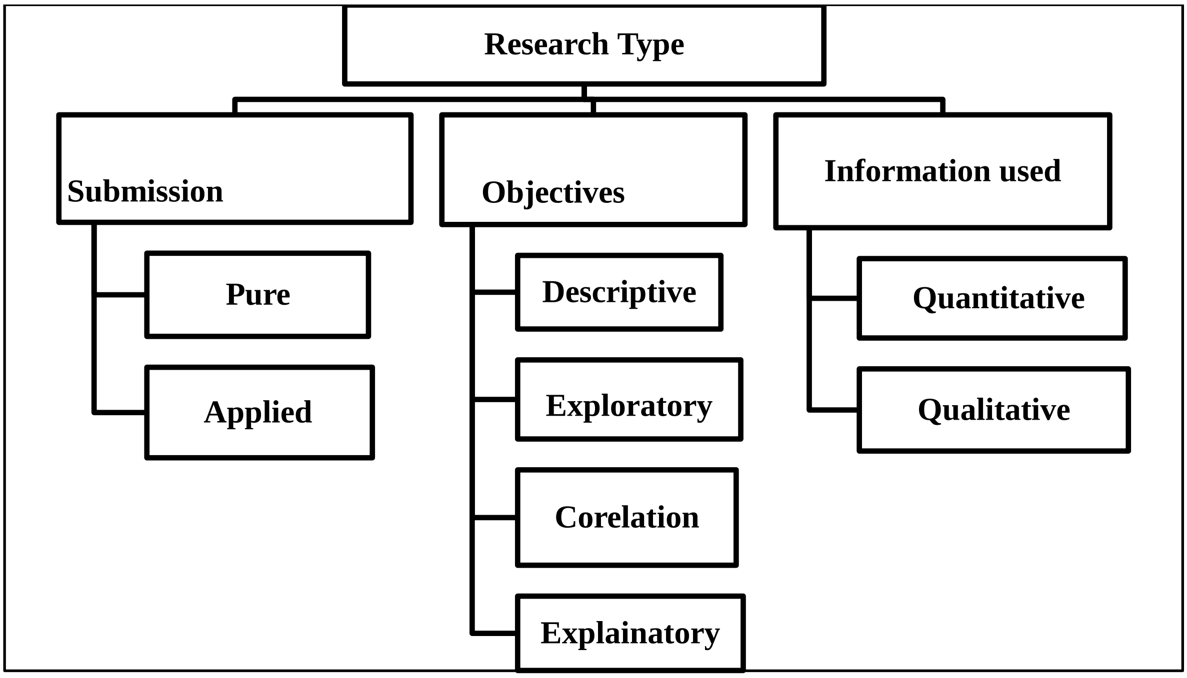


Figure 3.1: Research Types (Source: Kumar 1999)

Pure research is assumed for theoretical interest only and has no real-world implications and researchers apply the same research on relevant applications and make it applied. (Harinarayana et al., 2006b), while applied research tries to apply the prevailing academic knowledge to a specific application or problem (Assistance, 2003). This study applies the theory of fuzzy logic for investment risk assessment in small hydro power projects of Uttarakhand state in India and therefore is applied research.

While in view of the objective for undertaking this research it falls in the category of exploratory research, which means that the research is executed to explore the likelihoods of undertaking a larger research study (Kumar 1999). In the case of exploratory research, a small-scale research is anticipated to select if it is feasible to do a comprehensive investigation. (Lundmark & Patterson, 2010)

There is a clear distinction in the procedural literature between empirical and conceptual research, Empirical research starts with existing models and thoughts and frames hypotheses that are successively tested; its vantage-opinion is received theory. Inductive research starts with actual data, and groups, thoughts, designs, models, and finally, theories arise from this effort (Salmon, Meurice, Wobus, Stern, & Duaime, 2011). Accounts of research are often presented as being either inductive (method, data, findings, theory) or deductive (theory, method, data, findings) and this proposes that the government research process follows a series of rationally directed steps. In this aspect this research aligned with deductive research.

Each research has to opt few vital elements or phases and direction in which these stages are performed which will help to structure the thesis. In theoretical reports, theory is used as an outline that will guide the study and clarification of the collected primary data (Schaefli et al., 2007),(Finn et al. 2000). Finn et al. (2000, p.14) said that: “Research needs theory as a framework for analysis and interpretation, and theory needs research to constantly review theoretical details”. Therefore, in this research use has been made of the deductive approach, meaning that the theory (described in chapter 2) has been used to deduct hypotheses before primary research was performed (Salmon et al., 2011).

The classification based on information required and the connected use of qualitative or quantitative research where it will be elucidated which data collection method has been used for the research. In this research after exploratory research dealing with quantitative of variables impacting in output are assessed so it is quantitative research as well. Some part of the linguistic variables or non-parametric variables is also assessed based on theories so it make the study somewhere as qualitative too. As this research is exploratory and quantitative research, it should be viewed as a forerunner of a bigger project that could have as a goal to test the hypotheses, to see if they can be accepted or should be rejected.

In this study an assessment of risk on investments in hydropower plants associated to the construction and operational stage risks problem is conducted. More sophisticated fuzzy logic approach is applied for assessing the subjective risk factors. Though quantitative risk assessment using Monte Carlo simulation tool is used for checking the financial indicators

(NPV/IRR/PI) certainty using available historical quantitative data of various impacting variables which supports this research moving from Monte Carlo to fuzzy logic theory. The Monte Carlo reflects the stroke flexibility of the firm's management, the uncertainty related to the acceptance probability of various risks recognized. The results of the model comprise the financial assessment of the investment using NPV, IRR & PI along with the identification of the optimal NPV, IRR & PI using Monte Carlo techniques; thus, focus the optimal strategy for the investors. Moreover, the study identifies the advantages and drawbacks of the Monte Carlo method compared to the classic methodology that is currently used within the sector. In order to address the nonlinguistic variables the relative importance of those variables are assessed based on Fuzzy logic approach.

The applied work will make several contributions in the area of evaluation in developing markets of small hydro power sector that would be of great attentiveness to entrepreneurs, investors, and policy maker. While such creativity is relaxed, the rationale for capital allocation is not clear, researcher believes that this work will serve to provide a market-based framework that would guide such a new financial architecture to identify investor and assure global investors of the potential risks and return on their investments. For all this to work properly, notwithstanding market efficiency issues, valuation techniques for developing and emerging economies will have to improve substantially. The applied work will provide to fill that gap prevailed in small hydro power area that ignores influential risk variables both qualitatively and quantitatively.

3.2 The Research Process

The research process, and hence the methodology employed, is not a clear cut sequence of procedures following a neat pattern, but a messy interaction between the conceptual and empirical world, with deduction and induction occurring at the same time (Bechofer,1974). Clearly then it can be argued that the methodological framework cannot be seen as a rigid, purely objective construct. Rather, it should be perceived as a framework, the final version of which is determined by environmental pressures. It is within such a context that the methodological framework employed in this research has evolved. Consequently, in seeking to demonstrate the significance, generalizability, validity and reliability of the data gathered and the results presented, it is necessary to examine and evaluate critically the actual research process undertaken and this is the aim of this chapter. The next section will examine the research process highlighting the methodological approach adopted and the specific research instruments used to explore the research questions. (Fig 3.3)

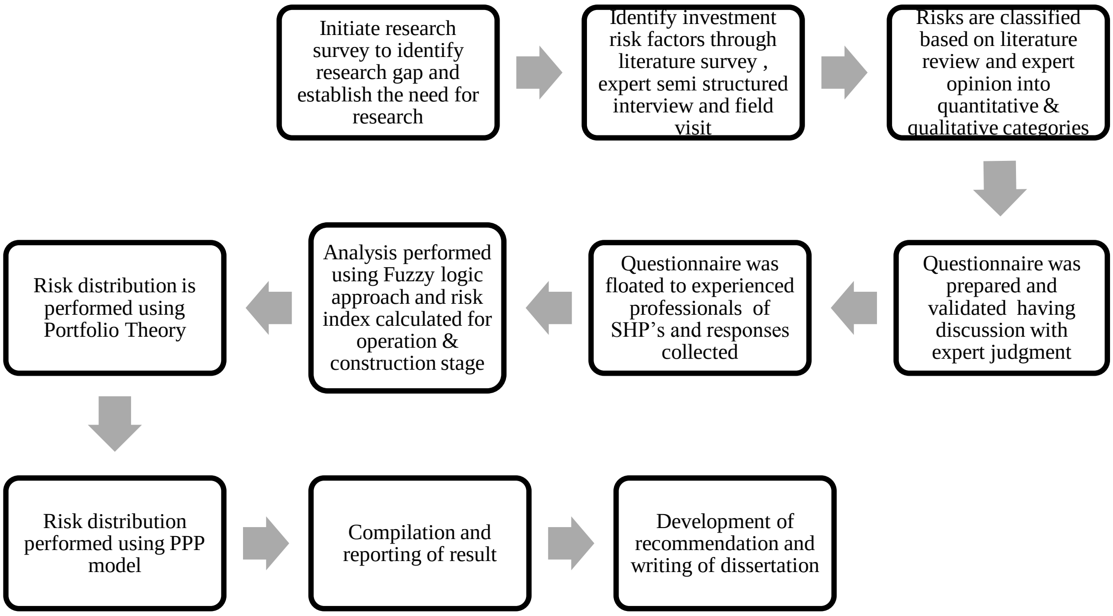


Figure 3.2: Research Process

This section will detail the research process followed during the course of this study. Fig. 3.4 mentioned below provides a useful summary of this process. Each step will be examined in this section. The section is structured so that it first discusses the approach used to undertake the literature review and it then proceeds to examine the methodological approach adopted and research methods used to answer each of the research questions.

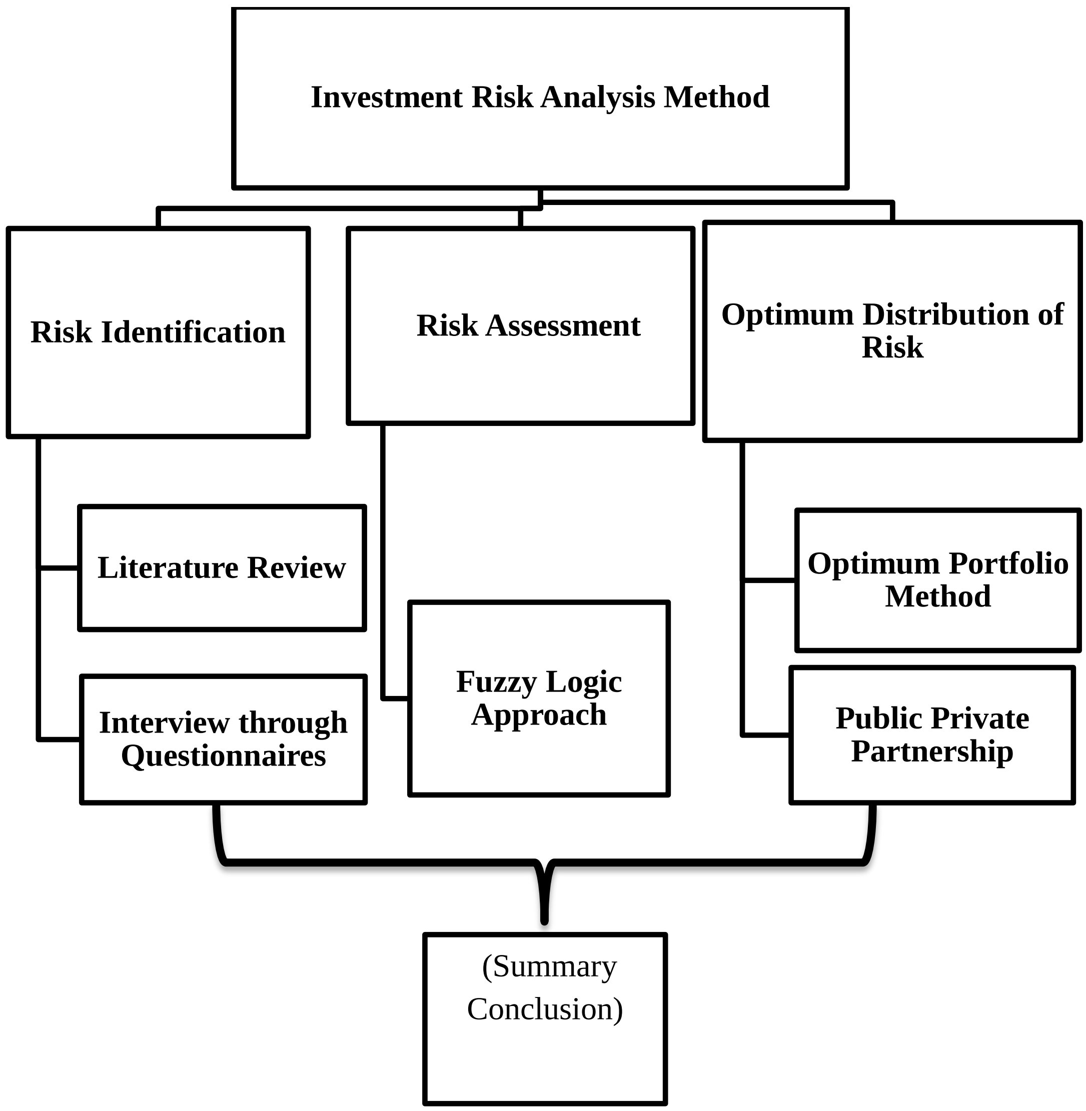


Figure 3.3: Research Model for Current Research

3.3 Aim & Objectives

After reviewing the literature, the preliminary goal and objectives, which had been defined for the research scheme, have been redefined and made more precise and engrossed. The initial aim and objectives were rather broad, as it had not been decided at that point what the authentic focus of the research would be. The aim and objectives stated below are the ones that have been redefined after the literature review was done and therefore they are the ones that were used for the primary research and analysis of the results.

3.3.1 Objectives

In seeking to explore the risk assessment for investment decision-making process of the small hydro power Sector, the literature review for the study, examined research from two different areas. Firstly, it investigated the academic literature on risk identification in small hydro power projects that impact operational and construction stage investor's globally specifically Indian context and secondly, it explored the literature relating to the risk assessment of identified risk in small hydro power industries and its investment decision-making process. Reviewing these literatures highlighted gaps in existing knowledge and the identification of the research objectives for the current study. These three objectives are:

1. To identify investment risks during construction and operational stage SHP's of Uttarakhand.
2. To assess the identified risk impact in construction & operation phase SHP Projects of Uttarakhand.
3. To distribute investment risk for investors in SHP's of Uttarakhand.

3.3.2 Central Research Question

This section will examine the research process highlighting the methodological approach adopted and the specific research instruments used to explore the research questions.

What are the risks and how it can be assessed in SHP's of Uttarakhand?

Research question Q1: What are the various investment risks during construction and operation stage of small hydro power projects of Uttarakhand?

Research question Q2: What is the assessment of identified risk in construction & operation stage of SHP's of Uttarakhand?

Research question Q3: What is the risk distribution for investors in SHP's of Uttarakhand?

Objective 1: Identify leading risks for construction and operational stage Small Hydro Power Project investors of Uttarakhand.

Identify set of key risk factors through Literature review, semi structured questionnaire. Research design is exploratory research.

Observational Design

- Literature review- published articles, Reports, DPR
- semi structured interview- to finalize the risk factors with 40 officials, (average experience 15-17 years), SHP's developers, investors, approvers
- Result is validated using Z score.

Sampling Design

- Non Probabilistic sampling
- Judgmental sampling due to limited expertise in the area

To answer the first research objective for identifying various investment risk that are most appropriate for small hydro power sector literature, the current study drew primarily on the Risks in small hydro power sector literatures. In practices the literature as an exploration method based on secondary data analysis. This intricate initially, classifying the whole variety of risks that are available and, secondly deciding which of these risks are the most appropriate for small hydro power operational and construction phase investors. It demanded cautious thought of factors such as the business environment of the small hydro power sector.

The various classes of risk factors have been determined based on the detailed literature review followed by expert interviews. The risk factors from literature review starts with global literatures available for small hydro power project which further funnel down to India and Uttarakhand. Not only has this literature review covered major regions of Uttarakhand Ganga, Yamuna & Bhagirathi. Total 37 risk variables have been identified from literature review.

The risk factors identified from literature review are site geology (geotechnical properties of the construction site), land use (right to use of the land for the construction of hydropower scheme), environmental issues (impact on ecosystem), grid connection (connection to the power system), social acceptance (impact on local community who use the river or the surrounding lands), financial (the status of the inflation and interest rate), natural hazards (earthquake, flooding and landslide), political/regulatory changes (level of political stability, clearances, PPP), access to infrastructure (road, electricity and water), revenue (cash flow), climatic(River flow), technological (operation and maintenance , silting, turbine efficiency, dam head), socio economic, environmental i.e.

Once the risk variables identified from literature review for the confirmation of those risk whether applicable for Uttarakhand a semi structured interview is taken from 40 officials of Small hydro power projects experts having 15- 17 years of average experience involved with hydro power as a developer, approver, and investors. The 40 official's responses collected because the risk variables are repeated every time with the selected people. Judgmental sampling used for this objective due to limited expertise in the area. The responses of experts were further validated and significance checked using Z score (Eq. 3.1).

$$z_{score} = \frac{p - P}{\sqrt{\frac{pq}{N}}} ---------- (3.1)$$

Where p-possibility of getting result;

q- Possibility of not getting result;

P- Respondents responded/total sample;

N- Sample Size (Hosfete,G.; 2008)

The risk factors have been further classified into construction and operation stage small hydro power project based on the expert opinion collected. Further risk variables have been distributed for risk assessment objective.

Objective 2: Assess the impact of all identified risk on investment for Small Hydro Power Project in Uttarakhand.

It Estimates the risk index and checks the impact of each risk using Fuzzy logic approach using Quantitative research design.

Observational Design

- Questionnaire framed based on output of objective 1
- 5 point Likert type scale is used
- Reliability of the questionnaire to be tested through pilot study
- Finalized questionnaire after pilot study
- Questionnaire send for response collection to 397 respondents having average experience 15-17 years, professionals, approvers, developers, investors & researchers of Uttarakhand area
- 119 responses collected and analyzed using Fuzzy Logic approach.
- Fuzzy logic validated- out of box method.

Sampling Design

- Non Probabilistic sampling
- Judgmental sampling due to limited expertise in the area

In exploring the second research question, the current study aimed to establish current practice in risk assessment in the existing small hydro power project globally than focus on India and Uttarakhand area. Two factors directly affected the choice of research method chosen to investigate this question. Firstly, previous empirical research into other similar projects. Through in this process, the research identified the various risk analysis techniques that are particularly useful for small hydro power sector but anyone can make it generalize as well for almost many infrastructure projects. A tactic to risk assessment for investment decision-making in the small hydro power was developed that utilized the full range of tools recognized. Some risk analyzers using judgment analysis technique for risk assessment and impact on investment appraisal (for example, Hammond, 1966). However, in reality, each tool has limitations (Lefley and Morgan, 1999) some that are inherent, others which are caused by a lack of evidence.

Therefore, a combination of risk identification and assessment are used. Risk assessment contains both impact assessment and risk quantification. Some hydro power analysts have recognized this and presented the collection of Risk analysis tools that they believe constitute those that investors ought to use for risk assessment in small hydro power sector (for example, Fleten,2007). However new techniques have only recently been applied to the industry (for example, Galli *et al.,* 1999; Dixit and Pindyck, 1998 and 1994; Ross, 1997; Smith and McCardle, 1997) and as such, these previously presented approaches now require modification. Consequently, although informed through secondary data sources, the identification of the risk and impact assessment techniques that are most appropriate for Risk assessment for investment decision making in small hydro power projects presented in this thesis, are believed to be two of the main findings of the research.

Risk assessment processes had typically used quantitative survey-based research. These studies had normally produced statistical results that indicated the percentage of organizations using in their decision analysis techniques (for example see studies by Arnold and (Hatzopoulous, 1999; Carr and Tomkins, 1998; Schuyler, 1997; Buckley *et al.*, 1996; Shao and Shao, 1993; Kim, Farragher and Crick, 1984; Stanley and Block, 1983; Wicks Kelly and Philippatos, 1982; Bavishi, 1981; Oblak and Helm, 1980 and Stone hill and Nathanson, 1968). Researchers such as (Clemen;1999) perceived that through using survey-based research methods these studies had overlooked many interesting issues.

By making a sustained focus on context integral to their work, qualitative researchers look at social worlds holistically, as interactive, complex systems rather than as discrete variables that can be measured and manipulated statistically. Therefore for these reasons, the researcher decided to use a qualitative & quantitative approach to answer the second research objective and understand small hydro power sector.

Having decided the overall methodological approach, the next step in the research process involved deciding which small hydro power project would comprise the population for the current study. In subjective research, participants are carefully selected for inclusion based on the possibility that each participant will expand the variability of the resulting sample (Gambeson, 2000). With so much of the data analysis taking place in the sub-conscious mind, it is impossible to present a full account of it (Whyte, 1955). The current study then uses the approach of who believes one way to ensure the integrity of the data and the objectivity of the resultant findings are for researchers to use verbatim accounts taken within their original context. Through this process a description of current practice was produced and, therefore, research question two was answered.

The questionnaire has been framed based on risk identified from objective 1. The questionnaire framed on 5 point Likert scale between 1-5, where one represents “low” and five “very high". The same was sent for pilot study to experts for validation. After validation the same questionnaire sent for survey. In order to determine the relative importance (impact) of the risk factors, a survey was conducted with the experts from the officials of UJVNL, investors, developers and approvers that have involvement in the construction & operation of hydropower structures from almost 15- 17 years. 397 respondents were selected and questionnaire was sent using e-mails, Google docs form was shared. Out of 397, 119 responses were collected (Yamane, 1968). The response rate was found is 30%. Judgmental sampling was used for the selection of respondents as limited availability of expertise is there in this area.

The participants were asked to grade the importance of the risk variables regarding their importance and significance of apprehension. They ranked the risk factors using a 5 point Likert scale. Fuzzy logic is one of the strategic techniques that consider both linguistic and nonlinguistic risk factors all together. There are some parametric risk assessment tools are available which deals with nonlinguistic or numeric data as Monte Carlo simulation is one of them.

The risk quantification even for parametric risk factors has been performed before applying fuzzy logic risk assessment using Monte Carlo simulation. With MCS risk assessment performed taking historical data of variables chosen based on their availability as price, generation, river flow, interest rate, tax rate, head; Operations &Maintenance cost, capital cost and revenue. The data has been taken for 19 years (1996-2013) and probability density functions were created using crystal ball software. The probability density function (PDF) is created for all the variables and each PDF will give the probability of occurrence of the event and severity or impact is also created.

Monte Carlo tool is used to check the impact of these risk variables on financial indicators (NPV, IRR, and BCR). Probability density function implied using Crystal Ball to check the impact on financial indicators which provide certainty over estimated deterministic values of NPV, IRR & PI. The outcome is useful for investors as it will as they get clarity in the certainty of their desired result.

Monte Carlo simulation is treating with parametric risk factors only but Fuzzy Logic approach deals with both parametric and non-parametric risk variables so transition from Monte Carlo to fuzzy logic is required. The fuzzy logic process methodology is explained in detail in chapter 5.

Objective 3: To distribute investment risk for investors in SHP's of Uttarakhand.

Distribute risk using optimum portfolio theory and Public Private Partnership model using Quantitative research design.

Observational Design:

- Literature review- Risk distribution- portfolio theory & PPP model
- Portfolio theory- Risk assessed comes from objective 2 and for return DPR of one construction & operation stage SHP's

- Optimum portfolio theory applied for risk distribution between operational & construction project

PPP model – risks impact used comes from Objective 2, distributed in different business models based on literature review, and judgment.

Once the risk is assessed based on objective 2 investors get relief while they can distribute the risk properly. For risk distribution there are three major theories has been identified portfolio theory, concession agreement using business models and extreme value theory as mentioned in chapter 2 in detail. Among the three theories two major theories has been selected for the study as concession agreement and portfolio theory as extreme value theory has some limitation which discussed earlier. In portfolio theory the risk has been assessed based on results of Monte Carlo simulation and Fuzzy logic approach. Risk has been distributed between two different SHP projects using mean variance portfolio of risk and return which will be discussed in detail in chapter 6. This theory helps investors to distribute their risk between two different projects and it also optimizes their returns.

Concession agreement has been also implied using different business models as BOT, BOOT, and BTO i.e. in which the risk is distributed among public and private investors which is another beneficial step for investors. The individual risk variables quantified based on fuzzy logic theory has been used for risk distribution among different business models and it gives optimum results to investors.

3.3.3 Data Collection Methods

This paragraph will shape the methods that were used to attain the Goals and objectives. Figure 4.2 shows that the starting point of the research process should be the theory, after which the analysis can be defined and the primary research designed, implemented and analyzed (Finn et al., 2000). Therefore, the secondary research will be discussed first, trailed by the primary research.

3.3.3.1 Secondary research

Every study should contain secondary research because secondary data gives on overview of what has been explored before in the equivalent subject area, which will not only help to select a research topic and place the research in context, but is also vital for the decision on research design for the own research (Zhang et al., 2010a).

3.3.3.1 Secondary Data Methodology

The secondary data research started with a search for articles and books that explained the basics of Small hydro power risk identification and assessment and their impact on investment decision making and that elucidated the theories of several researchers in the field (e.g. (Heggedal et al., 2011a). Hereafter, the books and articles from these main researchers (e.g. Hofstede 2001) were read and a start was made with the literature review. In order to get a stronger and more unbiased view of the theories, articles and books were sought that conferred and assessed them. To find more sources, the lists of the texts that were already used were divided, and as a result much more relevant literature was found. When the researcher academically found sufficient information on the relevant theories, the rest of the literature review was transcribed, joint the focus towards the final research area.

3.3.3.3 Sources

The sources for the literature review consisted for the greater part of research papers from journals, articles and books about the risk assessment and investment decision making practices Hydro power projects. Other sources were books, articles and websites about energy sector, renewable energy sector, hydro power sector, risk management process in hydro power sector, investment theory practices globally and in Uttarakhand, DPR's of existing small hydro power projects. Secondary data will be culled out from reports and publications of these following organizations.

- Reports of Ministry of New and Renewable Energy, Government of India
- World Bank
- International Energy Agency (IEA)
- National Renewable Energy Laboratory (NREL)
- Reports of Planning Commission of India
- Indian Renewable Energy Development Agency – IREDA
- Central Electricity Authority (CEA), Govt. of India
- Central Electricity Regulatory Commission (CERC), Govt. of India
- Uttarakhand Electricity Regulatory Commission (UERC), Govt. of India

- Ministry of New and Renewable Energy (MNRE), Govt. of India
- Uttarakhand Ministry of Power, Govt. of India
- Uttarakhand Jal Vidyut Nigam Limited, (UJVNL), Govt. of India
- Detailed project reports of construction stage, operational stage small hydro power projects.
- Scholarly journals

3.3.3.4 Primary Research

This paragraph will elaborate on the methodology that has been used for the primary research. It will review the method used for data collection and validate the choice, the sample will be discussed, and validity, reliability and representativeness will be examined.

3.3.3.5 Primary Data methodology

In the introduction of this chapter, it has been indicated that the most suitable primary data collection methodology depends on what kind of information is sought (Kumar 1999). A research is defined as qualitative if "the purpose of the study is primarily to describe a situation, phenomenon, problem or event and if analysis is done to establish the variation in the situation, phenomenon or problem, without quantifying it" (Kumar 1999, p.10). If the purpose is to "quantify the variation in a phenomenon, situation, problem or issue, if information is gathered using predominantly quantitative variables, and if the analysis is geared to ascertain the magnitude of the variation, the study is classified as a quantitative study".

In the case of a quantitative application, use could be made of the risk index scores of projects to explain a variety of measured phenomena. In the case of qualitative applications, the dimensions could help to explain and understand observed similarities and differences between corresponding phenomena in different power projects. While quantitative application requires data for preferably more than two or three power projects, qualitative application is possible for any comparison of two projects. (Hofstede 2001).

When the definitions of qualitative and quantitative research and the guidelines of (Fougère & Moulettes, 2002) are taken into account it can be established that this research is best described as quantitative as its main purpose is to establish what differences exist between the views of investors with and without considering risk with quantified data. Therefore, the initial idea was to use structured questionnaires from experts in small hydro power projects whether they are developers, investors or higher officials as research methodology to form a picture of the situation of risk in small hydro power sector in Uttarakhand region. When the literature review was done and the research questions were better focused and defined, it has been decided, however, with literature review planned research method of structured interviews has be followed further in the following way:

- The initial plan was to perform the interviews in the officials of UJVNL, MOEF, investors in Uttarakhand, India. This was decided mainly because these officials and investors are directly related with small hydro power sector investments whether it belong to any class. However, it proved very hard to make the initial contact and when the researcher had finally succeeded in reaching the right person; it was difficult to coordinate the visits to the chosen persons due to other pre-occupations of the staff.

- It was also believed that it might be better to have information typically for construction and operational stage power projects as compare to other stages; probably it creates confusion to investors.
- Further reasons for aborting the interview approach were time constraints. Doing the primary research from the UJVNL Uttarakhand through questionnaires would be less time consuming.

When the above-mentioned reasons were taken into account, it was decided to use self-administered questionnaires for the primary research. The initial plan was to use structured interviews to enable comparison and in fact, a questionnaire is not much different from a structured interview. The disadvantage of a questionnaire is however, that it is not possible to clarify the questions when they are not well understood or to press for a clear answer when the respondent has the tendency to give a short or ambiguous answer on an important subject. An advantage of the questionnaire is that it can be sent to as much respondents as possible and therefore gives the opportunity to clarify the results. The first set of questionnaire mentioned in annexure A2 is used for risk identification and taxonomy. After the risk has been identified the two different set of questionnaire prepared for construction and operational stage small hydro power projects mentioned in annexure A3 & A4. The questionnaire for risk assessment was prepared with pilot study conducted with experts of UJVNL.

3.3.4 Sample size

Questionnaire surveys usually involve only a proportion, or sample, of the population in which the researcher is interested (Veal 1997). Although it is said that there are no set rules on how many questionnaires should be distributed or interviews given, the aim should be to acquire a range of responses that is as representative as possible to allow the fulfillment of the objectives of the study and to present answers to key questions (Bell 2001). In this research, it has been decided to send the questionnaires to all technical, managerial, operational people and investors of UJVNL, researchers who have average experience of 15-17 years and those who are directly or indirectly related with investment in small hydro power plants. For risk identification 40 officials were interviewed using semi structured questionnaire and for risk assessment 397 questionnaires were sent out of which 119 responses are gathered which is around 30% responses rate (Yamane, 1968).

For checking the impact of identified risks and risk quantification four power plants were chosen in which two are from Ganga basin Mohammadpur near Haridwar and Pathri in operation stage, and in construction stage one project from Ganga, Kaldigad and one from Yamuna basin AsiGanga I is selected.

The base for considering these plants are they all have capacity less than 25 MW (Small hydro Power Projects) and they have same geological conditions so result possibilities are similar. Judgmental sampling was used for the study due to limited availability of experts in this area.

3.3.5 Reliability, validity and representativeness

Each research and research method should be examined critically on its reliability, validity and representativeness (Finn et al. 2000). The reliability of a method is related to the consistency of the results obtained from it. In the case of a questionnaire, the questions should obtain the same answer from a person each time it is asked. To assure this, the questions should be simple and clearly worded (Finn et al. 2000; Bell 2001). The rationality of a research mechanism indicates if it measures what it is supposed to measure and if the collected information really reflects the phenomenon that is studied (Veal 1997). Finally, the representativeness of a research's results indicates to what extent these results can be generalized (Finn et al. 2000), by asking if the data and the research methods, together with conclusions derived from data analysis, are broader in their application than the sample of respondents studied (Clark et al. 2002).

To ensure the reliability of the results, special care was taken to ensure that the questions were clear and easy to answer. Where needed, certain concepts were explained to ensure that there could be no mistake to what was meant.

Concerning the validity of the results, the Cronbach alpha of the questionnaire was checked twice one after taking 35 responses Cronbach alpha comes as 0.72 later after 75 responses again Cronbach alpha was checked it came around 0.74 later after 119 responses Cronbach alpha of the questionnaire would be 0.79. This gives validity of the responses of the questionnaire survey. The physical verification of the responses were also performed randomly which shows that respondents give the responses properly if any vague things come across that was removed from analysis.

It can be said that the risks that were identified as representing small hydro power plants at first two phases as construction and operation stage, were derived from indications in the literature further in the form of questionnaire.

For risk identification purpose the major risks were identified based on literature review and further those risk were validated using Z_{score} discussed in detail in chapter 4. Further risk assessment is validated using out of box analysis mentioned in chapter5. The questionnaire survey proven its validity with Cronbach alpha and historical data is taken from DPR's and crosschecked with concerned departments of UJVNL.

Therefore, the results will probably not be reliable for all regional and sub-regional hydro power investors across. The researcher believes however, that in an exploratory research it is not that important that the sample is representative as the main objective is to establish if it is feasible to start a larger research which in that case should indeed have a representative or at least closer matched sample than could be assured in this research.

3.3.6 Description of the questionnaires

All respondents received the same email with a cover letter and questionnaire in English so that the respondents could be comfortable to choose right answers. For risk identification a semi structured questionnaire was prepared mentioned in annexure A2 includes 41 question and three different zones of responses are collected using dichotomous questionnaire yes or No which states whether the risk variables is exiting and if yes belong to which classification operation, construction or both.

There is another set of questionnaire is used for risk assessment for operational stage and construction both stages individually as risk variables are different.

32 and 30 questions were framed in each case respectively (Annexure A3 & A4). Some questions are common in both the questionnaire reason behind this is the same risk factor exists in both the stages with different risk impact and severity. Question 1-7 represent the general information of the respondent after that the risk related questions originated and based on that survey conducted. The confidentiality of respondent kept with proper concern.

3.3.7 Breakup of Respondents

The respondents are taken as developer, approvers, researchers, investors and other professionals of hydro power projects in which proportion of investor is highest as 33% and then approvers with 22%.

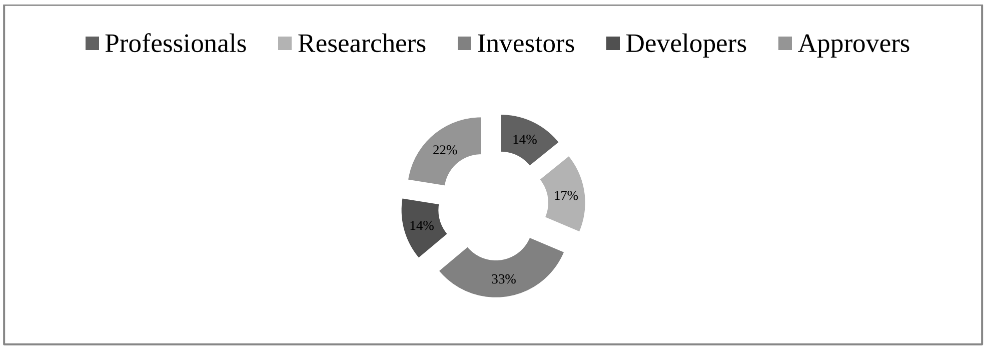


Figure 3.1: Respondents Distribution for Questionnaire Responses

3.4 Analysis Technique

The objective of the research mentioned above starts with to find out various investment risks in small hydro power sector stage specific viz. construction and operational. For identification of risk detailed literature review followed by semi structured kind of interview or discussion with officials was performed. The risks were classified into operation & construction stages.

Advance Excel is used for proving this objective. For validation **Zscore** is applied.

For quantitative risk assessment Stochastic Monte Carlo simulation used with the help of Crystal Ball an add in extension of Microsoft Excel. In Crystal Ball input data is required of all risk factors in probabilistic form which is created using crystal ball. Monte Carlo simulation result raised in financial indicators NPV, IRR & BCR. The certainty of the result is shown with graphical representation and statistical table that shows result.

For qualitative risk factors a questionnaire was floated among respondent and based on responses the Fuzzy logic approach is applied for risk assessment. The fuzzy logic approach applied using Microsoft excels with various advances in build functions as count, average, sum product etc.

For estimation of the optimum portfolio the Microsoft excel is used for preparing mean variance portfolio, different weights of projects considered randomly using random number function and then the optimum portfolio is created. The optimum portfolios are also prepared using Excel graphical representations.

3.5 Limitations

This paragraph will name the major limitations for the secondary and primary encountered during the research.

3.5.1 Secondary research

One of the major limitations of the secondary research has been the non-accessibility of sources. Although the researcher has been able to locate many useful sources, it was impossible to locate others, which were considered very valuable to the research. Especially books, articles and web sources commenting on the investment risks in SHP's globally. In Indian context no such literature is available so far that makes it challenging for current study. Another limitation of secondary research is presence of lag data in data set, i.e. while collecting data for river discharge, researcher found daily discharge is missing few places which create loss of potentially and valuable information, simultaneously it creates subjective bias also in result. The collection of detailed project report stage specific is another challenge for researcher, as DPR are available in different department and coordination takes time. Simultaneously all DPR's are not shared due to confidentiality issues or under processing purpose which may skip some valuable information.

3.5.2 Primary research

Problems that were encountered during the primary research were mostly related to the accessibility of the persons that were needed for the research (first to arrange interviews and later to fill in the questionnaires). The fact that the research had to take place nearby elections and holidays as a result that it was difficult to reach the right persons because they either were on election duties or on holiday or did not have time because they were in their busy period. When some respondents were phoned to ask if they received the questionnaire well, it appeared that many emails did never arrive or had been forwarded to someone who was occupied some other activities, which could be a reason for the low response rate. Unfortunately, it would have been impossible to make multiple phone calls to all persons of UJVNL to obtain a contact name and to control if all questionnaires had actually been received. No of respondents could be increased which make sample size small.

The researcher recognizes that the sample covered is only operational and construction stage power project which is limited area, therefore the conclusions are rather limited. As this is an exploratory research, it is not the outset to make conclusions based on statistical facts but it is the idea to make tentative conclusions that can be used to establish if any further research would be feasible.

3.6 Chapter Summary

The methodology that was used to explore the research questions set out in this section has been described and critically evaluated. In doing so, it has provided an example of how research can differ from the ordered and rational approaches of the more prescriptive research methodology texts. The limitations of the current study have been highlighted. Directions for future research will be proposed.

The Uttarakhand power system is an ideal case study since it is based almost entirely on hydroelectricity. In Uttarakhand hydropower is the major source of electricity its potential is very high when this potential is harnessed more properly than Uttarakhand government will be able to supply more electricity to nearby states and generate more revenue (Energy statistics, 2011). However, the hydel power sector of uttrakhand is still based upon the traditional approach for investment planning unlike developed countries, where all the major uncertainities and risks associated with the investment are considered before investment (Hydropower policies and Guidelines, 2011).

The next chapter examines the context for the current study. It will show how the small hydro power sector is such an inspiring example of investment risk assessment under conditions of best investment decision practices that it provides a useful environment in which to invest and flourish the sector and economy.

CHAPTER 4

RISK IDENTIFICATION IN SMALL HYDRO POWER: AN OVERVIEW OF UTTARAKHAND PROJECTS

4.0 Introduction

This chapter draws on the hydroelectric power to present a brief description of the sector that highlights the main challenges facing it in the 21st century. Since the current study focuses on Small Hydro Power projects that constructed in Uttarakhand or those which are under construction, the effects of these global changes on the Small Hydro Power is examined. This indicates the growing complexity of the business environment of those hydro power projects which are either operational or under construction. This research highlights why decision analysis is beginning to receive increasing attention in the projects and, consequently, why it provides such a useful context in which to study investment decision making.

4.1 Energy scenario in India

The world is increasingly aware that fundamental changes will be necessary to meet the growing demand for energy. There are many possible scenarios which may emerge in the foreseeable future. The Indian economy has experienced unprecedented economic growth over the last decade. As per (Government planning commission report, 2012) the Indian economy to grow at 8.5% per cent, it is imperative for the power sector to grow at 8.1 per cent per annum. Today, India is the ninth largest economy in the world, driven by a real Gross Domestic Product (GDP). The growth of GDP is 8.7% in the last 5 years (7.5% over the last 10 years) (Pharlia, 2007). In 2010 itself, the real GDP growth of India was the 5th highest in the world. (Basu & Garg, 2012)This high order of sustained economic growth is placing enormous demand on its energy resources. The demand and supply imbalance in energy is pervasive across all sources requiring serious efforts by Government of India to augment possible energy supply.(Basu & Garg, 2012) India's energy basket has a mix of all the resources available including renewables. Other renewables such as wind, geothermal, solar, and small hydro represent the Indian fuel mix. (Salmon et al., 2011)

The International Energy Agency (IEA) statistics shows that globally the electricity demand almost tripled from 1971 to 2008 (*Energy statistics 2011*, 2011) shown in fig. 3.1.The various sources which are require to fulfill the energy demand in which thermal power plants play a major role at the same time hydro, nuclear and non-utilities also has influence. Hydro is considered to be the second potential source of electricity after thermal ("Hydro Power in Uttarakhand," 2008). Though thermal is a potential resource of electricity perhaps reliability only on thermal power projects for longer duration is questionable as it is nonrenewable source of energy. (Sørensen, 1974)

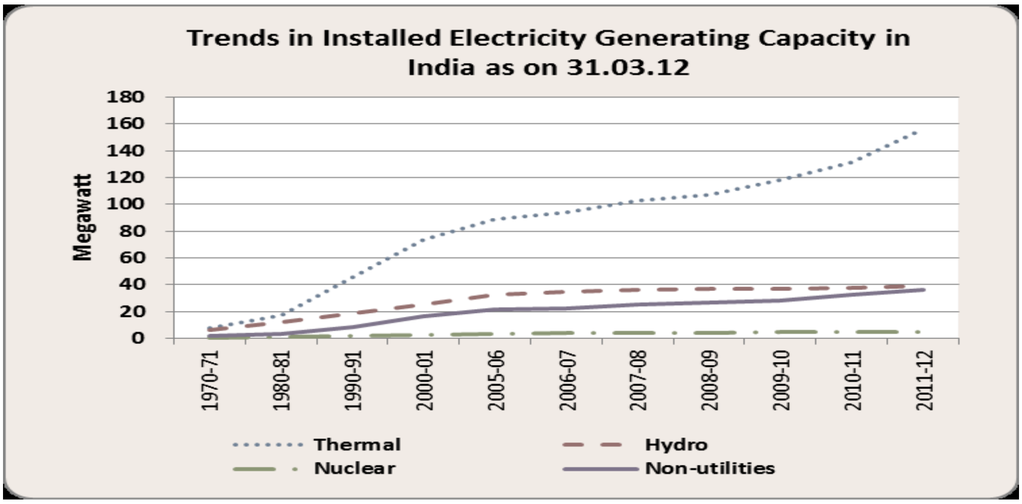


Figure 4.1: Trend in Installed electricity Generating Capacity in India as on 31.03.2012

Coal is the dominant fuel in India's energy mix. India has vast coal resources, but most are of low quality. Indigenous Small Hydro Power sector reserves are in short supply while demand for Oil almost quadrupled from 1980 to 2005(Montgomery, 2009). Oil imports are projected to increase even more going forward, leaving the country more vulnerable to international price spikes and potentially unreliable supplies. (Macmillan, F.; 2000)Fossil energy resources are not only limited, expensive but are also associated with a number of negative environmental effects. At some point the contribution of renewable energy sources must form a substantial portion of the overall energy bucket. (Jayant Sathaye (USA), Oswaldo Lucon (Brazil), 2012a)The reasons are well known and well documented – Environmental concerns, depleting fossil fuel resources, excessive dependency on Oil imports etc. – that it hardly merits repetition.

Renewable energy (RE) sources form a small portion (less than 10%) of India's overall energy consumption today ("International Energy Agency," 2013). Wind power is one of the major potential sources of renewable energy followed by Solar and bio power which are other reliable sources.

There are few problems that power sector is facing as reforms of power market to encourage competition (IEA-2013), Rising prices of electricity(Nandy & Bhattacharya, 2012) and Greenhouse Gas Emission (Zhang et al., 2010c). Above all worldwide escalating energy demand requires developing "clean energy" source as the future energy source. It was observed from various sources (Castaldi, Chastain, Windram, Ziatyk, & Sciences, 2003b); (Ministry Of Environment And Forests New Delhi , 2006)Teacher's manual, IIT Roorkee, 2008; (Knutsen & Poulsen, 2010b) that currently there is no significant clean energy production. Hydroelectricity is considered as the best source of "clean energy" resource and low price source of electricity.(EIA, 2012.) Hydropower has acted as a catalyst for economic and social development by providing both energy and water management services. The Eleventh Plan calls for grid connected renewable energy to exceed 30000 MW by 2020. (*National hydroelectric power corporation limited*, 2007)Renewable energy technologies are being deployed at industrial facilities to provide supplemental power from the grid, and over 70% of wind installations are used for this purpose. Biofuels and solar energy have not yet reached a significant scale in India. (Pillai & Banerjee, 2009)

Energy exploration and exploitation, capacity additions, clean energy alternatives, conservation, and energy sector reforms are critical areas for energy security (Mckinsey, 2010). Energy conservation has also emerged as one of the major issues in recent years. Conservation and efficient utilization of energy resources play a vital role in narrowing the gap between demand and supply of energy. Improving energy efficiency is one of the most desirable options for bridging the gap in the short-term. (Mckinsey, 2010)

Above mentioned reasons are the challenges in front of government so they emphasize on and safety and clean source of energy yet small hydro power is considered as best source of clean energy. Small Hydro Power energy constitutes more than 15% of the overall renewables mix (Phuyal, 2006) as shown in Table 4.1. However, contribution from Small Hydro Power plants towards the hydro energy generation in India is much unexploited as most of the hydro energy generated is only through large or medium hydro power projects.(Indian Institute of Technology, 2007) With increased pressure on availability of electricity and less complicacy for land and development purposes, agriculture and irrigation, India has to quickly exploit its unharnessed Hydro potential through SHP projects for producing power. Several European countries, most notably, Denmark, Germany and the UK have proactively tapped the Small Hydro Power energy potential to reduce their dependence on fossil fuels.

Source/System	**Estimated Potential (MW)**	**Capacity addition till 9th Plan (MW)**	**Capacity addition in 10th Plan (MW)**	**Capacity additions in 11th Plan till Dec '10 (MW)**	**Total capacity as on Dec 2010 (MW)**
Wind Power	**48,500**	1667	5427	5973	13,066
Small Hydro	15,000	1438	538	963	2939
Bio Power	23,700	390	795	1427	2632
Solar Power	20-30 /sq. km	2	1	14	18
Total	**~ 90,000 MW**	**3475**	**6761**	**8377**	**18,655 MW**

Table 4.1: Plan Period Wise capacity addition in Grid Connected Renewable energy Based power generation installed capacity (in MW); Source: MNRE, Government of India

4.2 Indian Power sector

Power development is the key to economic development. Power sector has been receiving adequate priority ever since the process of planned development began in 1950. (Joshi, 2007a)This sector was getting 18-20% of the total public sector outlay in the initial plan periods (Joshi, 2007a). A remarkable growth and progress have led to the extensive use of electricity in all the sectors of economy in the successive five year plans. It has been empirically established that energy consumption is positively correlated to GDP. (Fatai *et al.*, 2004).

Ever since India attained Independence, development of the electricity sector has primarily been the responsibility of the government, with a relatively small contribution from private enterprises, in the form of licensees like the Bombay Suburban Electricity Supply Company (BSES), the Tata Electricity Company (TEC), the Calcutta Electricity Supply Company (CESC), and the Ahmedabad Electricity Company (AEC).(Pharlia, 2007)

Over the years (since 1950) the installed capacity of power plants (utilities) increased to 147,965 Mega Watt (MW) (March 31, 2009)2 from a merger 1,713 MW in 1950, registering an increase of 86 times in 59 years.(Planning commission report, 2011) In the field of rural electrification and pump set energization, the country has made a tremendous progress. About 85% of the villages have been electrified except the far-flung areas in the Northeastern States, where it is difficult to extend the grid supply.(Basu & Garg, 2012)

The per capita consumption of electricity in the country also increased from 15 kWh in 1950 to about 704 kWh in 2007-08, which is about 47 times. The

Ministry of Power has set a goal—Mission 2020: Power for All. The main objectives behind the mission are: Sufficient power to achieve a GDP growth rate of 8%, (Wong & Kelley, 2010b) reliable power; quality power; optimum power cost; commercial viability of the power industry and power for all.

There is a fine interconnection between the availability of power and economic development of the masses of any country.(Rana, 2003) Power leads to industrialization and helps in the creation of jobs. Industrialization and power lead to automation, improvement in the banking and communication system, and further affects the money markets and financial institutions. The funds that are generated could be used for further development of power and other core infrastructure sectors. (UJVNL, 2010)

Indian economy is clocking an impressive growth of close to 9% for many years now and is likely to maintain this momentum in the foreseeable future.(IEA, 2008) To sustain this spectacular GDP growth, power sector in India needs to build additional power generation capacity at unprecedented pace to support the ever growing energy demands of communities of consumers and industries.(Jayant Sathaye (USA), Oswaldo Lucon (Brazil), 2012a)

Indian power sector has an installed capacity of 86000 MW. Out of which 25% is hydro power and remaining are thermal, nuclear and gas-based projects. ("The Indian power sector : investments, growth and prospects," 2013)Power shortages in our country are estimated as 9% of total energy and 18 % of peak capacity requirements (IEA technical Report, 2013). Thermal based power projects have environmental repercussions related to emission of suspended particles and gases. While, large hydro power plants could lead to degradation and erosion of soil, loss of forests, wild life habitat and bio-diversity and most important is the resettlement of people. To promote the environmentally sound energy investments as well as to help in mitigating the acute shortfall in power supply, the Government of India is promoting development of country's renewable energy resources and had made it a priority thrust area under India's National Environmental action plan(Smith, 1999). The global overview of hydro power sector is discussed in section 3.2.

4.3 Global view of Hydro Power Sector

India's potential of hydroelectricity ranked fourth following China, Brazil, and Canada. Whereas on the ground of installed capacity India ranked fifth because its utilization is only 18% of its potential (Flippani, 1988). Contrary Norway whose potential stands only one third of India's potential but installation exceed to 58% which creates benchmark for other countries. (Table 4.2).

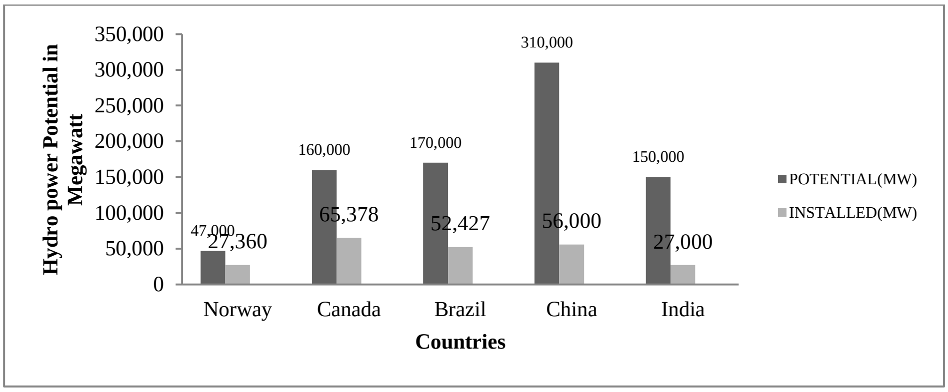


Figure 4.2: Potential and Installed capacity of Hydro Potential Globally

Country	Potential(MW)	Installed(MW)	Percentage (%)
Norway	47,000	27,360	58
Canada	1,60,000	65,378	48
Brazil	1,70,000	52,427	31
China	3,10,000	56,000	18
India	1,50,000	27,000	18

Table 4.2: Exploitation of Hydro Potential in Global

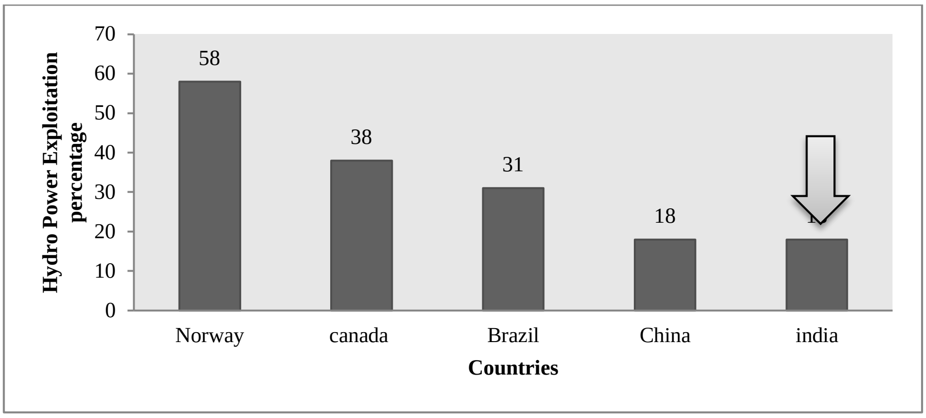


Figure 4.3: Percentage of Hydro Power Exploitation in Various Countries percentage

The Himalayan region covers mainly eight countries i.e. India, China, Nepal, Bhutan, Bangladesh, Myanmar, Pakistan and Afghanistan. In Indian perspective Himalayas consist of four ranges extending about 2500 kilometers from Arunachal Pradesh on the Tibetan border in the east to Jammu and Kashmir in the West. (Meeting, Ggf, Workshop, & Power, 2012b)The mountains in the range are between 5 000 meters and 9 000 meters in height and fall steeply through sheer-sided gorges and river valleys to the northern Indian plain over only a few hundred kilometers (Joshi, 2007a). The total land area of the Himalayas is about 600 000 square kilometers. Nineteen major river systems, including the Brahmaputra and the Indus, rise among the mountains.(S. A. Hosseini, 2011b) Our image of the Himalayas is dominated by jagged, snow-capped peaks, but in fact the bulk of this land area is below the snow line.

The physical geography provides excellent hydropower potential which was recognized very early in the history of modern hydropower (Bloom et al., 2007). This inevitably pushes up the unit cost of installed capacity. Nevertheless, there are a number of practical obstacles to the realization of this potential (Gains et al., 2002). The region is quite harsh in climate and in some areas construction work is not feasible for a large part of the year. Many prospective sites are in quite remote locations and the infrastructure costs associated with their development are high. (Jalsrot Vikas Sanstha, 2007.) Indian small hydro power sector is discussed in detail in section 4.4.

4.4 Indian Small Hydro Power sector

Small hydro power sector in Indian context is defined as that hydro power project whose installation capacity is less than 25 MW. (Kucukali, 2011a)The small size and clean source of energy makes SHP development is one of the thrust areas of power generation from renewables in the ministry of Renewable and energy resources (MNES). MNES is encouraging development of small hydro projects in the State sector as well as through private sector participation in various States (MNES, 2003). Small or mini–micro hydro power is one of the earliest known renewable energy sources, in existence in the country since the beginning of the 20th century. In fact much before that, the technology was used in Himalayan villages in the form of waterwheels to provide motive power to run devices like grinders. (Phuyal, 2006)References to mechanical energy extraction have been found from as early as twelfth century.

Small Hydro Power technology was introduced in India shortly after the Commissioning of the world's first hydroelectric installation at Appleton, USA in 1882. The 130 kW plant at Darjeeling in the year 1897 was the first Small Hydro Power installation in the country("Hydro Power in Uttarakhand," 2010.). A few other powers houses belonging to that period such as Shivasundaram in Mysore (2 MW, 1902), Galgoi in Mussoorie (3 MW, 1907), and Chamba (1.75 MW, 1914) and Jubbal (50 kW, 1930) near Shimla are reported to be still functioning properly (IIT Roorkee, 2007)

In 1989, when the subject of small hydro up to 3 MW station capacities was given to the MNES, the total installed capacity of such projects was only 63 MW. In just 10-15 years, this capacity has increased fourfold. (Growth & Development, 2010.)Among the major initiatives taken in this regard includes identification of potential sites and their feasibility studies, R&D-cum demonstration projects with new and innovative approach and technical and financial support to set up grid connected as well as decentralized small hydro projects.

From 1989 to 1993, the thrust of the programme was on setting up of demonstration projects in various States to regenerate interest of State Governments/ SEBs to set up Small Hydro Power projects. (Growth & Development Uttarakhand Report, 2012.)For this purpose capital subsidy of up to 50% of the cost of project subject to a maximum of Rs. 2.50 crores per MW was provided (Producers, 2006)

During 1993-94, keeping in view the overall policy of Government of India to encourage private sector participation in the field of power generation, the thrust of Small Hydro Power programme was also shifted to encourage private sector for setting up of commercial Small Hydro Power projects. (Naik & Rathod, 2008a)All the states were requested to announce suitable policies for private sector participation in the field of Small Hydro Power. For this purpose guidelines were issued by MNES to the states. So far 15 potential states have announced their policies for private sector participation in Small Hydro Power sector. Till December 31, 2004, 514 Small Hydro Power projects with an aggregate installed capacity of 1693 mw have been installed (Joshi, 2007a). At the end of the 9th plan the total installed capacity of Small Hydro Power projects station capacity was 1438.89 mw. A capacity addition of 80.39 mw was added during 2002- 03. Small Hydro Power projects with a total capacity of 84.04 mw were commissioned during the year 2003- 04, taking the total installed capacity to 1603 mw from 496 projects. In 2004- 05, 90 mw capacity from 18 projects was commissioned till December 2004. Besides these, 159 Small Hydro Power projects with an installed capacity of 489 mw are under implementation. Small Hydro Power of station capacity up to 25 mw is being promoted. (S. A. Hosseini, 2011b)

Hydro power is recognized as a renewable source of energy, which is economical, nonpolluting and environmentally benign. Small hydel projects have the potential to provide energy in remote and hilly areas where extension of grid system is un-economical (Secretariat & Roorkee, 2005) These projects are economically viable, environmentally benign and need a relatively short time for implementation and are not generally affected by the constraints associated with large hydro projects. Realizing this fact, Government of India is encouraging development of small hydropower projects in the country. (Planning commission, 2006)

In order to promote activities in this sector and to exploit Small Hydro Power potential in the country in a systematic manner, the Ministry is adopting a multi-pronged strategy. Various physical and financial incentives are being extended to develop this sector (Pasha & Nasab, 2012a). The focus of the Small Hydro Power programme is now towards commercialization through private sector participation. ("Hydro Power Project Financing Scenario in India – A Case Study on Hydro Power Projects in India Publication Details :," 2004.)The small hydropower projects are developed in the potential regions by the SEBs/ State Agencies. Most of the Small Hydro Power projects are grid connected. However, there are some projects, which are decentralized and are managed by local community/ Non-governmental organization (NGOs). Recently, a programme on development and up-gradation of water mills has been started to directly use mechanical power for different applications. The Ministry is also implementing an UNDP-GEF Hilly Hydro Project in 13 States of Himalayan and Sub-Himalayan Region (Montgomery, 2009)

The major hydro power electricity generation states in India are Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Arunanchal Pradesh etc. Potential wise Himachal ranked first followed by Uttarakhand (Fig.3.4). However installed capacity of Uttarakhand is more as compare to Himachal which is around 23% (fig. 3.5) so Uttarakhand is having more scope for harnessing the potential so it is to be chosen as a research area. (IEA Report, 2013)

State	Potential(MW)	Project Installed(MW)	Project Under Implementation(MW)		percentage
Arunanchal Pradesh	1328.68	78.835	38.71	117.545	8.84675
Himachal Pradesh	2267	375.385	132.2	507.585	22.39016
Uttarakhand	1577.44	134.12	230.65	364.77	23.12418
Jammu& Kashmir	1417.08	129.33	5.91	135.24	9.543568
Chhattisgarh	993.11	19.05	1.2	20.25	2.039049
Tamil Nadu	659.15	94.05	33	127.05	19.27482

Table 4.3: Small Hydro Power Potential in India

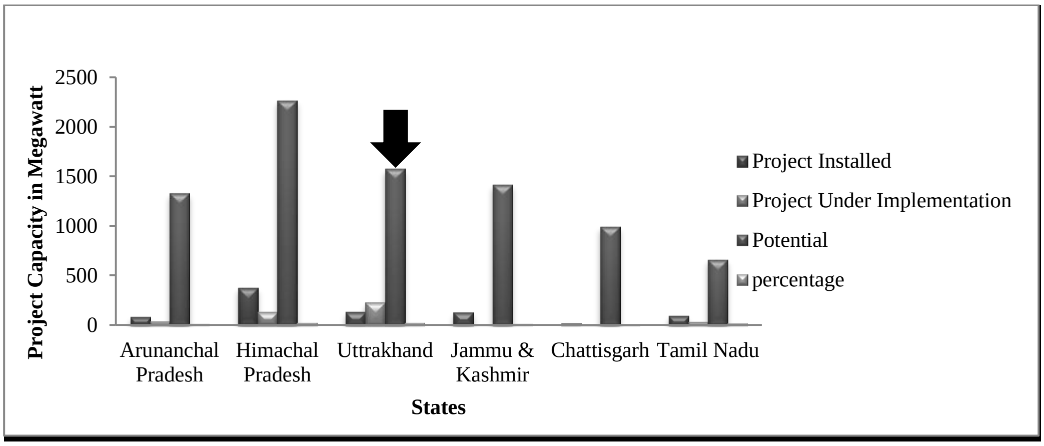


Figure 4.4: state wise estimated small hydro power potential of India as on 31-03-2013(In MW)

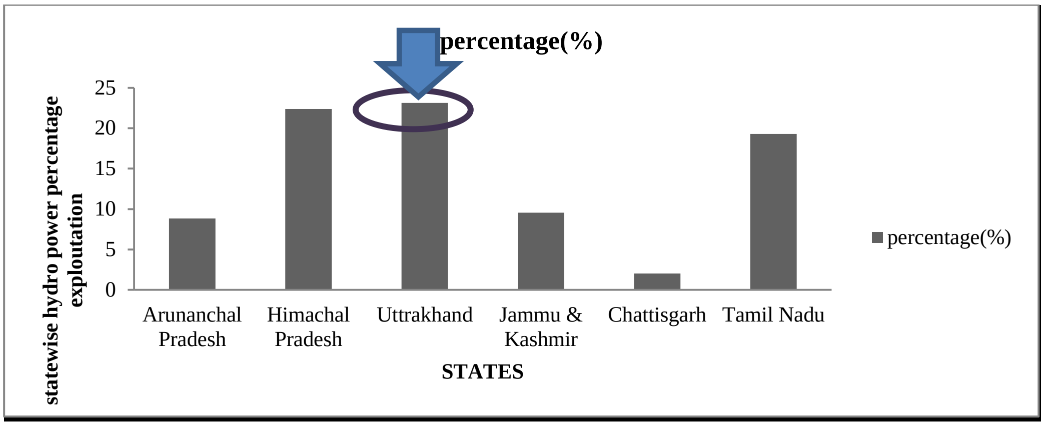


Figure 4.5: State wise estimated Small Hydro Potential percentage (%) in India as on 31-03-2013

As there is vast potential for development of Small Hydro Power projects, enormous funds shall be required to tap this potential. (Pasha & Nasab, 2012a)Considering the large requirement of funds, it may not be possible alone by Government to provide adequate finances. To mobilize additional resources for the Small Hydro Power, private sector participation has to be encouraged (Hussain Ahmed Siddiqui & javed Iqbal Mufti, 2005) In many states, private sector has been invited to tap the hydro power resources for captive use as well for commercial purpose. Private sector participation in renewable energy has also increased significantly in recent years as Government of India has opened the power sector to private sector participation. The run-of-river schemes are existing mainly in hilly areas of Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh, West Bengal and North Eastern States of our country. (Chaurasiya et al., 2013a)

4.5 Small Hydro Power sector Uttarakhand

Uttaranchal Jal Vidyut Nigam Limited (UJVNL) was incorporated as a Company by the Government of Uttaranchal on 14th February 2001, under the Companies Act 1956. UJVNL manages hydropower generation at existing power stations, organizes development and promotion of new hydropower projects with the purpose of harnessing already identified and yet to be identified hydro power resources of the State of Uttaranchal (Growth & Development Uttarakhand, 2012.) UJVNL is one of the large hydropower companies of the country operating more than 31 power stations of different sizes ranges from 0.2 MW to 240 MW with a combined capacity of 1000 MW and of different vintages up to 100 years. Currently, UJVNL is in the process of developing 14 new large hydropower projects and 16 new small hydro projects.

In Uttaranchal, the estimated capacity of Small Hydro Power projects is 1478 MW out of approximate estimated capacity of 20000 MW (Uttarakhand report, 2011) The estimated capacity of Small Hydro Power projects of

Uttaranchal is 8.7% of total estimated capacity of hydro power in Uttaranchal and 10.25% of targeted contribution of hydro power in 10th Five Year Plan.

Uttaranchal is currently a net importer of electric power, but generates a seasonal surplus and plans to become a net exporter of power by 2015 by expanding its hydropower and high voltage transmission capacity. Total capacity expansion of 10,000 megawatts (MW) is planned through 2018("Hydro Power in Uttarakhand," 2012.). Currently 14 projects totaling 5,525 MW are under construction and expected to be commissioned by 2010. An additional 4,791 MW are under development, with expected commissioning dates after 2010, and another 9,090 MW are planned. Fig. 4.6 shows the projected annual and cumulative capacity additions from 2005 through 2018.

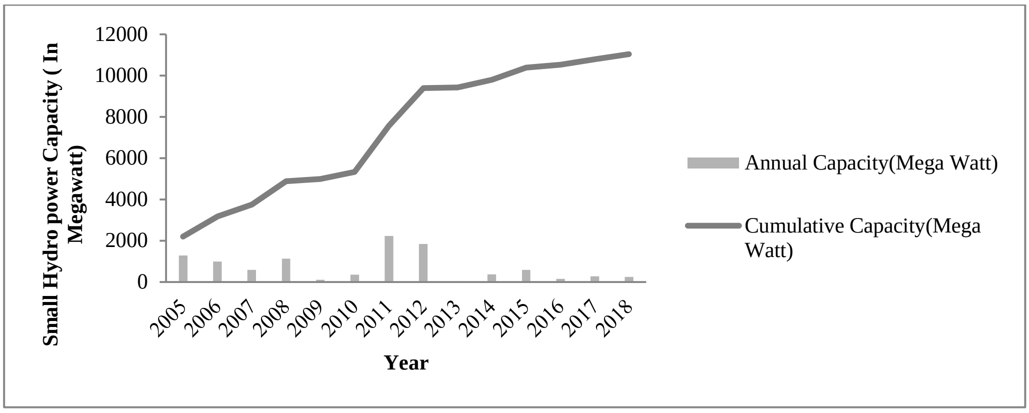


Figure 4.6: Planned Hydropower Capacity Additions Through 2018

The Small Hydro Power plants of Uttarakhand are classified into four different categories as pre construction, under construction, under operation, and under development. The classification in number of small hydro power project and installed capacity is shown in fig 4.7.

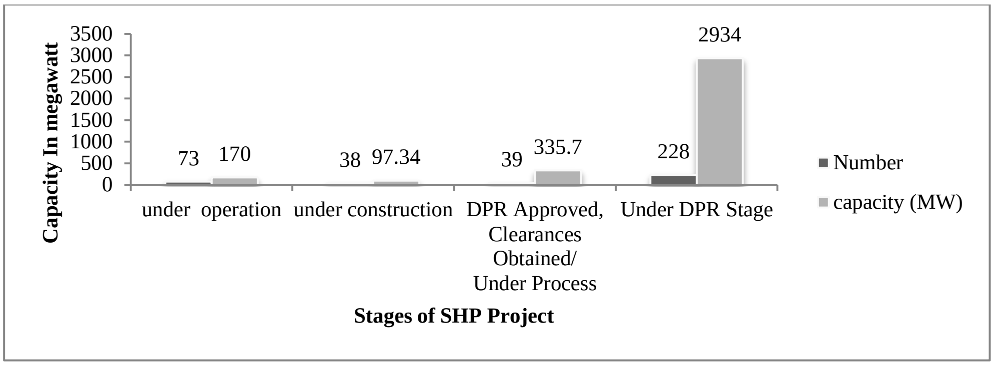


Figure 4.7: Small hydro power type distribution based on capacity and number

	Number	Capacity
Under operation	73	170
Under construction	38	97.34
Under Development and process	39	335.7
Under Pre construction	228	2934

Table 4.4: Small Hydro Power Plants Distribution in Uttarakhand

Uttarakhand Jal Vidyut Nigam is primarily responsible for the Small Hydro development in Uttaranchal & is a nodal agency to speed up this development (Joshi, 2007a). Still the preconstruction stage small hydro power projects are more in number that displays that investors are ready to invest in power projects but the projects are still in DPR stage. The reason for this gap is identified with this research and probable results are suggested.

4.5.1 Small Hydro Electric power Project and investor contribution

Investors are associated with hydro power projects in major three stages as mentioned in fig. 3.8 firstly generation, secondly transmission and lastly distribution. Investors invest in generation phase in the form of dam construction, turbine, generators etc., in transmission phase investment through transmission lines and transmission channels and finally distribution through distribution channels. Uttarakhand jal vidyut Nigam Ltd. (UJVNL) is the body who works for generation part of hydroelectric power projects of Uttarakhand. However transmission is governed by power transmission corporation Limited (PTCUL) and distribution is controlled by Uttarakhnad power corporation limited (UPCL). All the above mentioned departments are work as per UERC (Uttarakhand Electricity regulatory commission) guidelines. This thesis focused on generation phase of electricity and how investors behavior towards this phase.

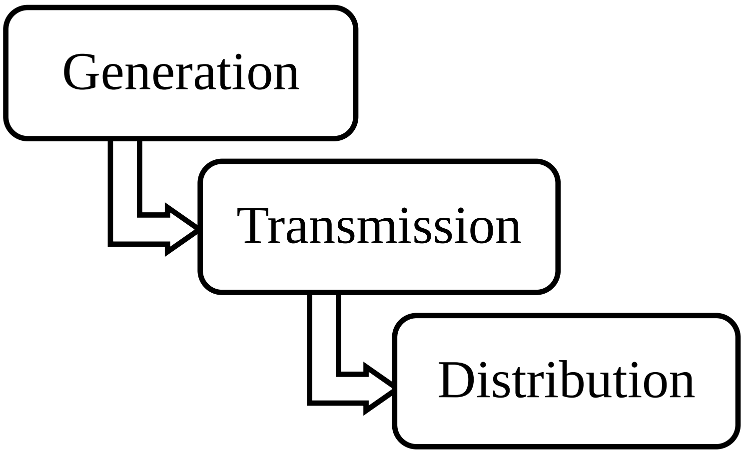


Figure 4.8: Investment stages in hydroelectric power projects

4.6 Project life cycle of small Hydro power project

Each activity or process, regardless of the area of business domain, has a beginning and an end. Similar concepts are used in the engineering world to systemize projects over time. The term project life cycle is used as a management tool to improve a project's performance. (Bhattacharyya, 2007a)The scope of life cycles differs among industries and diverse terminology with a various number of phases is used depending on the sectors. However, several terms are often used within one particular sector even though a number of phases can vary (Smith *et al*., 2006). Therefore, it is difficult to systemize and provide one common scope and definition of a project life cycle.in small hydro power project lifecycle is mentioned below in fig. 4.9.

4.6.1 Major Planning and Implementation Stages

In Small Hydro Power projects the investors are integrated with all phases of power production mentioned in the Fig. 3.9. The major four stages in Small Hydro Power projects are described as primarily the initial phase where the power projects are under pre construction or detailed project Report (DPR) phase. The stage when the plant is proposed after detailed prefeasibility study by the investors. After preconstruction approval secondly project construction will start. Operation followed construction which sustains for the longer duration. With continuous operations and usage of power project wear and tear starts in project. With need of technological advancements and high cost overrun investor rethink about renovation and modernization of the existing plant with latest practices. This phase consider all the previous problems faced by project and implement it with innovation. Detail of all the above mentioned stages is defined in next section.

A) Pre construction or Detailed Project Report Phase*:* Pre-construction ***or*** DPR Phase includes two sub stages as feasibility study and general design. Feasibility Study has three components: Preliminary Design, Hydropower study and Financial Analysis. preliminary designs includes three tasks: designing the civil structures, working out the details of the Electro-mechanical equipment and transmission line, and based on these two, preparing the initial estimate of project Costs. Hydropower Study involves the calculation of annual energy generation. This [CEA Guidelines (2)] calculation is based on prescribed values of available discharge in a 75 % dependable year. Financial Analysis is done by calculating the most commonly used financial indicators, viz., NPV (Net Present Value) and IRR (Internal Rate of Return). A Feasibility Report (FR) that establishes the financial viability of the project in all respects. (Pasha & Nasab, 2012a)The feasibility report is submitted to the various departments from whom clearances are sought. The acquisition of project land is also initiated at this stage.

General Design has four activities undertaken: Desk Study, Site Visit, topographical Survey and River discharge Measurement and Estimation. Desk study is conducted, off-site, with the help of a Survey of India topographical map of the area. Second phase under this stage is site visit serves to physically verify the results of the desk study. (Soni,G., 2010)The site visit involves site measurements and refined calculations of elevations and discharges to study possible alternative alignments and accurately establish the location of project components and the plant installed capacity. This survey covers the general layout, diversion structure, water conductor system, penstock, powerhouse, tail race, switch yard and showing land use, land-slides, loose rock slopes, historical flood levels etc. Result of pre-construction phase is known as Prefeasibility Report (PFR) that is ready to be submitted to the State Nodal Agency for appraisal and approval.

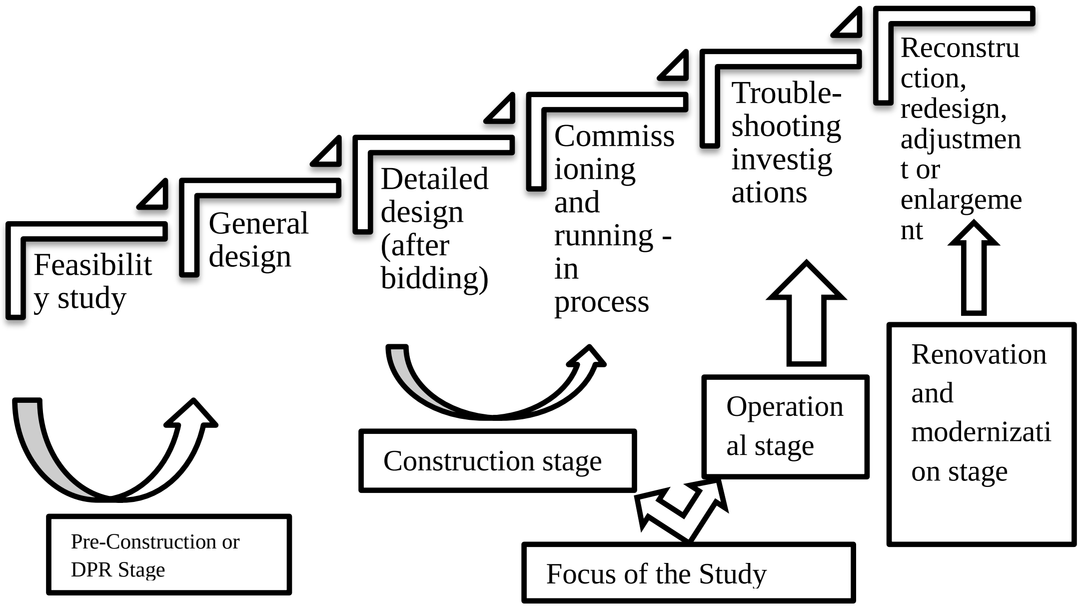


Figure 4.9: Detailed stages of Investor involvement in Hydro Power projects

B) Construction Phase*:* construction phase of small hydro power project also includes two sub stages which are detailed Design and commissioning & running in process.

Detailed Design includes seven activities undertaken at this stage which are conducting detailed hydrological studies, conducting a detailed topographical survey, conducting a power potential and optimization study, an analysis of the rates for principle civil items, the cost estimates, treating the environment and getting environmental clearance, and finally, making the drawings required for the DPR.

There are five sub-activities that comprise detailed hydrological studies are Discharge and silt measurements, Determination of 75 % dependable year and its discharges, Flow duration curve, Water requirement for irrigation and other riparian rights and Calculation of design flood and flood during construction period.

Detailed Topographical Surveys & Investigations has three sub-activities that comprise this activity Confirmatory detailed topographical surveys of project components and Geological investigations about soil and rock types, slope stability and future surface movements (loose rock, slopes, mud flows, rock falls snow storms and flood behavior) and Construction material surveys and testing.

Power Potential & Optimization Studies for installed capacity has to take clearances from State Pollution Control Boards', Gram Panchayat, Water Supply & Irrigation Department, Public Works Department, Fisheries Department and Land Revenue Department.

All civil structures have to be designed to withstand flood events. This is usually done by designing them for the worst case flood expected to happen at about 100 years intervals (referred to a "100 years return period"). In very practical terms, this means that the final civil structures must be designed such that, in case of flood, the excess water should be able flow over the retaining structure (dam or weir) or get discharged by the side of the canal. During the construction period there is a risk of flood events. In this sub-activity, studies for power output and optimization for various installed capacities are carried out. Based on these studies the power output and energy generation corresponding to the adopted installed capacity for 75 % dependable year are calculated (Zhang et al., 2010c).

Analysis of rates for principal items of civil works and construction machinery involves working out the project specific analysis of rates of construction materials, labour, construction plant and machinery in order to determine the unit rates for principal items of civil works.

The cost estimates covering civil works, electro- mechanical works, transmission and interconnection bay works are prepared as per CEA guidelines and incorporated in the DPR. The complete proposal of financing is prepared with details of funding, phasing of expenditure, loan repayment schedule, interest, depreciation, O&M expenses, gross and net annual generation, and cost per unit. Financial indicators, like NPV and IRR, are used to determine the financial viability of the scheme (Woksepp & Ph, 2005).

The environmental aspects such as, catchment area treatment, consent of the State Pollution Control Board to establish and operate the unit under the water (Prevention and control of pollution) Act and Air (Prevention and control of pollution) Act on account of the project implementation are included. Conclusion of this phase in the form of DPR which is submitted to Director of energy for Techno-economic Clearance**,** Electricity Board for Interconnection to GRID **and** Financial Institutions or Funding Agencies Commissioning of turbine, generator, power house and various auxiliary units and their running starts when the detailed design is over (UJVNL, 2010). The testing of above mentioned equipment's is essential criteria at this stage. Any faults will impact the generation of electricity and so as revenue from the power project.

C) Operational Phase: Under operational phase one major stage that is assigned as trouble shooting and investigation. The major activities in this stage are monitoring regular operations and provide troubleshoot if any problem persist. On other hand this stage is quite sensitive as all the previous stages are turn up in revenue in this phase. Regular watch on operations & maintenance cost and Working capital requirement is considered in this phase. Problems are investigated and suggestive measures are implemented.

D) Renovation & Modernization Phase:

The hydro power project has a specific life after the wear and tear is very high that effects electricity generation and so as revenue operation & maintenance cost is increasing exponentially. In order to overcome these issues every hydro power project goes for renovation and modernization in which huge amount of capital investment is not required as initial base is already created as dam and other auxiliary units. Based on previous experiences it is easy for the investor at this stage to go for renovation and previous mistakes are also avoided. Reconstruction, redesigning, enlargement and adjustment are performed under this stage, reconstruction of more destroyed parts sometimes head redesigning in order to stop head loss and replacement of technical auxiliaries as turbine, generators etc. Adjustment in calibrations and enlargement of hydro power capacity is also possible using high level turbines and generators.

4.7 Investment in Uttarakhand various stages of hydro power projects

The investment program will obviously create employment, tax revenues, and royalties to the state. Investment in hydro power projects of Uttarakhand is segregated into three stages as discussed earlier, the investment The Investment Program from 2006–2012, including cost estimates and financing is presented in the table 4.5.

Generation	
UJVNL Large Hydropower	700
UJVNL Small Hydropower	335
Central Public Sector Utility and/or Independent Power Companies	3200

Transmission	550
Distribution	**370**
Total	**5155**
Financing Plan	
Domestic	
UJVNL	440
UPCL	40
PTCUL	100
GOU	580
Central Power Sector Utilities	1600
Private Sector	750
Power Finance Corporation	300
Local Banks, Private Equity, and Capital Markets	245
International	
ADB	300
Bilateral	300
International Financial Institutions	500
Total	5155

Table 4.5: Investment Program 2006-12 $ Million

Source: ADB, Power Transmission Corporation of Uttaranchal, Limited, UJVNL, Uttaranchal Power Corporation, Limited, and UED.

From table 4.5 it is visible that investment in generation stage of small hydro power project is maximum private sector investment is also high as compare to central power sector and power Finance Corporation. The investors are willing to invest in this area subject to obstacles or investment issues that we discussed in chapter 1 out of which risk is the major concern for investors. Subject to the matter of concern risk identification and assessment in small hydro power project in Uttarakhand is matter of information. In purview of this classification of risk is required in SHP of Uttarakhand.

The classification of all the stages of SHP is done in this chapter. The classification gives four different phases and risks in all these stages are also vary. The risk impact and severity in all the phase keeps on changing. May be some risk having impact only in operational phase but not applicable in construction phase. In order to consider this thing in mind this study focuses only construction to operation phase of small hydro power projects of Uttarakhand. Though the other phases are also matter of concern but time constraint would not permit the researcher to apply in this study.

4.8 Risks Identification in Small hydro power projects

(Knutsen & Poulsen, 2010b)Knight, (1921) describes risks as a situation where probabilities cannot be objectively assigned and where all future contingencies may not be known. (Filippini & Luchsinger, 2002); Luce and Raffia (1957) explained risk is uncertainty that occurs in future which needs to be coped so as to evade variation of penalties ranging from negative wonders to enduring loss.

In this research risks have been identified using global literature review based on small hydro power projects. Based on literature studies it was noticed that there are around 37 risk variables are associated with small hydropower projects across the world discussed in chapter 2 section 2.5. Those risk variables are enumerated below.

- Delay from suppliers(Wiemann, 2011)
- Approvals (Mittal, 2004)
- Fund Blockage (Wiemann, 2011)
- Clearances ((Berchmans, 2013a)
- Relocation (Kucukali,S, 2011)
- Noise pollution (Wiemann, 2011)
- Water quality (Wiemann, 2011)
- Employment (Pharlia, 2007)
- Flora & fauna (Wiemann, 2011)
- Financing Resources (Kucukali,S. 2011)
- Interest rate (Ghosh & Kaur, 2011)
- Tax rate (Ghosh & Kaur, 2011)
- Inflation (Wiemann, 2011)
- Climate (Wiemann, 2011c)
- River flow (Noor-E-Alam & Doucette, 2010b)
- Soil erosion (Kucukali,S. 2011)
- Precipitation (Noor-E-Alam & Doucette, 2010b)
- Construction schedule (Wiemann, 2011)
- Construction Budget (Tuna, 2013)
- Machinery (Fleten et al., 2010)
- Regulatory (Kucukali,S. 2011)
- Breakdown technical (Wiemann, 2011)
- Public private partnership (Jayant Sathaye (USA), Oswaldo Lucon (Brazil), 2012a)
- Tourist attraction (Kucukali,S, 2011)
- Clearances (Kucukali & Report, 2011a)
- Capital cost (S. M. H. Hosseini, Forouzbakhsh, & Rahimpoor, 2005b)
- Generation (Kucukali,S, 2011)
- Evaluation technique (Shang & Hossen, 2013b)
- Terrorism (Kucukali,S, 2011)
- Breakdown technical
- Operation & Maintenance (Pasha & Nasab, 2012)
- Electricity price (Kucukali & Report, 2011a)

However, in case of Uttarakhand small hydro power project all these risk variables are not applicable as was observed with the expert and officials of uttarakhand Small hydro power projects and investors, with average experience of 15-18 years in the form of semi structured interview. A total of 32 risk variables were found to be significant in Uttarakhand small hydro power projects such as generation, modeling techniques, terrorism, breakdown technical, operation & maintenance, electricity price, capital cost, clearances, machinery, tourist attraction, water quality, regulatory, interest rate, inflation, tax rate, employment, noise, precipitation, soil erosion, river flow, construction time, construction schedule, delay from suppliers, relocation, fund blockage, approvals, public..

4.8.1 Identification of Risks for SHP's of uttarakhand

All the risk variables which are applicable for uttarakhand small hydro power projects which come after semi structured interview with officials are categorized further. There are many different risks existing which should be subdivided into tangible (quantitative) and intangible (qualitative) features (Chaurasiya et al., 2013). Typical tangible features are costs and benefits because they can be expressed in monetary terms. Intangible features cannot be readily valued in money, for example socio-economic and environmental risks (Goldsmith, 1993). Fig. 4.10 shows the classification of small hydro power risks in Uttarakhand and it is important to mention that this is a selection – and not a complete list – of possible risks facing a low head, small hydropower project. The importance and emphasis of every kind of risk depends on the target group, the technology, the potential site and the stage for an implementation of a hydropower plant. The following scenario describes some risks in different stages of a hydropower project.

The risk in small hydro power projects of Uttarakhand are classified few major categories and then further subdivided in various risk factors. The major classes of risk are as follows:

- **Technical Risk:** as mentioned in chapter 2 the various risk classes has come out from literature review in compilation the technological risk in SHP of Uttarakhand includes mainly segregated as operation & Maintenance, machinery and Breakdown which further moved in tributary as delay from suppliers. (Finke, 1998); (Bazmi & Zahedi, 2011); (Jenab & Ahi, 2010b).
- **Construction Risk:** construction is major area in small hydro power sector as dam construction is huge capital investment project which includes construction schedule and construction budget risk (Walke, 2012).
- **Financial Risk:** Financial risk is interim risk which plays major role in small hydro power project. The financial risk diversified into financial resources, tax rate and inflation risk. Financing resources again divide into fund blockage and interest rate risk. Though foreign investment in small hydro power project is less in Uttarakhand so exchange rate risk is not play major role in this area.(Pasha & Nasab, 2012);(Gains et al., 2002); (R.V.Shahi, 2006).
- **Legal Risk:** Legal or regulatory have vital importance in SHP of Uttarakhand which is divided into clearances and regulatory. There are various clearances that hydro power project investor has to take into

consideration as MOEF, gram panchayat, high court stay, NGO's i.e. the regulatory further subdivided into Public private partnership and norms and rule & regulation changes that affects the investor benefit altogether (For & Technologies, 2002; Hosseini, 2011; Mckinsey, 2010).

- **Business risk**: This is the risk that issuers of an investment may run into financial difficulties and not be able to live up to market expectations. The classification in this area into electricity price, generation and modeling techniques (Kristiansen, 2006; Zhang et al., 2010).
- **Environmental Risk:** Environmental risk is also considered as huge project of power if it creates environmental problems as removal of forests so clearance is necessary. The Environmental risk further classified as climate and forest. Which is further associated with river flow, precipitation and flora & Fauna (Schaefli et al., 2007; Harrison et al., 2005; Fleten et al., 2007)
- **Socio Economic Risk:** Socio-economic is one of the important areas moving around Hydro power projects. The further sub classification is segregated as local community and safety. These are further moves to another stage considering noise, employment, tourist places, rehabilitation, and water quality and soil erosion. (Júnior & Reid, 2010); (Han et al., 2008b).

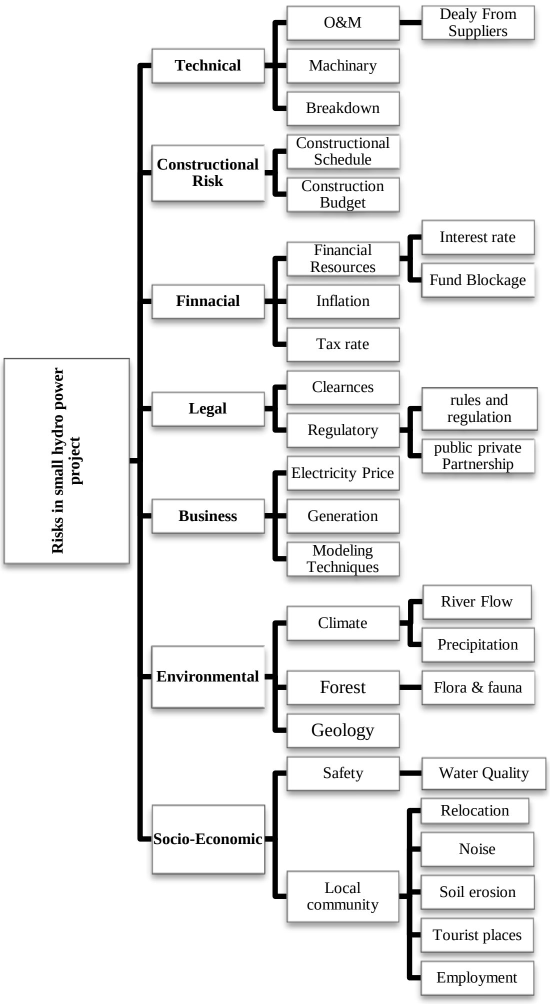


Figure 4.10: Small Hydro power sector of Uttarakhand Risks classification

4.8.2 Risk Classification Based on Life cycle of Small Hydro Power project

Risk classification is another pertinent task as per this research, study area is decided only operational & construction stage small hydro power project. The classification of risks has been done based on responses of experts. The questionnaire for risk identification and classification is enclosed in annexure A2. Based on the questionnaire responses taken from experts of small hydro power projects of Uttarakhand the risk variables has been classified into operational & construction stages. 25 & 23 risk variables has been categorized in Construction and operational stages mentioned in fig 4.11.The same risk variables will be used for risk assessment in chapter 5.

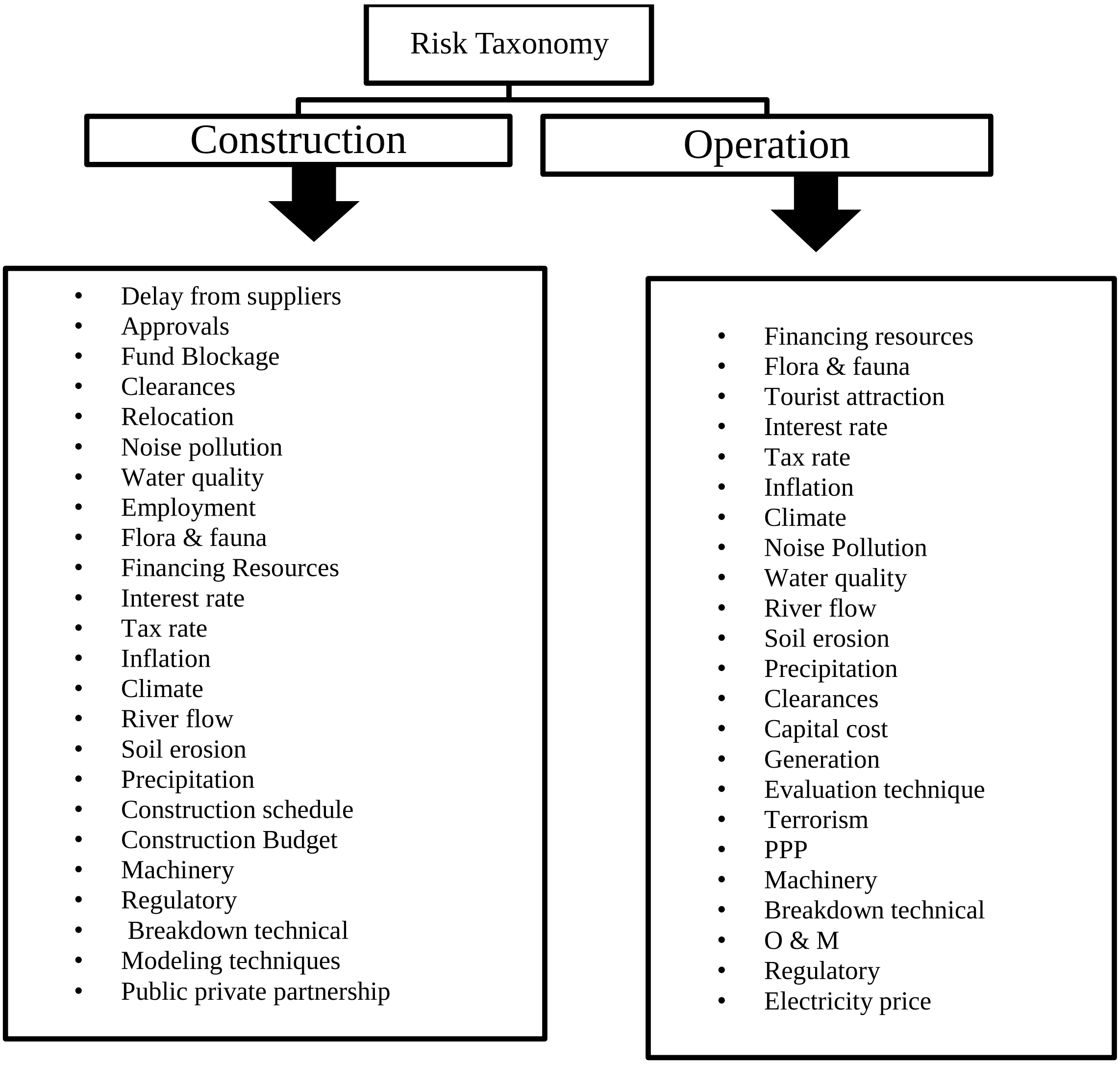


Figure 4.11: Risk taxonomy in construction & operation stage

4.9 Validation of Risk Identification

Validation of risk identified based on semi structured interview is performed using Z score formula mentioned in equation 4.1.

$$z_{score} = \frac{p - P}{\sqrt{\frac{pq}{N}}} - - - - - - - - - - - (4.1)$$

Where p-possibility of getting result (32);

q- Possibility of not getting result (0.8);

P- Respondents responded/total sample (0.2);

N- Sample Size (40) (Hofstede, G.; 2008)

Using $\mathbf{Z}_{\text{score}}$ the acceptance & rejection criterion is validated lies in the range between +3 to -3, the risk variables are validated and z core of all risk variables are mentioned in table 4.XX.

Risk Variable	Z score	Accept/Reject
Exchange rate	-10.28	Reject
Delay of supplies of technology, buildings and/or raw material	3.16	Accept
Approval by authorities	2.77	Accept
Financial resources	3.16	Accept
clearance	2.77	Accept
Relocation	3.16	Accept
Human factor	-12.65	Reject
local Community	1.19	Accept
Relocation cost	-9.49	Reject
Employment	1.58	Accept
Tourist Places	1.19	Accept
dam site	-10.67	Reject
Tourist Revenue	0.40	Accept
flora and fauna	1.19	Accept
Financing	2.37	Accept
Interest rate	0.00	Accept
tax rate	1.19	Accept
inflation rate	1.58	Accept
Climate	-0.40	Accept
Noise pollution	0.79	Accept

drinking water quality	0.40	Accept
River Flow	1.98	Accept
soil erosion	2.37	Accept
precipitation	1.19	Accept
construction time	2.37	Accept
Competency	-12.25	Reject
Budget Construction	3.16	Accept
Cost Overrun	-7.51	Reject
machinery	2.77	Accept
breakdown	-2.37	Accept
Preventive maintenance	-12.65	Reject
Regulatory	3.16	Accept
clearances	3.16	Accept
Electricity Price	1.19	Accept
System procedures	-8.30	Reject
Competitors	-12.65	Reject
evaluation techniques	2.37	Accept
Financial Resources	3.16	Accept
generation	1.98	Accept
Public private partnership	2.77	Accept
terrorism	0.00	Accept
Communication	-11.46	Reject
Fund Blockage	0.79	Accept

Table 4.6: Z score values of Risk Variables

The risk variables which come out from study has been validated using Z_{score} values which lie between -3 to +3 values and the result is validated using table 4.6.

4.10 Conclusion

This chapter has used the small hydro power sector literature to present a brief description of the industry. The main challenges facing the sector in the 21st century were identified in chapter 1. The effects of these changes on the Uttarakhand small hydro power sector were examined. This highlighted the growing complexity of the business environment of those investors associated with small hydro power projects that has prompted increasing interest in risk assessment for decision analysis in the sector Chapter 5. The chapter showed how there has been limitations in the recent studies into current practice in risk assessment in small hydro power projects in the hydro power sector and that therefore there is a need for a study to investigate investment decision in the small hydro power projects. The following chapter first states the methodological approach adopted for this study and second, evaluates its effectiveness.

CHAPTER 5

RISK ASSESSMENT IN SMALL HYDRO POWER PROJECTS OF UTTARAKHAND

5.0 Introduction

In chapter 2 & 3 the investment related risks were identified which are present is small hydro power projects. Such factors are identified based on literature reviews, expert interviews and field survey as follows: capital cost, operational and maintenance, energy generation, policy, market. The risk factors were categorized in parametric and non-parametric factors.

In this chapter all parametric risk factors are considered and analysed using Stochastic Monte Carlo simulation. Monte Carlo simulation is the probabilistic approach for dealing with risk factors. The relative importance of these factors are evaluated stochastically and ranked them accordingly. When dealing with the risk analysis problems, the prevalence of method has been showed: easier and more useful. Because of the stochastic nature of variables that compute financial indicators as NPV (net present value)/IRR (internal rate of return)/ BCR (Benefit cost ratio) it has some uncertainty which cause risk in investment decision.

5.1 A concept of risk Assessment Process

Risk assessment pays to decent corporate governance by providing rational promise to all direct and indirect associated people viz. boards, senior managers, stakeholders, investors that the organizational aims will be achieved within an acceptable degree of residual. (Júnior & Reid, 2010). Risk assessment is an inclusive development, maintained by suitable policies and outlines that are planned to detect, analyze, assess, display and communicate those risks that could prevent a department or agency from achieving its objectives (Mittal, 2004). It covers all categories of risk strategic as well as operational, financial and compliance risks.

Risk assessment is a concept which becomes very popular in a number of businesses. Many companies often establish a risk assessment procedure in their projects for improving the performance and increase the profits. Projects undertaken in multiphase widely complex and have often significant budgets, and thus reducing risks associated with every phase should be a priority for organization (McVeigh & Cohen, 2007). This master thesis presents an application of risk assessment in the early middle stage of a project life cycle of small hydro power of Uttarakhand focusing construction and operational phases. In order to examine how risk and risk assessment process is perceived few cases of each phase were chosen. Moreover, based on the conducted structured questionnaires and interviews, the research presents how risks change during a project life cycle. All analyzes are based on a theoretical as well as empirical background regarding risk, risk assessment process in the Small Hydro Power sector. Risk assessment process is generally defined as an iterative process that starts with identification of risk factors, followed by qualitative and/or quantitative assessment of risk factors using impact assessment or quantification of risk index. Based on risk quantification risk mitigation strategies are framed for development of projects or to maintain an optimum risk-return structure between the project participants (H.Zhi, 1995)**;** (Wang, 2004)**;** (Han, 2008)**, and** (Edwards, 2009)**.**

Risk assessment comprises the various component processes that are represented schematically in Fig. 5.1. At the highest level, risk assessment combines risk identification and then estimation, risk impact assessment and followed with risk quantification (Walke, 2012). Based on the above three steps investor or manager define risk mitigation strategies. Every small hydro plant owner is seeking to reduce risk and secure their return on investment, before, during and after construction.

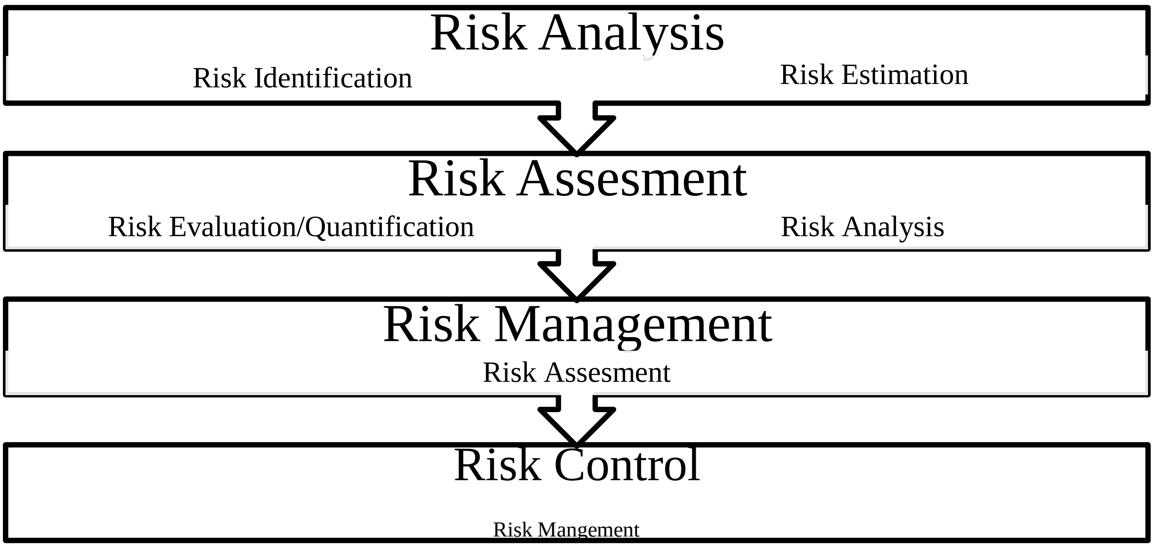


Figure 5.1: Risk Management process

A structured risk assessment approach also enhances and encourages the identification of greater opportunities for continuous improvement through innovation. This will assist to identify the risks investor face and prioritize them according to the likelihood of them occurring and the resulting impact on the business (Pharlia, 2007).

5.1.1 Determinants of effective Risk assessment program

The major determinants of effective risk assessment program are systematic, structured, evidence base, explicitly addresses uncertainty and its causes (Jenab & Ahi, 2010). It is a core organization process that is an integral part of decision making which leads to the optimization of control and maximization of net benefit. It is specific to the organization, applied enterprise wide and tailored to its external and internal context (Salling, 2005; Yang, 2007). It forms part of the organizational culture, which is transparent and understood by all interested parties through their inclusion and involvement in the process with dynamic, iterative and responsive to change (Noor-E-Alam & Doucette, 2010; Bloom et al., 2007).

5.1.2 Benefits with Risk Assessment

A risk assessment should commence with a clear definition of its purpose. This includes an identification of the decisions that it is intended to use the results of the risk assessment to inform, the decision bases and the desired level of confidence as determined by the small hydro power owner and other stakeholders (Heggedal et al., 2011). It should also include an identification of the factors affecting hydro power investment decision making in the context of the specific risk assessment purpose (Barajas & Agard, 2010). Some of the purposes for hydro power risk assessment have included systematically identify and better understand potential failure modes, based on this justify and prioritize investigations and analyses to reduce uncertainties in risk estimates (Parandin et al., 2013) Risk assessment also strengthens the formulation, justification and prioritization of risk reduction measures so as investment decisions would be acceptable. It helps to find out ways to improve safety, opportunities, cost effectiveness, expenditures, better framework for quantifying technical issues, evaluation of risks, non-technical basis for communicating to public , assess the suitability, strengthen the basis for corporate governance, due diligence and legal defensibility which are pre requisite of project.

5.2 Cost Overrun In Hydro power project

The private sector has been discover it enormously challenging to directing investment into new hydropower projects due to issues that can compromise an otherwise functional project, such as social and environmental opposition, unwanted project risks, large upfront costs, long lead times and lower returns on investments (Nandy & Bhattacharya, 2012). More importantly, in attempting to privatize hydropower electricity, the public sector looks to passing on the risks involved in construction, operation and maintenance, to the private sector.

Small hydropower plant investment involves risks due to a number of factors such as technical, market, financial, environmental, socio-economic, policies and various subcategories lie under these. These factors have influences on cost and revenue.

Current investment practice followed by Uttarakhand Jal Vidyut Nigam Ltd. are already discussed in chapter 2 which shows, currently risk factors association with investment decision making in neglected. Every decision for a small hydropower project is made with uncertainty. Ujvnl does investment decision for small hydro power projects using tariff calculation, in which if tariff comes more than the estimated one unit electricity generation cost than project considered as viable. It was observed in SHP's that estimated cost is always less than electricity production actual cost. There are many uncertainties are existing those are neglected at the time of DPR preparation, which creates cost overrun. Costs overrun of Pathri small hydro power project of Uttarakhand is shown in table 5.1

Description	**Estimated Cost (Lacs)**	**Actual Cost (Lacs)**	**Rate of Increase**	**Share of total Cost**
Turbine and generator(Electromechanical equipment's)	397	445.434	12.20%	3.56%
Transformers & Electricals(Electromechanical Equipment)	4816.09548	6900.5574	43.28%	55.17%
Hydro Mechanical Works (equipment)	329.6	421.68953	27.94%	3.37%
Civil Works(Design Changes)	195	219.102	12.36%	1.75%
IDC	1200.13	1747.1493	45.58%	13.97%
Grid Connection	2344.59452	2774.8276	18.35%	22.18%

Table 5.1: Cost Overrun in operational stage small hydroelectric power project

The cost of small hydro power project is distributed in segments as cost incurred in electromechanical instruments as Turbine, Generator, Transformer & electrical, hydro mechanical equipment's, civil work, interest during construction, grid connection i.e.

The costs of the segments are actually increased as compare to estimated one, shown in table 5.1. The total share capital is increasing actually 63.56% due to subcomponents cost increment. This cost overrun deviates investors to proceed further so motive of this chapter is find out the reasons and if possible assess it in real terms to make investors ready for investment. Globally the small hydro power projects consider many factors that create a possibility of cost overrun. As (Wiemann, 2011c) shows if running hour per hour is increased how electricity production cost is also increased. Similarly there are a lot of factors which create risk for small hydro power project.

Investors wishing to invest in renewable energy must be aware of all the risks to consider their effect on profitability. The investors benefit will be increased if more and more risks are identified in the beginning and if truly assessed so risk management would work well.

(Lundmark & Pettersson, (2002.); (Harrison, Whittington, Gundry, & Management, 2004.), (Kucukali, 2011a) and Chirikutsi (2006) explain major investment risks in small hydropower sector as price, market, climate, technology, regulatory, environmental, socio-economic, interest rate, (S. M. H. Hosseini et al., 2005b) who used different investment decision making approaches to quantify and asses the risk in small hydropower project. (Zhang et al., 2010c) and (Firestone et al., 1997) used various techniques, like deterministic, probabilistic, stochastic and strategic for risk assessment in small hydropower project (Gains et al., 2002) applied Monte Carlo simulation as a stochastic approach in for parametric risk analysis, he found as one of the best methods. Within the context this chapter intends to outline the major risk assessment involved in the small-scale hydropower projects of Uttarakhand.

5.3 Sensitivity Analysis of Major Risk Factor

Sensitivity analysis is a tool for checking the impact of one independent variable on dependent variable. In case of small hydro power project for the financial indicator estimation (NPV/IRR/BCR) the independent variables required capital cost, electricity price per unit, cost of capital, life of the project, average electricity generation i.e. it is necessary for investors to see panorama for all input variables as uncertainties are associated with that. The input variables vary with time and so as influence on financial indicators also varies with it. The investors should change the different values of input variables and then check the effect of outcome which gives clear picture or possibilities of output, which help investors for improved decision making. Here in this section sensitivity analysis on small hydro power project of Uttarakhand is applied on NPV with reference to increase in electricity price, increase in capital cost and decrease in cost of capital is shown in Fig 5.2 (a), (b) & (c).

The fig 5.2 (a) clearly shows as with the increase in electricity price NPV is decreasing and at one specific electricity price the NPV becomes zero and again it increased negatively. After checking the gradient of the NPV corresponding to electricity price the slope is very significant as it is increasing from 27% to 37% than again increase till 85% that is quite significant slopes are visible.

Fig 5.2 (b) shows the impact of Capital cost increment with respect to NPV where increments in the slope of NPV from 51% to 95% which is quite significant. Fig 5.1 c shows the sensitivity on NPV of decrease in cost of capital where changes from 23% to 96% slope. The above three parameters capital cost, electricity price and cost of capital impact NPV and these are very sensitive parameters for investors, because certain change in parameter shift NPV in vast extent.

In real life the changes in some of the these variable are quite often, which may be in future prove investment decision wrong, so in order to overcome this problem, scenarios are generated in which two or more variables are varies together and finally influence on output variable is computed. This analysis is explained in next section where more than two variables are varies in both positive and negative direction it creates impact on output.

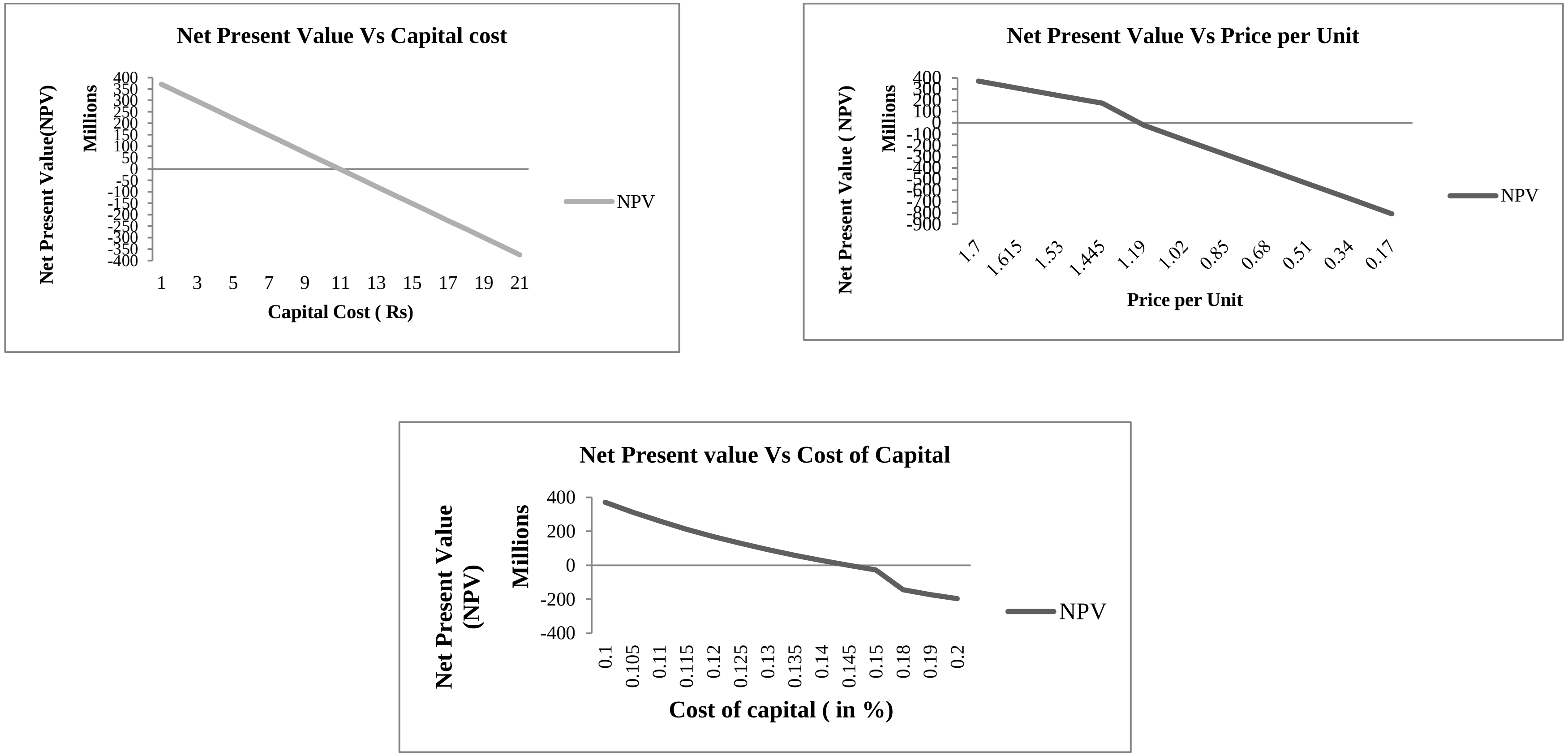


Figure 5.2:Sensitivity Analysis of NPV against (a) Capital cost; (b) Price; (c) Cost of Capital

5.4 Scenario Analysis in Small Hydro Power project

In previous section using sensitivity analysis output investment decision making indicators varies with independent input variables was assessed. In this section the impact of considering more than two input variables fluctuates than the output investment variable is also fluctuating.

As in one power plant of Uttarakhand shows miniature deviations in investment cost, River Head, River Discharge, maintenance cost will impact electricity production cost showed in figure 5.3.so the sensitivity of all the factors if combine together it gives variation in final outcome. All the risk factors are included and tornado chart is prepared which shows variation in risk factor values will impact NPV of the project positively as well as negatively.

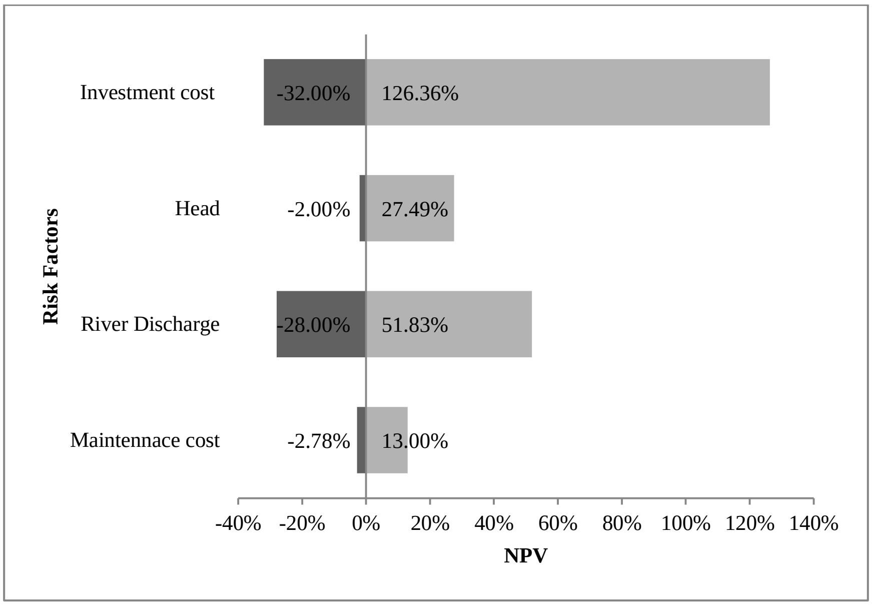


Figure 5.3 : Tornado chart for Small hydro power project investment decision with for risk factors consideration

5.5 Risk identification in small hydro power project

Risk identification is the process of recognizing the hazards (initiating events) to which the Small Hydro Power project is exposed, potential project failure modes, and the resulting adverse consequences. Although all the risk were identified in detailed in chapter 2 & 4 to summarized that thirty two risk variables has been identified based on the expert interviews and literature review and categorize them into quantitative and qualitative/subjective factor.

The major risk factors as per expert opinion and literature review for small hydro power projects of Uttarakhand are found as climate, technical, environmental, regulatory, policy, socio economic factors. The Uttarakhand rehabilitation problem for constructing dam for power production is not supported by local communities and high court as it creates environmental imbalances. The policy related with hydro power project keep on revising with market and political environment revisions. Market uncertainty changes the price of electricity so as political environment changes the price of electricity, tax rate, inflation consequently profit of investors are impacted. The other risk factor that affects the investors is fluctuating interest rate and tax rate Hydropower projects face many risks such as market risk, credit risk, simple construction and development risk, political risk, legal risk, force majeure risk, etc. The parametric risk factors are considered in this study.

The major parametric risk factors that are used for the study are capital cost, average capacity, average energy or generation, discount rate, breakdown cost, capital cost break up, operation & maintenance cost, interest rate, tax rate, electricity price per unit i.e. These all parametric risk factors are considered for further analysis. Among available measurable factors only those factors are taken into consideration, those historical data is available. The need of the historical data is required to evaluate behavior of each factor mathematically. The assessment of these factors impact is assessed and impact is checked on investor decision making.

5.6 Risk Analysis for Parametric Risk Factors

Risk estimation consists of determining existing uncertainty response and outcome probabilities, and the consequences of various cost overruns. No-cost overrun scenarios are considered so that incremental consequences can be estimated as the difference between the consequences estimated with cost overrun and without cost overrun scenarios. Probability and consequence estimates are then input to the risk model. Consequences are a function of many factors including, the nature and extent of the breach, the extent and character of the operations & Maintenance cost, capital cost, the season of the year, the warning time, and the effectiveness of evacuation and emergency action plans.

For quantitative analysis we used statistical method, selecting Monte Carlo Simulation technique (MCS) based on available historical data from two different projects in Uttarakhand SHP. Here researcher have analysed quantitative risk in two different projects in operational phase, viz. Pathri and Mohammadpur which are located in Uttarakhand area and their major cost components are shown in table 5.2 .these two projects are compared in the result section.

5.6.1 Study area

5.6.1.1 Case 1: Pathri Small Hydro power project

Pathri power house utilizes upper Ganga Canal water for power generation. Since this is irrigation canal based power house, the water releases are as per irrigation requirements. Water discharge utilized for power generation is measured by irrigation authorities at a weir on the downstream of powerhouse approximately at a distance of one kilometer. There are three units in the power project with installed capacity of 20.4 MW (3 X 6.8 MW). In summer the water availability is the highest and mostly all the three units can run at full load while in rainy and winter seasons the water availability in the canal is less and mostly two unit full load operation or three-unit part load operation is possible.

(A)Technical aspects of the project

The maximum discharge recorded in the canal is 318.1 cumecs (11235 cusec) and minimum discharge of 74.76 cumecs (2640 cusec). Normally the head race level is maintained at 918.48 ft. The by-pass gate operates automatically when the level is above 918.48 ft. **9.3 m** is considered as design head for the renovated units. The design head of existing units is 9.88 m. The expected generation for Pathri HEP average generation is 89.91 MU. The installed power generation capacity at the main powerhouse at the Pathri Hydroelectric project would be155.6 MU, distributed throughout free generating units, each with a unit power of 8000 kVA. The complementary plant, which would use the residual stream flow, would have an installed capacity of 20.4 MW and would have three Kaplan type turbines, with a unit power of 6800 KW.

(B) Project Costs

Total cost of pathri hydroelectric power project, considering for E&M and Hydro mechanical works comes out Rs 7364.42 lacs, Cost of Civil works is Rs. 241 lacs the total cost of Pathri project has been estimated Rs. 8082.29 lacs including interest during construction.

5.6.1.2 Case 2: Mohammadpur Small hydro power project

Mohammadpur Power House has been constructed on upper Ganga Canal at 49.5 km downstream of Mayapur Head Works, Hardwar. The power house, which has 3 units of 3.1 MW each.. The Power House was constructed by Irrigation department UP and taken over by the U.P.S.E.B later on. It remained under Distribution Wing of the then U.P.S.E.B. and finally handed over to Hydro Electric Projects, Dehradun in 1995. After trifurcation of UPSEB this power house was handed over to U.P. Jal Vidyut Nigam. This power house is running under Uttaranchal Jal Vidyut Nigam Ltd.

(A) Technical aspects of the project

Expected annual energy generation comes out to be 64.92 MU and Incremental annual energy due to M&U is estimated as 24.48 MU in comparison to average of five years. The maximum generation of 60.426 MU was achieved and minimum of 10.055 MU. The present generation is 30-35 MU per year the maximum discharge recorded in the canal is 225.26 cumecs and minimum discharge of 58.45 cumecs.

(B) Project Costs

Total cost for E&M comes out Rs 4738.08 lacs. Cost of hydro-mechanical and civil works comes out Rs. 307.33 lacs. Thus the total cost of Mohammadpur Project with & without IDC has been estimated Rs. **5366.72** lacs & **6435.49** lacs respectively. Total period of repayment of loan will be twelve years. Generation cost on total energy for 1st year will be Rs. 2.03 / Unit and after repayment of loan will be Rs. 0.74 / Unit.

The summary report for Pathri and Mohammadpur hydroelectric power project is mentioned in table 5.2. Based on the data and economic and environmental information available, comprising those surveyed in the feasibility studies done by UJVNL, the plan to construct the Pathri Hydroelectric plant on the Ganga River was evaluated. This was based on a comprehensive study of the costs and benefits.

The variables which are required for investment analysis for Pathri & Mohammadpur hydroelectric power project is summarized in table 5.2.

Variables	Mohammadpur SHP			Pathri SHP		
Capital cost	6435.49 Rs in Lacs			9282.42 Rs in Lacs		
Break down of Cost	**41%**	**36%**	**23%**	**15%**	**38%**	**47%**
O & M cost	0.134 Rs/KWH			0.15 Rs/KWH		
Installed Capacity	9.3 Mw			20.4 Mw		
Average Capacity	4.62 MW			10.3 Mw		
Average Energy	40.44 MU			89.91 MU		
Deterioration Rate	1%			1%		
Remaining Life	15 Years			15 Years		
Present Per Unit Rate	1.2 Rs/KWH			1.05 Rs/KWH		
Discount rate	10%			10%		

Table 5.2: summary overview of SHP Projects

5.7 Determination of Certainty for Parametric Risk Factors

In this section use of Monte Carlo simulation with parametric risk factors were analysed showing the real impact of result is discussed for both Pathri and Mohammadpur hydroelectric power project. For determination of certainty of parametric risk factors will be assessed using case study of operational stage SHP, pathri. In pathri & Mohammadpur the parametric risk factors are considered as interest rate, average Energy (generation) , capital cost, operation & maintenance cost, breakdown cost, price of electricity per unit for last 19 years (1994-2013)is considered. The probability density functions (PDF) of each risk parameter is created using easy fit software and concluded with best fit functions for each risk factor. The detail is shown in table5.3. The Monte Carlo simulation (MCS) runs including above mentioned PDF for financial indicators NPV, IRR & BCR shown in fig. 5.4 & 5.6 (a), (b) & (c) for pathri and Mohammadpur respectively. The 10,000 iterations run for seeking all the possible scenarios of project. The simulation shows that certainity of the estimated NPV, IRR & BCR in table 5.4. the result of this section is discussed further.

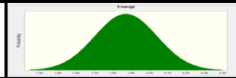
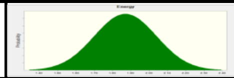
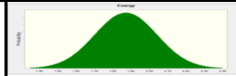
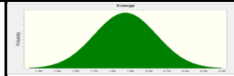
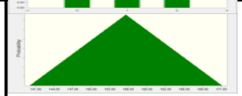
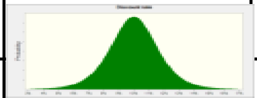
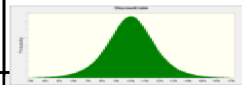
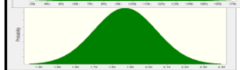
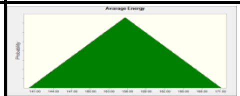
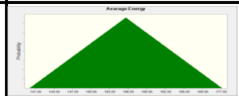
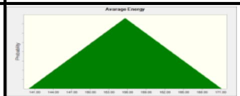
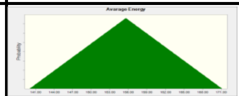
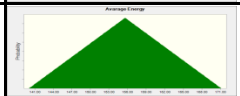
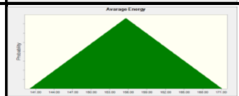
	Pathri			Mohammadpur		
Variable	**Distribution Type**	**Distribution**	**Parameters**	**Distribution Type**	**Distribution**	**Parameters**
Average Capacity	**Normal**		Mean-16.6,S.D-2.6	**Normal**		Mean-17.7,S.D-1.77
Average Energy(Generation)	**Lognormal**		Mean-56.60; S.D.-7.71	**Lognormal**		Mean-155.6; S.D.-1.57
Energy Price	**Uniform**		minimum-1.2; maximum-2.9	**Uniform**		minimum-1.2; maximum-2.9
Capital cost	**Triangular**		Min-5791.59; Likeliest-6435.49; Maximum-7579.36	**Triangular**		Min-8354.18; Likeliest-9282.12; Maximum-10210.66
Discount Rate	**Logistics**		Mean-12%; scale-2	**Logistics**		Mean-10%; scale-1
Operation &Maintenance cost	**Lognormal**		Mean-.15; SD-0.02	**Lognormal**		Mean-.15; SD-0.02
Capital cost Break Up Ist Year	**Triangular**		Min-12%; Most Likely-15%,Max-16.5%	**Triangular**		Min-14%; Most Likely-15%,Max-17%
Capital cost Break Up 2nd Year	**Triangular**		Min-30%; Most Likely-38%,Max-48%	**Triangular**		Min-35%; Most Likely-38%,Max-42%
Capital cost Break Up 3rd Year	**Triangular**		Min-42%; Most Likely-47%,Max-58%	**Triangular**		Min-42%; Most Likely-47%,Max-52%

Table 5.3: Risk Analysis criteria (Input Parameters) and their probability Density Functions (PDF)

5.8 Summary of Monte Carlo simulation

The certainty on estimated NPV is 25.39% & 61.54%, IRR is 24.62%& 62.04% & BCR25.33% & 62.07% for pathri and Mohammadpur projects respectively. The low certainty indicates that estimated financial indicator was not evaluated as risk free estimation in traditional practice; it was purely based on assumption of investment manager. The differences between estimated financial indicators as on the traditional practice (DPR document) and with risk adjustment using Monte Carlo Simulation (present study) is shown in table no 5..

Looking towards almost all financial indicators NPV, IRR & BCR the uncertainty or in other words investment risk associated with pathri hydro power project is almost 74.61% & with Mohammadpur power project it would be 38.46%. The amount of risk in pathri power project is more as compare to Mohammadpur power project though both the projects are in same stage of operation due to various risk factors changing. The risk in these power projects varies due to historical real values considered in this project.

Our sensitivity results on financial indicator shows the most influential factor comes out to be capital cost, interest rate, average capacity, operation & maintenance cost (see Figure5.3& 5.5 (a),(b) & (c). Table 5.4 shows significant cost overrun due to not considering risk parameters while estimating financial indicators. The MCS generates uncertainty on NPV/IRR/BCR values due to specific investment cost (total investment cost of the project divided by the installed capacity) of river-type hydropower plant in

Uttarakhand in the range of 2.7 Rs/kW that was assumed but actually it was varies from 1.7 to 3.9 Rs.

It is also reported that the civil works account for 60-70% of capital cost based on assumptions actually there is triangular distribution found in capital cost. Each hydropower project is site specific that can explain the wide range of investment costs. The main factors which can lead to capital cost breakup which was not considered creates cost overrun. The investment cost a hydropower plant can be classified as follows: Turbine and generator(Electromechanical equipment's); Transformers & Electricals(Electromechanical Equipment); Hydro Mechanical Works (equipment); Civil Works(Design Charges); IDC(interest During Construction); Grid Connection in Table 3 that shows the assumed and actual increase in the cost and increase in cost.

For pathri and Mohammadpur the certainty without and with risk estimation comes out to be different reason behind this is there are certain risk that are common in both power projects but the impact and severity is different, that makes the changes.

Secondly the historical values are considered for risk factors have few lag values in pathri hydroelectric power project contrary it is not applicable in mohammadpur power plant which varies certainty values.

It is concluded that risk in same phase of two power projects could be varied as the certainty values and impact and severity of risk is different due to geological constraints, transportation facilities, and landscape i.e. Though all these factors are not measurable as these are linguistic parameters so in order to consider the impact of these variables also next chapter using fuzzy logic the other risk parameters are also considered and give clear picture of risk impact on investment decision.

Risk reduction alternatives are developed and analysed in a similar manner to the existing dam with selected inputs, such as system response probabilities, changed to represent the improved performance estimated for each alternative.

Sensitivity of risk factors on each financial indicator is assessed using Monte Carlo simulation using crystal ball platform the NPV IRR & BCR sensitive factors would have come for both hydroelectric power projects. Energy generation is one of the most sensitive factors in pathri hydroelectric project whereas discount rate is the next influential factor. But in the case of Mohammadpur hydropower project Operation & Maintenance cost is the most sensitive factor reason is in mohammadpur power project is the machinery and technology used is obsolete and not up to the mark. Secondly silting and precipitation is the another area of concerned which is created due to river flow, so as soil is another factor for high operation and maintenance cost.

Where as in pathri the energy generation is fluctuating due to more days operational halt in power project reasons for halt are transportation is not feasible, safety concern, High River flow i.e. these factors which are linguistic in nature supports cost overrun and energy generation delay, which are not assessed so far in Uttarakhand. In order to consider these factors the fuzzy logic approach is applied and risk is assessed based on that in next chapter.

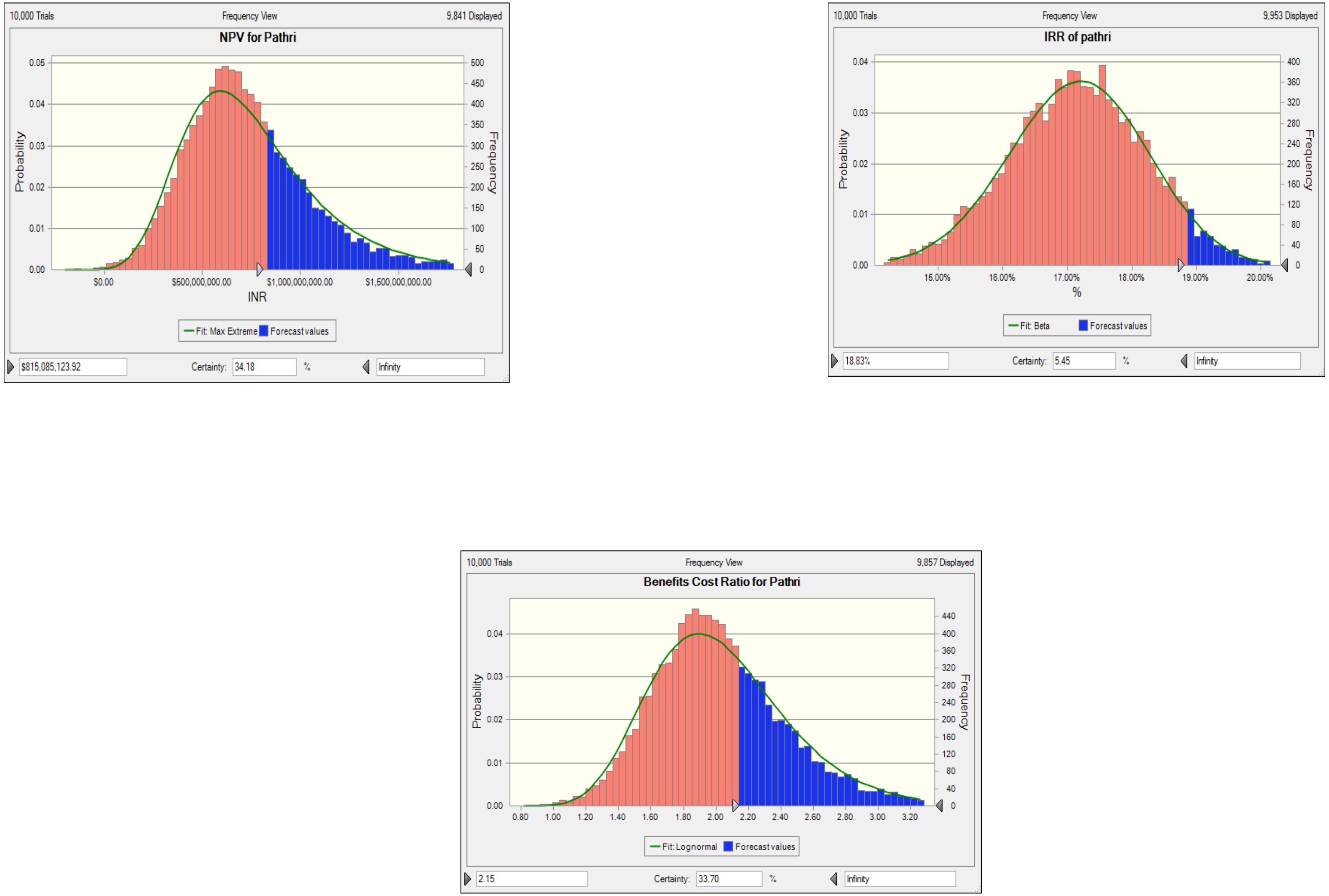


Figure 5.4:(a) ;(b) & (c): NPV, IRR & BCR certainty for Pathri Hydro Electric Power Project

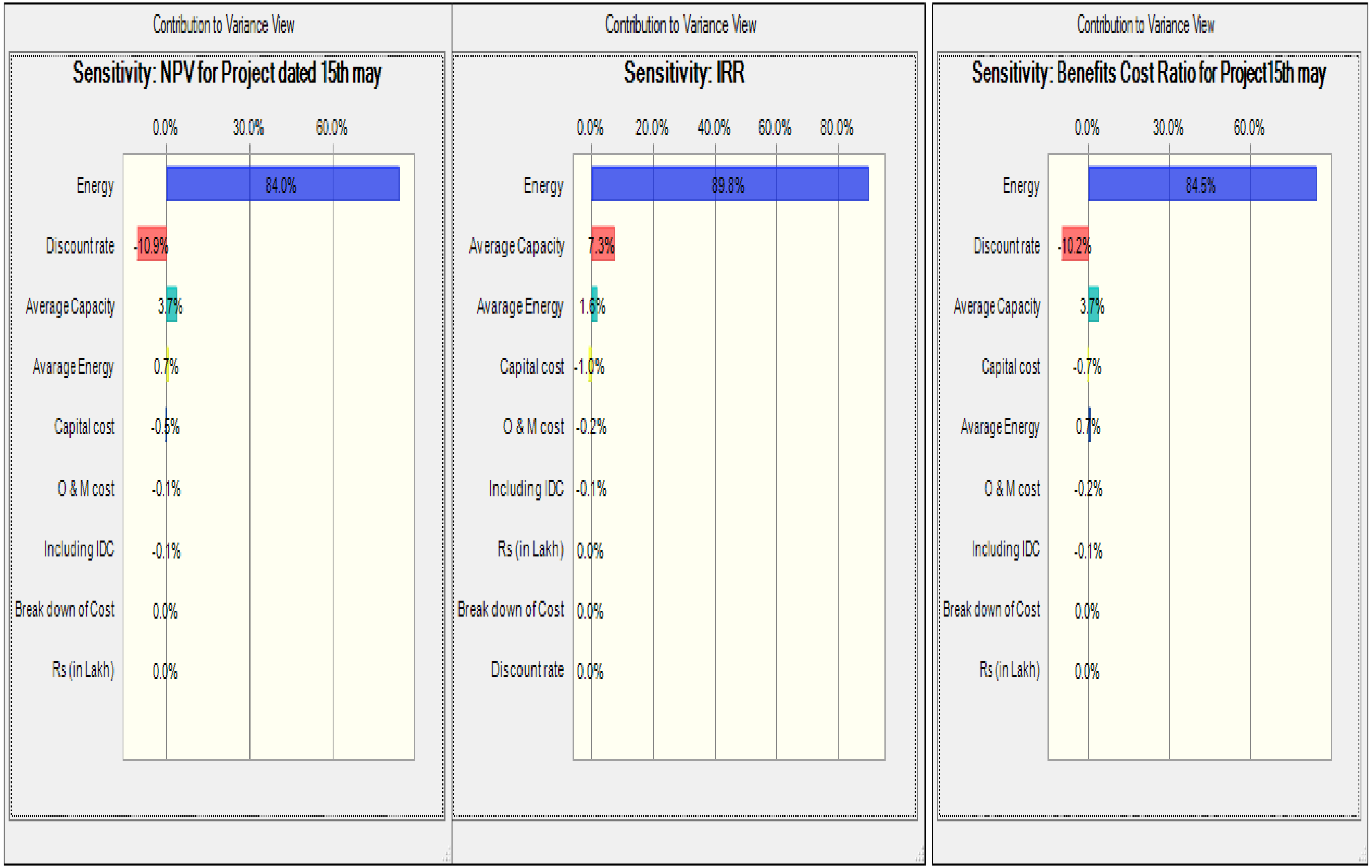
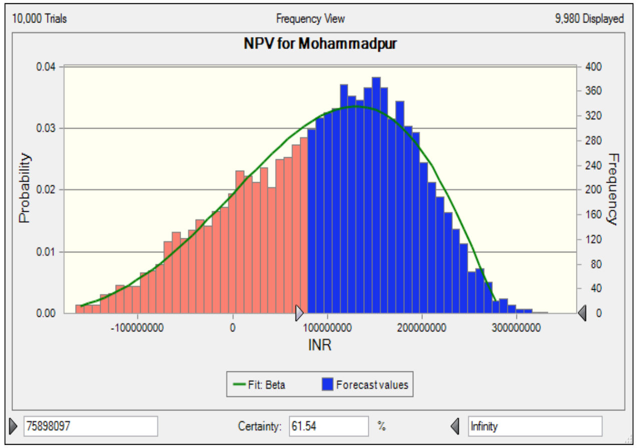
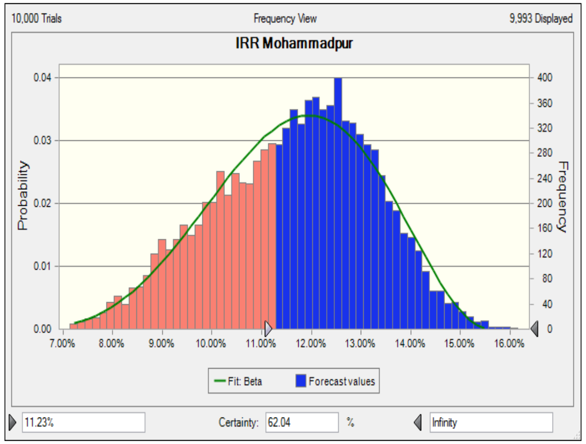


Figure 5.5: Sensitivity of Risk factors in pathri hydroelectric power project ((a) NPV; (b) IRR & (c) BCR)





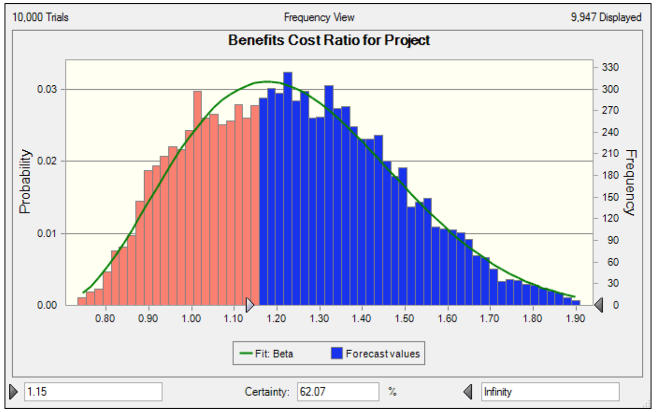


Figure 5.6:(a) ;(b) & (c): NPV, IRR & BCR certainty for Mohammadpur Hydro Electric Power

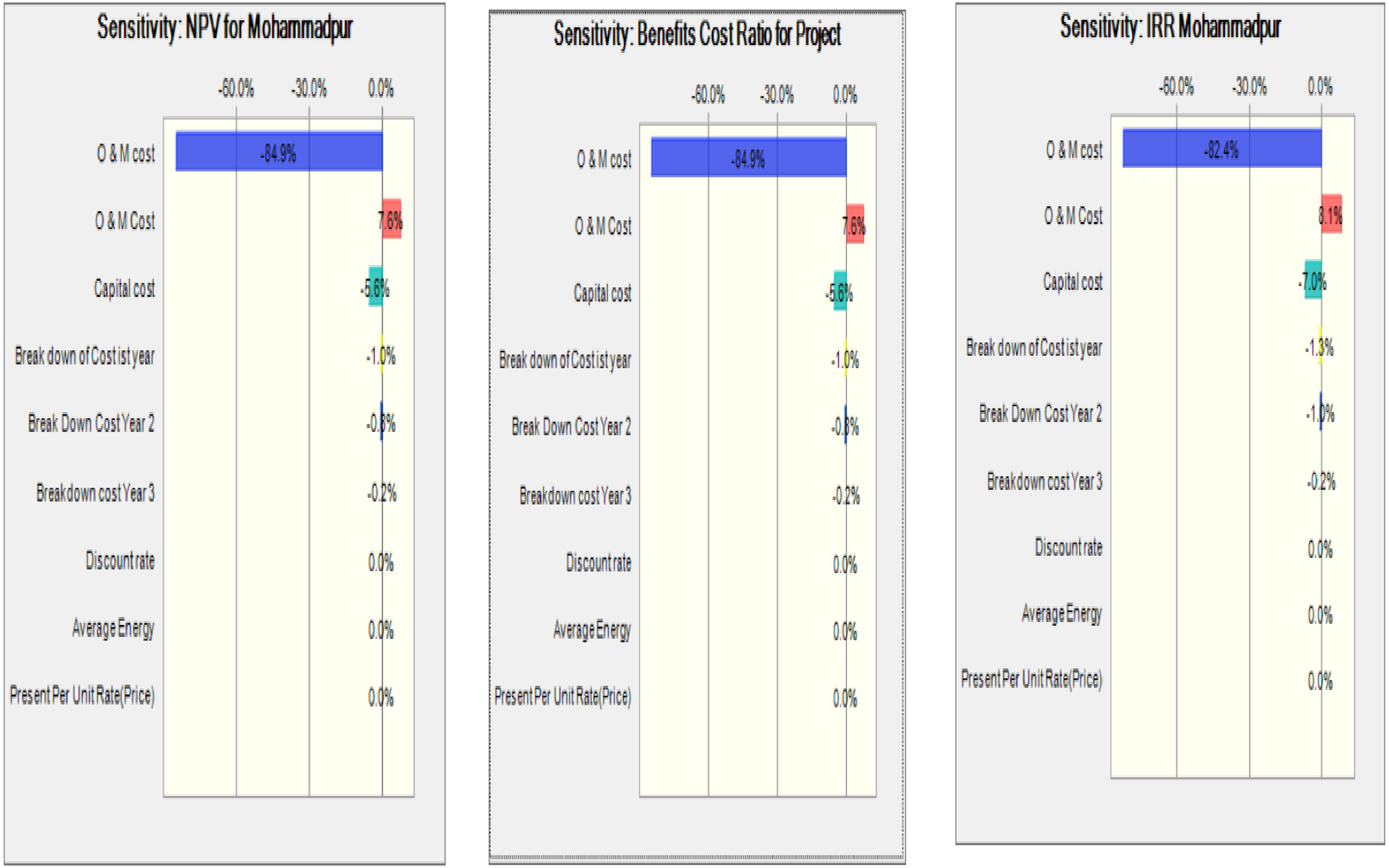


Figure 5.7: Sensitivity of Risk factors in Mohammadpur Hydroelectric power project ((a) NPV; (b) IRR & (c) BCR)

	Pathri small hydro Electric Power Project							**Mohammadpur Hydro Electric Power project**						
Financial Indicators	**Estimated Values**	**Certainty of estimation result without using MCS**	**With Risk Consideration certainty(Using MCS)**	**With Risk Consideration Uncertainty(Using MCS)**	**Estimated Values(Ideal condition)**	**certainty(Using MCS)**	**Risk in pathri(Using MCS)**	**Estimated Values**	**without considering risk Certainty**	**With Risk Consideration certainty(Using MCS)**	**Risk in Mohammadpur (Using MCS)**	**Estimated Values(Ideal Condition)**	**certainty(Using MCS)**	**Risk in mohammadpur(Using MCS)**
NPV(Net Present Value)	815085124	100%	34.18%	65.82%	0	99.85%	0.15%	75898097	100%	61.54 %	38.46%	0	48.17%	51.83%
IRR(Internal rate of Return)	18.83%	100%	5.45%	94.55%	10%	99.86%	0.14%	11.83%	100%	62.04 %	37.96%	10%	48.17%	51.83%
BCR(Benefit Cost Ratio)	2.15	100%	33.70%	66.30%	1	99.86%	0.14%	1.15	100%	62.07 %	37.93%	1	48.17%	51.83%

Table 5.4: Summary sheet for operational stage Small Hydroelectric power project with and without using MCS

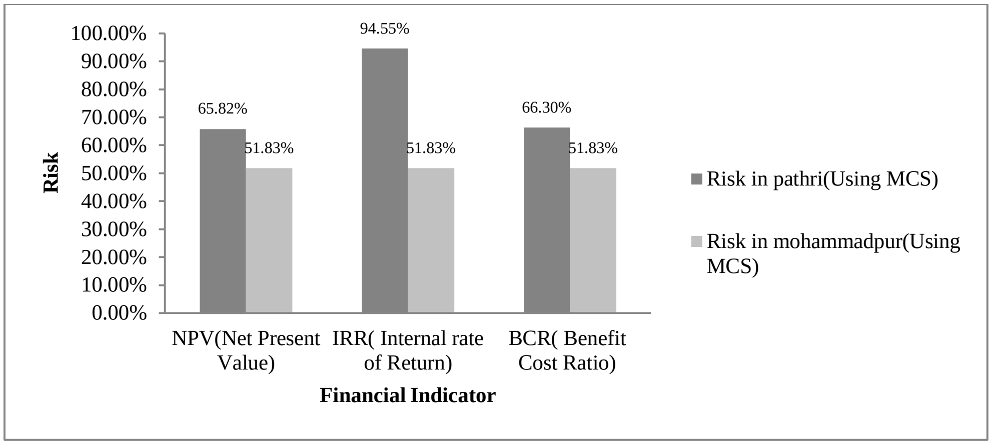


Figure 5.8: Risk with and without using Monte Carlo simulation Pathri & Mohammadpur Hydro power Project

5.9 Validity of Monte Carlo simulation

In order to check the validity of applied Monte Carlo simulation that is the test of randomness with which we check the standard deviation & mean are checked. The number of iteration used for analysis is keep on revised under out of box analysis in which the number of iterations are repeated taking 100, 1000 & 10,000 iterations respectively. In both power projects of all three financial indicators Mean & SD is checked as mentioned in table 5.5 the error is estimated using standard deviation and mean values and it is computed using crystal ball simulator.

	Project Name	**Mohammadpur**			**Pathri**		
Iterations	Financial Indicators	NPV	IRR	BCR	NPV	IRR	BCR
10000	Mean	18311320	9.73	0.99	410295306	13.61	1.56
	Standard Deviation (SD)	87588756	1.36	0.14	634222550	6.49	0.86
	SD/ Mean	4.783312	0.14	0.14141	1.5457709	0.4768553	0.5513
1000	Mean	19675002	9.71	0.98	410369320	13.63	1.57

	Standard Deviation (SD)	89473927	1.39	0.14	626565225	6.43	0.85
	SD/ Mean	4.547594	0.143	0.14286	1.5268325	0.4717535	0.5414
100	Mean	16112245	9.77	0.99	414368988	13.65	1.56
	Standard Deviation (SD)	81042023	1.25	0.13	647732791	6.26	0.86
	SD/ Mean	5.029841	0.128	0.13131	1.5631792	0.4586081	0.5513

Table 5.5: out of box error test summary

The mentioned test was performed at 95% significance scale and it was observed that the financial indicator error is within the range of 5 to 8% which is quite insignificant. So the validity of the model is not questionable.

If we assume the condition of getting standard values of NPV as 0, IRR as 10% (equivalent to given discount rate) & BCR as 1 so the values in all the iterations is not moving with high error at same 95% significance scale the randomness is not much that is within 3-5%.

5.10 Introduction of fuzzy logic for risk assessment

In the previous section the risk identification and assessment was performed using Monte Carlo simulation a probabilistic approach which consider only parametric risk factors. Whereas in this chapter assessment of investment related risks in small hydro power project in Uttarakhand state of India is evaluated using Fuzzy logic approach which is stochastic in nature. The main focus of this research is to analyses both parametric and non-parametric investment risk factors in small hydro power project of the area. Simultaneously this study also segregates risk factors for both operation and construction stage which is not a common risk identification practice performed in this particular area. The relative importance of risk factors was also identified and at the end risk index will be assessed. Although Probability models are widespread in risk quantification and assessment. They have become the fundamental basis for informed decision-making related to risk in many areas discussed in chapter 2 as well. However, a probability model built upon classic set theory may not be able to describe some risks in a meaningful and practical way. Lack of experience data, entangled cause-and-effect relationships and imprecise data make it difficult to assess the degree of exposure to certain risk types using only traditional probability models.

Sometimes, even with a credible quantitative risk model calibrated to experience data, the cause of the risk and its characteristics may be incompletely understood. Because of the stochastic nature of variables that compute financial indicators, has some uncertainty which cause risk in investment decision. Apart from stochastic variables there are some external variables that are not stochastic by nature also influence on investment decision. Other models, such as fuzzy logic, hidden Markov and decision tree models, and artificial neural and Bayesian networks, explicitly consider the underlying cause-and-effect relationships and recognize the unknown complexity. These newer models might do a better job in understanding and assessing certain risks, such as operational risk. Interestingly, while well-accepted and complex quantitative models are available for market, credit and insurance risk, these risks are normally outside the control of business managers. On the other hand, with appropriate risk identification and risk control in place, operational risk can be significantly mitigated, despite the lack of consensus concerning which quantitative models should be used. Therefore, it may be beneficial to build and implement more appropriate operational risk models using a newer approach such as fuzzy logic.

Such external variables are identified based on literature reviews, expert interviews and field survey. The relative importance of these factors are evaluated strategically and ranked them accordingly.

This chapter focuses on the use of fuzzy logic, introduced by mathematician Lotfi A. Zadeh in 1965, (Jenab & Ahi, 2010a) to risk assessment. Unlike probability theory, fuzzy logic theory admits the uncertainty of truth in an explicit way; it also can easily incorporate information described in linguistic terms. Fuzzy logic models are more convenient for incorporating different expert opinions and more adapted to cases with insufficient and imprecise data. They provide a framework in which experts' input and experience data can jointly assess the uncertainty and identify major issues. Using approximation and making inferences from ambiguous knowledge and data, fuzzy logic models may be used for modeling risks that are not fully understood. Some operational and emerging risks evolve quickly. Risk managers may not have enough knowledge or data for a full-blown assessment using models based on probability theory. Fuzzy logic models can be instrumental in assessing a business enterprise's exposure to these risks. This chapter highlights the risk assessment process for Construction and operational stage small hydro power projects of Uttarakhand using Fuzzy Logic approach.

5.11 Qualitative & Quantitative Risk Identification in small hydro power project

Risk concerning to Small hydro Power project was identified in construction and operational stage in which some are measurable and some are non-measurable by a study including literature survey and expert interview. The identified risks are combination of linguistic and nonlinguistic in nature Twenty five and twenty three parameters were considered separately for construction and operational stage small hydro power projects of Uttarakhand.

The risks identified from literature review(Detailed in Chapter 2& 4) & expert opinion are as, Clearance, Climate, Construction Budget; Capital cost, Construction Schedule, Delay from Suppliers, Flora fauna, Noise Pollution, Soil Erosion, Water Quality, Financing Resources, PPP, Tax Rate, Inflation, Interest Rate, Electricity Price, Relocation, Employment, Tourist attraction, Terrorism, River Flow, Machinery ,O&M, Modeling Techniques, Precipitation, Generation. The segregation for risk in operational and construction phase is performed based on expert opinion. Risk Factor (F) for construction and operation stage is denominated as

Subsets of $\boldsymbol{F_{construction}}$ & $\boldsymbol{F_{operation}}$ are formed from the following listed risk variables mentioned in Equation 5**.1(A) & 5.1 (B)**.

$$\begin{aligned} F_{Construction} = \ (&\textbf{\textit{Clearances}}, \textbf{\textit{Climate}}, \textbf{\textit{Construction cost}}, \textbf{\textit{local community}}, \\ &\textbf{\textit{Construction Schedule}}, \textbf{\textit{Delay from Suppliers}}, \textbf{\textit{Flora fauna}}, \\ &\textbf{\textit{Noise Pollution}}\ , \textbf{\textit{Soil Erosion}}, \textbf{\textit{Modeling Techniques}}, \textbf{\textit{precipitation}} \\ &\textbf{\textit{Water Quality}}, \textbf{\textit{Financing Resources}}, \textbf{\textit{Public private partnership}}, \\ &\textbf{\textit{Tax Rate}}, \textbf{\textit{Inflation}}, \textbf{\textit{Interest rate}}, \textbf{\textit{Electricity price}}, \textbf{\textit{Relocation}}, \end{aligned}$$

$$\boldsymbol{Employment, Tourist\ Attraction, Terrorism, River\ flow, Machinery, Regulatory, fund\ Blockage)} \quad \textbf{5.1(A)}$$

$$F_{Operational} = (\boldsymbol{Approval\ by\ authorities, Financial\ Resources, Tourist\ Places, Employment, Flora\ \&\ fauna, Capital\ Cost, Interest\ rate, Tax\ rate, Inflation, Climate, Noise, Drinking\ Water\ Quality, River\ Flow, Soil\ erosion, Precipitation, Machinery, Breakdown, Regulatory, Electricity\ Prices, Preventive\ Maintennace, Generation, Terrorism, Operation\ \&\ Maintennace\ cost, PPP, Evaluation\ technique, Fund\ Blockage} \quad \boldsymbol{5.1(B)}$$

All risk variables were scaled on the scale of **1-5** where **1 is very low and 5 for extreme**. All risk factors are scaled based on natural language input statement having discussion with experts from area and site visits. Some risk factors are non-measurable and some are measurable. The risk parameters and their attributes can be seen in Table 5.6 (a) & (b) for construction and operation phase power projects.

It is more like to determine the actual state of the power project according to attributes than scoring. As an example, in construction stage construction schedule is one of the risk factor has five attributes as Project Constructed within estimated time, project exceed within 6 months from estimated time, project exceed between 6 months to 1 year from estimated time; project exceed within 1 year to 3 year from estimated time and project exceed more than 3 year from estimated time from 1 to 5 rating respectively.

That is a power project with construction schedule stretched by 1.5 year would be scored as 4. Although some of the parameters can be measured (such as Tax rate, electricity price, Interest rate), the others are subject to the expert's view of the hydro power project. However, the scoring of all parameters was done by visual perception of the observer where biases and preferences of the expert, instantaneous events occurring in the area during scoring may be effective.

Table 5.6 (a): Risk Factors Score Allocation Classification for Construction Stage Small Hydro Power Projects

Risk Factor	score 1 (very Low)	score 2 (Medium)	score 3 (High)	score 4 (very High)	score 5 (Extreme)
Clearances	Getting clearances is very Easy	Getting clearances is Easy	Getting clearances is Moderate	getting clearances is Difficult	Getting clearances is very Difficult
Capital Cost	no extra money required as per estimation	10% budget exceed from estimated cost	more than 10 %-30% budget exceed from estimated cost	more than 30 %-50% budget exceed from estimated cost	more than 50% budget exceed from estimated cost
Construction Schedule	Project Constructed within estimated time	project exceed within 6 months from estimated time	project exceed 6 months to 1 year from estimated time	project exceed more than 1 year to 3 year from estimated time	project exceed more than 3 year from estimated time
Delay from Suppliers	immediate supply	supply delay by 15 days to 1 month	supply delay by 1 month to 3 months	supply delay by 3 month to 6 months	supply delay by more than 6 Months
technical Breakdown	No Breakdown occurs in power plant and no impact	Breakdown occurs once in a year but manageable	Breakdown occurs Twice in a year creates cost overrun	Breakdown occurs 2-4 times in a year creates high cost overrun	Breakdown occurs frequently and cost overrun exceed severity
Employment	employment given to all local community people and permanent profile is given	employment given to few educated local community people and rest are on contractual bases	employment given to people in moderate number	employment given to few local community people on contractual basis	No employment given to local community people and for other it is contractual
Financing Resources	Very Easily Accessible from Financial Institution	Easily Accessible with less formalities	Available with more paper work and clearances	Finance available but takes much time and efforts	Not Available projects are stopped due to finance non availability
Flora fauna	Flora fauna is not available near the power project area	flora &fauna is not so much affected as area is quite less	flora &fauna is less affected and measures are taken for prevention	flora &fauna is affected and preventions are in the implementation stage	flora &fauna affects so much that environment clearance stop
Fund Blockage	Fund is never Blocked by Financing Sources	fund blockage released within 7 days to 15 days	fund blockage released within 15 days to 1 Month	fund blockage released within 1 Month to 3 months	fund blockage released after 3 months
Inflation	No inflation increment	No revision in one year	Revised twice in a year	Revised two to three times in a year	inflation changes frequently
Interest Rate	Fixed interest rate	No revision in one year	Revised twice in a year	Revised two to three times in a year	Inflation changes frequently
Machinery	machinery used as generators and turbines give 100% efficiency	machinery used as generators and turbines give 70%-80% efficiency	Machinery used as generators and turbines give 50%-70% efficiency	machinery used as generators and turbines give 20%-50% efficiency	machinery used as generators and turbines give less than 20% efficiency
Modeling Techniques	no modeling techniques used for assessment based on tariff	obsolete methods used for assessment as PBP	Moderate methods used for evaluation as NPV,IRR	Moderate methods used for evaluation as Sensitivity analysis,	Very Advanced Techniques used for assessment

	calculation			Scenario manager	
Noise Pollution	Hydro project not creates any sound	Hydro power project creates moderate sound as near to isolated places so no impact	Hydro power project creates moderate sound as near to industrial area so less impact	Hydro power project creates sound but sound proof measures are initiated	Hydro power project creates very high sound pollution and local community affected
PPP	for SHP PPP agreement not required	PPP agreement Depends on Investor desire	PPP agreement feasible only for certain stages	PPP agreement is mandatory only few stages	PPP agreement is mandatory
Precipitation	No Precipitation from river	precipitation accumulates once in a year	precipitation accumulates seasonal	precipitation accumulates 15 days or 1 Month	precipitation accumulates every 7 days to 15 days
Regulatory	Government is stable norms are not changing frequently	Government norms remain same for 2-3 years	Government norms are changing once in year	Government norms are not changing 2-3 times in a year	Government is unstable norms are not changing monthly basis
Relocation	Local community benefit from the river or the surrounding lands	Project has no Social Impact Report	Project has Moderate Social Impact Report	Project has Social Impact Report	Project has detailed Social Impact Report
River Flow	river flow uniform throughout the year	river flow is monsoonal but under controlled	river flow is monsoonal but partly controlled	river flow is monsoonal but damage controller available	river flow is very high so damage power project
Soil Erosion	Rock mass quality is very good:70%-100%	Rock mass quality is Good:55%-70%	Rock mass quality is not so good:40%-55%	Rock mass quality is poor :20%-40%	Soil withhighgroundwaterlevel
Tax Rate	No changes in tax	No revision in one year	Revised twice in a year	Revised two to three times in a year	Tax changes frequently
Terrorism	terrorism risk index of the state is very low	terrorism risk index of the state is low	terrorism risk index of the state is Moderate	terrorism risk index of the state is High	terrorism risk index of the state is very High
Construction Budget	no extra money required as per estimation	10% budget exceed from estimated cost	more than 10 %-30% budget exceed from estimated cost	more than 30 %-50% budget exceed from estimated cost	more than 50% budget exceed from estimated cost
Water Quality	Drinking water quality is not creating health issues	Drinking water quality creates minor health issues	Drinking water quality creates major health issues	Drinking water quality creates severe health issues	Drinking water quality creates epidemic
Climate	no landslide and cloud bursting in the Uttarakhand area	landslide and cloud bursting occurs in 10 years in the Uttarakhand area	Landslide and cloud bursting occurs every 5 year in the Uttarakhand area.	landslide and cloud bursting occurs within 2-3 years in the Uttarakhand rea	landslide or cloud bursting occurs many times in a year in the Uttarakhand area

Risk Factor	score 1 (very Low)	score 2 (Medium)	score 3 (High)	score 4 (very High)	score 5 (Extreme)
capital cost	no extra money required as per estimation	10% budget exceed from estimated cost	more than 10 %-30% budget exceed from estimated cost	more than 30 %-50% budget exceed from estimated cost	more than 50% budget exceed from estimated cost
Clearances	Getting clearances is very Easy	Getting clearances is Easy	Getting clearances is Moderate	getting clearances is Difficult	Getting clearances is very Difficult
Climate	no landslide and cloud bursting in the Uttarakhand area	landslide and cloud bursting occurs in 10 years in the Uttarakhand area	landslide and cloud bursting occurs every 5 year in the Uttarakhand area	landslide and cloud bursting occurs within 2-3 years in the Uttarakhand area	landslide or cloud bursting occurs many times in a year in the Uttarakhand area
technical Breakdown	No Breakdown occurs in power plant and no impact	Breakdown occurs once in a year but manageable	Breakdown occurs Twice in a year creates cost overrun	Breakdown occurs 2-4 times in a year creates high cost overrun	Breakdown occurs frequently and cost overrun exceed severely
Generation	Electricity generated more than average capacity	Electricity generated +- 5% than average capacity	Electricity generated +- 10%to 20% than average capacity	Electricity generated +- 20-40%% than average capacity	Electricity generated less than 50% of average capacity
Electricity Price	price fluctuates once in 10 year	price fluctuate every 5 year	price fluctuate within 2-4 years	price fluctuation once in a year	price fluctuation 3 times in a year
Operation & Maintenance cost	Operation and maintenance c cost is 1-2% of capital cost	Operation and maintenance c cost is 2-5% of capital cost	Operation and maintenance c cost is 5%-10% of capital cost	Operation and maintenance c cost is 10%-20% of capital cost	Operation and maintenance c cost is more than 20%of capital cost
Evaluation technique	no modelling techniques used for assessment based on tariff calculation	obsolete methods used for assessment as PBP	Moderate methods used for evaluation as NPV,IRR	Moderate methods used for evaluation as Sensitivity analysis, Scenario manager	Very Advanced Techniques used for assessment
Financing Resources	Very Easily Accessible from Financial Institution	Easily Accessible with less formalities	Available with more paper work and clearances	Finance available but takes much time and efforts	Not Available projects are stopped due to finance non availability
Flora fauna	Flora fauna is not available near the power	flora &fauna is not so much	flora &fauna is less affected and	flora &fauna is affected and preventions are in the	flora &fauna affects so much that environment clearance

	project area	affected as area is quite less	measures are taken for prevention	implementation stage	stop
Inflation	No inflation increment	No revision in one year	Revised twice in a year	Revised two to three times in a year	inflation changes frequently
Interest Rate	Fixed interest rate	No revision in one year	Revised twice in a year	Revised two to three times in a year	Inflation changes frequently
Machinery	machinery used as generators and turbines give 100% efficiency	machinery used as generators and turbines give 70%-80% efficiency	Machinery used as generators and turbines give 50%-70% efficiency	machinery used as generators and turbines give 20%-50% efficiency	machinery used as generators and turbines give less than 20% efficiency
Noise Pollution	Hydro project not creates any sound	Hydro power project creates moderate sound as near to isolated places so no impact	Hydro power project creates moderate sound as near to industrial area so less impact	Hydro power project creates sound but sound proof measures are initiated	Hydro power project creates very high sound pollution and local community affected
PPP	for SHP PPP agreement not required	PPP agreement Depends on Investor desire	PPP agreement feasible only for certain stages	PPP agreement is mandatory only few stages	PPP agreement is mandatory
Precipitation	No Precipitation from river	precipitation accumulates once in a year	precipitation accumulates seasonal	precipitation accumulates 15 days or 1 Month	precipitation accumulates every 7 days to 15 days
Regulatory	Government is stable norms are not changing frequently	Government norms remain same for 2-3 years	Government norms are changing once in year	Government norms are not changing 2-3 times in a year	Government is unstable norms are not changing monthly basis
River Flow	river flow uniform throughout the year	river flow is monsoonal but under controlled	river flow is monsoonal but partly controlled	river flow is monsoonal but damage controller available	river flow is very high so damage power project
Soil Erosion	Rock mass quality is very good:70%-100%	Rock mass quality is Good:55%-70%	Rock mass quality is not so good:40%-55%	Rock mass quality is poor :20%-40%	Soil with high ground water level
Tax Rate	No changes in tax	No revision in one year	Revised twice in a year	Revised two to three times in a year	Tax changes frequently
Terrorism	terrorism risk index of the state is very low	terrorism risk index of the state is low	terrorism risk index of the state is Moderate	terrorism risk index of the state is High	terrorism risk index of the state is very High
Tourist attraction	Every project has tourist place near dam site and generates employment	project has tourist place near dam site and generates not so major employment	Few project has tourist place near dam site and development is going on other dam sites as well	few project has tourist place near dam site but not so developed	No tourist place near dam site
Drinking Water Quality	Drinking water quality is not creating health issues	Drinking water quality creates minor health issues	Drinking water quality creates major health issues	Drinking water quality creates severe health issues	Drinking water quality creates epidemic

Table 5.6 (b): Risk Factors Score Allocation Classification for Operational Stage Small Hydro Power Projects

The scores of attributes for a particular risk variable in both types of projects are illustrated in risk identification score histograms by plotting Risk Factors in Y axis and corresponding scores on the X axis. The score attribute histogram for construction and operation stage is visible in Fig 5.8 (a) & (b).

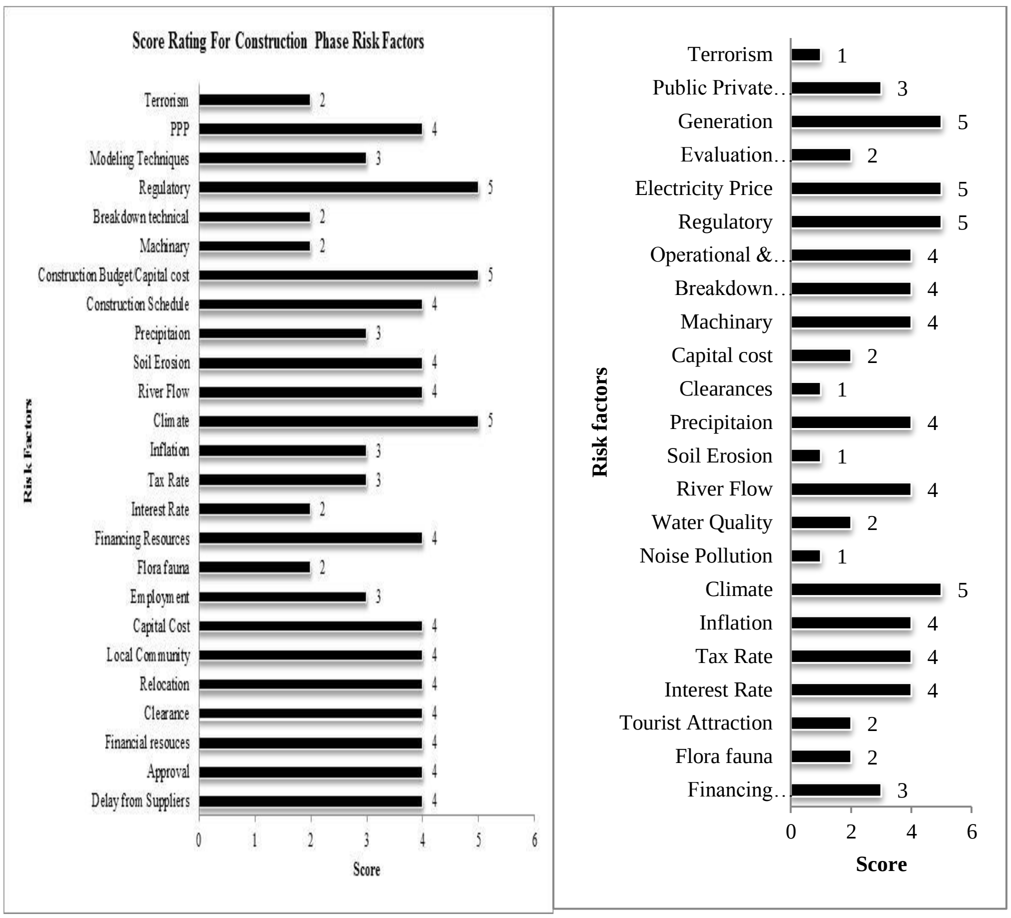


Figure 5.9(a & b): Score Assigned to Each Risk factor based on Expert Interview (constructional/operation Stage)

5.12 Questionnaire survey

All parameters cannot have the same weight comparing to each other as some parameters may certainly be more important than the others. For example, drinking water quality was expected to have a less weight than precipitation or silting. Questionnaires were framed based on expert opinion and literature review was floated among UJVNL Officials, Investors, Researchers in India, especially Uttarakhand, to determine the weights of parameters. Questionnaire survey inquiry form used can be seen in Annexure 5.1 A & B.

The questionnaire surveys were carried out by sending questionnaire through Emails and some places face to face interview by project members, investors, developers, approvers, researchers etc. Each respondent were asked to check their importance rating on a five scale for each parameter. Rating one means less importance whereas rating five means more importance.

The total number of respondents in public perception surveys in small hydro power projects of Uttarakhand with the study was 376 in total. A survey was conducted with the experts from Uttarakhand Jal Vidyut Nigam Ltd. (UJVNL) and investors that have experience in the construction of river-type small hydropower schemes. 119 respondents were participated to the survey.

The total number of ticks for attributes of each parameter can be seen in Table 5.7 (a) & (b), the same was used in calculation of the weights of the risk parameters for construction and operational stage of power projects.

A detailed questionnaire study was discussed in Chapter 3. In this section, only methodological contributions of the surveys will be described in the method.

Risk factors	No of 1s	No of 2s	No of 3s	No of 4s	No of 5s
Delay of supplies	7	21	28	21	42
Clearances	2	2	21	35	59
Financial resources	0	12	21	44	42
Relocation	14	14	14	21	56
local Community	1	34	68	11	5
Tourist Places	0	31	73	7	8
flora and fauna	0	21	21	42	35
Financing	0	7	70	21	21
Interest rate	14	3	41	35	26
tax rate	15	26	44	22	12
inflation rate	1	16	38	28	36
Climate	21	7	14	42	35
Drinking water quality	70	9	29	4	7
River Flow	8	7	27	21	56
soil erosion	0	7	35	35	42
precipitation or silting	7	7	21	7	77
construction time	29	21	30	31	8
Construction Budget	67	8	16	25	3
Machinery	0	2	16	65	36
Regulatory	21	1	3	30	64
Evaluation techniques	1	8	51	51	8
Public private partnership	36	28	22	17	16
Terrorism	49	21	20	8	21
capital cost	21	0	35	42	21
Fund Blockage	14	35	46	24	0

Table 5.7(a): Construction stage Respondent Responses

Risk factors	No of 1s	No of 2s	No of 3s	No of 4s	No of 5s
Financing Resources	7	14	21	35	42
Flora fauna	0	28	21	28	42
Tourist Attraction	0	31	73	7	8
Interest Rate	14	28	49	21	7
Tax Rate	0	21	21	42	35
Inflation	0	7	70	21	21
Climate	14	3	41	35	26
Noise Pollution	15	26	44	22	12
Water Quality	1	16	38	28	36
River Flow	21	7	14	42	35
Soil Erosion	56	14	28	14	7
Precipitation	70	9	29	4	7
Clearances	7	7	28	21	56
Capital cost	0	7	35	35	42
Machinery	7	7	21	7	77
Breakdown technical	0	2	16	65	36
Operational & Maintenance	21	35	56	0	7
Regulatory	1	8	29	32	49
Electricity Price	21	1	3	30	64

Evaluation Techniques	44	15	30	16	14
Generation	1	8	51	51	8
(PPP)	8	7	65	23	16
Terrorism	36	28	22	17	16

Table 5.7 (b): Operational stage Respondent Responses

In calculation of the Relative weights of parameters, the following method was applied:

1. The number of ticks for each parameter attributes in the public survey were counted. One to five attributes were taken into consideration in the calculation of overall weighted averages of parameters to promote precise preferences.

2. Each parameter had a significance grades $\mathbf{g_i}$ that demonstrates the significance of the feature compared to the others Parameters, here in this case the each parameter significance considered to be same so significance grade comes out as had **1/25 & 1/23** in operation & construction respectively.

3. Weights of parameters were obtained by multiplying overall weighted averages with significance grades.

4. Weights of physical and human parameters were normalized separately. Normalized final weights of parameters **($\mathbf{W_r}$)** were used in the fuzzy logic application.

The calculation of weights of construction & operation phase power projects risk parameters as described in Table 5.8 (a) & (b) from questionnaire survey responses.

Table 5.8 (a): Weights of Different Factors Risks Based on Fuzzy Assessment (construction)

Assessment Parameters	no of 1s	no of 2s	no of 3s	no of 4s	no of 5	Weighted Average (W_A)	Rating (r_i)	Weight(w_r)=Rating(r_i)*weighted average (W_A)	(Relative weights)(w_r)(%)
Delay from Suppliers	7	21	28	21	42	3.5882	0.04	0.14353	4.29%
Approval	2	2	21	35	59	4.2353	0.04	0.16941	5.07%
Financial resources	0	12	21	44	42	3.9748	0.04	0.15899	4.76%
Clearance	14	14	14	21	56	3.7647	0.04	0.15059	4.51%
Relocation	1	34	68	11	5	2.8739	0.04	0.11496	3.44%
Local Community	0	31	73	7	8	2.9328	0.04	0.11731	3.51%
Capital Cost	0	21	21	42	35	3.7647	0.04	0.15059	4.51%
Employment	0	7	70	21	21	3.4706	0.04	0.13882	4.15%
Flora fauna	14	3	41	35	26	3.4706	0.04	0.13882	4.15%
Financing Resources	15	26	44	22	12	2.916	0.04	0.11664	3.49%
Interest Rate	1	16	38	28	36	3.6891	0.04	0.14756	4.42%
Tax Rate	21	7	14	42	35	3.5294	0.04	0.14118	4.22%
Inflation	70	9	29	4	7	1.8992	0.04	0.07597	2.27%
Climate	8	7	27	21	56	3.9244	0.04	0.15697	4.70%
River Flow	0	7	35	35	42	3.9412	0.04	0.15765	4.72%
Soil Erosion	7	7	21	7	77	4.1765	0.04	0.16706	5.00%
Precipitation	29	21	30	31	8	2.7311	0.04	0.10924	3.27%
Construction Schedule	67	8	16	25	3	2.0672	0.04	0.08269	2.47%
Construction Budget/Capital cost	0	2	16	65	36	4.1345	0.04	0.16538	4.95%
Machinery	21	1	3	30	64	3.9664	0.04	0.15866	4.75%
Breakdown technical	1	8	51	51	8	3.479	0.04	0.13916	4.16%
Regulatory	36	28	22	17	16	2.5714	0.04	0.10286	3.08%
Modeling Techniques	49	21	20	8	21	2.4202	0.04	0.09681	2.90%
PPP	21	0	35	42	21	3.3529	0.04	0.13412	4.01%
Terrorism	14	35	46	24	0	2.6723	0.04	0.10689	3.20%
								3.341848739	**1**

Table 5.8 (b): Weights of Different Factors Risks Based on Fuzzy Assessment (Operational)

Assessment Parameters	no of 1s	no of 2s	no of 3s	no of 4s	no of 5	Weighted Average (W_A)	Rating (r_i)	Weight(w)=Rating (r_i)*weighted average (w_A)	(Relative weights)(w_r)
Financing Resources	7	14	21	35	42	3.765	0.043	0.164	4.91%
Flora fauna	0	28	21	28	42	3.706	0.043	0.161	4.84%
Tourist Attraction	0	31	73	7	8	2.933	0.043	0.128	3.83%

Interest Rate	14	28	49	21	7	2.824	0.043	0.123	3.69%
Tax Rate	0	21	21	42	35	3.765	0.043	0.164	4.91%
Inflation	0	7	70	21	21	3.471	0.043	0.151	4.53%
Climate	14	3	41	35	26	3.471	0.043	0.151	4.53%
Noise Pollution	15	26	44	22	12	2.916	0.043	0.127	3.81%
Water Quality	1	16	38	28	36	3.689	0.043	0.16	4.82%
River Flow	21	7	14	42	35	3.529	0.043	0.153	4.61%
Soil Erosion	56	14	28	14	7	2.176	0.043	0.095	2.84%
Precipitation	70	9	29	4	7	1.899	0.043	0.083	2.48%
Clearances	7	7	28	21	56	3.941	0.043	0.171	5.14%
Capital cost	0	7	35	35	42	3.941	0.043	0.171	5.14%
Machinery	7	7	21	7	77	4.176	0.043	0.182	5.45%
Breakdown Technical	0	2	16	65	36	4.134	0.043	0.18	5.40%
Operational & Maintenance	21	35	56	0	7	2.471	0.043	0.107	3.23%
Regulatory	1	8	29	32	49	4.008	0.043	0.174	5.23%
Electricity Price	21	1	3	30	64	3.966	0.043	0.172	5.18%
Evaluation Techniques	44	15	30	16	14	2.504	0.043	0.109	3.27%
Generation	1	8	51	51	8	3.479	0.043	0.151	4.54%
(PPP)	8	7	65	23	16	3.269	0.043	0.142	4.27%
Terrorism	36	28	22	17	16	2.571	0.043	0.112	3.36%
								3.331	**1**

Relative importance significance for each risk factors for both the stages are plotted in figure 5.10 (A) & (B) for construction and operational stages respectively. Where X axis shoes the relative importance and Y axis shows the risk factor.

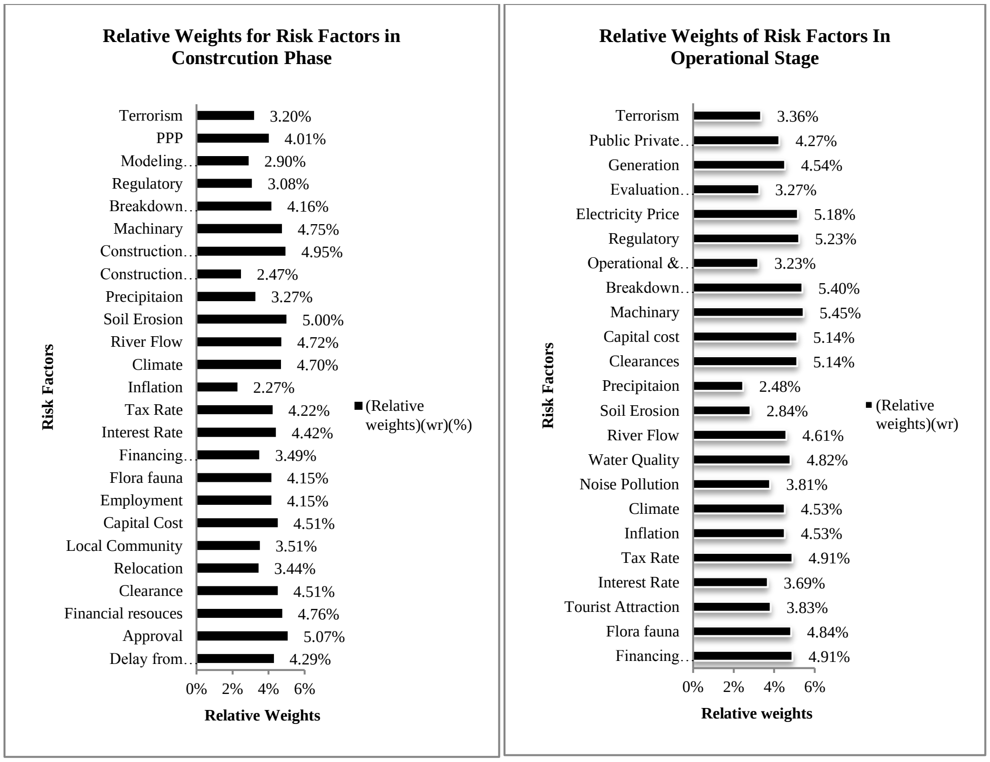


Figure 5.10 (a &b): Relative importance of risk factors using Fuzzy logic (Construction/Operation Phase)

Top five columns in Table 5.10 (a) & (b) demonstrates the top five parameters which respondent consider the most dominant risk factors. Although this column does not affect the procedure in any way, it can be used to as a simple tool to see the important parameters. In same Table 5.9 (a) & (b), the total number of ticks for top five columns can also be seen for construction and operational stage power projects. As seen in Table X & Y, among the 25 & 23 parameters, the following five parameters got the highest percentage for top five ranking in table 5.10.

Table 5.9: Top five Risks in constructional and operational stage SHP project

Ranking	**Construction stage Top Five Parameters**	**Operational Stage Top Five parameters**
1	Clearances/Approvals	Machinery
2	Soil Erosion	Breakdown
3	Construction Budget	Regulatory
4	Machinery	Electricity prices
5	River Flow	Capital cost

5.13 Fuzzy Logic Approach

In fuzzy logic approach in order to quantify linguistic risks, a specific model for risk assessment of small hydro power projects that integrate expert opinions, site visits and relevant public inclinations, were utilized. As the scoring of parameters were to be done by expert/ trained persons, the weights of the parameters were to be determined by expert's survey preference questionnaires.

Expert opinion data acquisition method is recognized to a great extent to be subject to uncertainty and involves bias. The uncertainty and bias are greatly affected by the way the collection process is conducted and by the group of experts invited to participate in the process. (Parandin, Seidzadeh, & Hamedi, 2013b); (Bilal, 1998).

The scoring process in fuzzy logic approach is subjective as site attributes were determined solely by experts, visual, existing literature survey and experimental work towards the small hydro power projects environment. Different experts participated in the same type of study evaluation may lead to some biases and differences in the evaluation; that is, one expert might score a parameter for a specific site different from another expert.

Fuzzy logic approach was used to overcome the uncertainties and subjectivity in the processes of parameter ratings. Fuzzy logic provides a natural way of dealing with problems in which the source of imprecision is the absence of sharply defined criteria of class membership rather than the presence of random variables

(Zadeh, 1965) and enables an expert group to quantify the uncertainties and subjectivities in most scientific studies.

5.14 Matrices

In order to avoid subjectivity in responses the procedure follows is as below,

i) For each 25 & 23 parameter in each category, a 1x5 input matrix is developed, each column corresponding attributes 1- 5. The value is 1 for the attribute scored for the parameter and 0 for the other attributes. As an example in construction stage the clearances score as per expert opinion as 4 which is mentioned by input matrix as per Equation 5**.2**

$$\mathbf{I} = |0 \quad 0 \quad 0 \quad 1 \quad 0| \qquad (\mathbf{5.2})$$

ii) Each parameter has a membership grading matrix. The fuzzy grading matrices were developed considering the degree of error a scoring observer may cause due to subjectivity and bias in the assessment process. **Eq. (6.3)** shows the fuzzy grading matrix **(*FG*)** used for operation stage risk factor financial resources whose score as per expert opinion is 3, but fuzzy grading matrix is shown in **Equation 5.3**.

$$\mathbf{FG} = \boldsymbol{score}\begin{bmatrix} \mathbf{1} & \mathbf{0.3} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{1} & \mathbf{0.4} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0.4} & \mathbf{1} & \mathbf{0.4} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0.4} & \mathbf{1} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0.3} & \mathbf{1} \end{bmatrix} \qquad \textbf{(5.2)}$$

Each row in the matrix corresponds to attribute scores from 1 to 5 respectively. If Boolean logic was used, the matrix would be identity matrix. However, a 100 % score for a specific attribute may take some parts from lower and upper attributes to some degrees. It is scored as 100 % as 3, 40 % as 2 and % 40 as 4. This may be considered as an error modification.

The membership degrees were determined by the expert group. The membership grading matrices can be seen in Appendix- II & III. The parameters and interval attributes which are more difficult to judge and distinguish from others have more membership degrees in adjacent attributes.

iii) The Assessment fuzzy matrix ***(AF)*** was obtained by taking product of input matrices (*I*) with Rating fuzzy matrix (R*F*) of the parameter, expressed in **Equation 5.4**

$$\mathbf{AF_j = I_j \; X \; RF_j \quad (j = 1 \text{ to } 25 \text{ and } 1\text{-}23 \text{ respectively})} \qquad \mathbf{(5.4)}$$

Where, j is the row number of the fuzzy assessment matrices. The membership degree matrix ***(MD)*** was obtained by multiplying relative weight of parameters **(w_r)** with assessment fuzzy matrix ***(AF)*** and summing the columns resulting in a one row matrix;

Where, j is the row number of the fuzzy assessment matrices. The membership degree matrix (*MD*) was obtained by multiplying weight of parameters **(w_r)** with assessment fuzzy matrix ***(FA)*** mentioned in **Equation 5.5**. Summing the resulting in a one row matrix; known as Membership degree matrix.

$$MD = w_r * AF \tag{5.5}$$

The Final membership degree matrix for risk index assessment for both types of project is shown in Table 5.11 (a) & (b).

Table 5.10(a): construction stage fuzzy assessment matrix

Risk Index assessment table using fuzzy logic for Constructional phase small hydro power project																					
Assessment Parameters	(Relative weights)(w_r)(%)	Score	Input Matrix(I)					AF=I * RF	Assessment Fuzzy Matrix(AF)					MD= w_r * AF	Membership Degree Matrix (MD)				
			1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
Delay from Suppliers	4.30%	4	0	0	0	1	0		0	0	0.3	1	0.4		0.0000	0.0000	0.0129	0.0430	0.0172
Approval	4.89%	4	0	0	0	1	0		0	0.5	1	0.5	0		0.0000	0.0000	0.0489	0.0245	0.0000
Fund Blockage	3.53%	4	0	0	0	1	0		0	0	0.2	1	0.3		0.0000	0.0000	0.0071	0.0353	0.0106
Clearance	2.63%	4	0	0	0	1	0		0	0	0.2	1	0.3		0.0000	0.0000	0.0053	0.0263	0.0079
Relocation	4.85%	4	0	0	0	1	0		0	0	0.4	1	0		0.0000	0.0000	0.0194	0.0485	0.0000
Noise Pollution	3.60%	4	0	0	0	1	0		0	0	0.2	1	0.2		0.0000	0.0000	0.0072	0.0360	0.0072
Water Quality	1.58%	4	0	0	0	1	0		0	0	0.3	1	0.4		0.0000	0.0000	0.0047	0.0158	0.0063
Employment	1.58%	3	0	0	1	0	0		0	0	1	0.2	0		0.0000	0.0000	0.0158	0.0032	0.0000
Flora fauna	4.81%	2	0	1	0	0	0		0	1	0	0	0		0.0000	0.0481	0.0000	0.0000	0.0000
Financing Resources	4.52%	4	0	0	0	1	0		0	0	0.2	1	0.3		0.0000	0.0000	0.0090	0.0452	0.0136
Interest Rate	4.41%	2	0	1	0	0	0		0	1	0.4	0	0		0.0000	0.0441	0.0176	0.0000	0.0000
Tax Rate	3.84%	3	0	0	1	0	0		0.3	1	0.4	0	0		0.0115	0.0000	0.0154	0.0000	0.0000
Inflation	4.81%	3	0	0	1	0	0		0	0.5	1	0.5	0		0.0000	0.0000	0.0481	0.0240	0.0000
Climate	4.54%	5	0	0	0	0	1		0	0	0.3	1	0.4		0.0000	0.0000	0.0136	0.0454	0.0182
River Flow	5.00%	4	0	0	0	1	0		0	0	0.5	1	0.5		0.0000	0.0000	0.0250	0.0500	0.0250
Soil Erosion	5.00%	4	0	0	0	1	0		0	0	0.4	1	0		0.0000	0.0000	0.0200	0.0500	0.0000
Precipitation	5.36%	3	0	0	1	0	0		0	0	1	0.4	0		0.0000	0.0000	0.0536	0.0214	0.0000
Construction Schedule	3.75%	4	0	0	0	1	0		0	0	0.3	1	0.3		0.0000	0.0000	0.0113	0.0375	0.0113
Construction Budget	2.46%	5	0	0	0	0	1		0	0	0.3	1	0.3		0.0000	0.0000	0.0074	0.0246	0.0074
Machinery	5.44%	2	0	1	0	0	0		0	1	0.2	0	0		0.0000	0.0544	0.0109	0.0000	0.0000
Breakdown Technical	3.20%	2	0	1	0	0	0		0.2	1	0.2	0	0		0.0064	0.0320	0.0064	0.0000	0.0000
Regulatory	5.07%	5	0	0	0	0	1		0	0	0	0.2	1		0.0000	0.0000	0.0000	0.0101	0.0507
Modeling Techniques	4.65%	3	0	0	1	0	0		0	0.5	1	0.5	0		0.0000	0.0000	0.0465	0.0233	0.0000
PPP (Public Private Partnership)	3.20%	4	0	0	0	1	0		0	0	0.4	1	0.2		0.0000	0.0000	0.0128	0.0320	0.0064
Terrorism	2.94%	2	0	1	0	0	0		1	0.2	0	0	0		0.0294	0.0294	0.0000	0.0000	0.0000
									Risk Index (RI) (Construction)						0.0015	0.0091	0.0187	0.0250	0.0078
															0.0053	0.0139	0.0218	0.0164	0.0574
															A12	A23	A34	A45	AT
															2.8582				

Risk Index assessment table using fuzzy logic for operational stage small hydro power project																			
Assessment Parameters	% Relative importance	Score	Input Matrix(I)						Assessment Fuzzy Matrix(AF)						Membership Degree Matrix (MD)				
									1	2	3	4	5		1	2	3	4	5
Financing Resources	5.24%	3	0	0	1	0	0		0	0.3	1	0.2	0		0.0000	0.0157	0.0524	0.0105	0.0000
Flora fauna	3.85%	2	0	0	0	1	0		0	1	0.2	0	0		0.0000	0.0385	0.0077	0.0000	0.0000
Tourist Attraction	1.69%	2	0	1	0	1	0		0	1	0	0	0		0.0000	0.0169	0.0000	0.0000	0.0000
Interest Rate	4.84%	4	0	0	0	1	0		0	0	0	0.2	1		0.0000	0.0000	0.0000	0.0097	0.0484
Tax Rate	4.72%	4	0	0	0	1	0	AF=I * RF	0	0	0.2	1	0.4		0.0000	0.0000	0.0094	0.0472	0.0189
Inflation	4.11%	4	0	0	0	1	0		0	0	0	0.2	1	MD= wr* AF	0.0000	0.0000	0.0000	0.0082	0.0411
Climate	5.14%	5	0	0	0	0	5		0	0	0	0	1		0.0000	0.0000	0.0000	0.0000	0.0514
Noise Pollution	4.86%	1	1	0	0	0	0		1	0.2	0	0	0		0.0486	0.0097	0.0000	0.0000	0.0000
Water Quality	5.36%	2	0	1	0	0	0		0	1	0	0	0		0.0000	0.0536	0.0000	0.0000	0.0000
River Flow	5.36%	4	0	0	0	1	0		0	0	0	1	0		0.0000	0.0000	0.0000	0.0536	0.0000
Soil Erosion	5.73%	1	1	0	0	0	0		1	0	0	0	0		0.0573	0.0000	0.0000	0.0000	0.0000
Precipitation	3.43%	4	0	0	0	1	0		0	0	0.4	1	0		0.0000	0.0000	0.0137	0.0343	0.0000
Clearances	5.43%	1	1	0	0	0	0		1	0	0	0	0		0.0543	0.0000	0.0000	0.0000	0.0000
Capital cost	3.15%	2	0	1	0	0	0		0	1	0.3	0	0		0.0000	0.0315	0.0094	0.0000	0.0000

Machinery	3.95%	4	0	0	0	1	0		0	0	0.2	1	0		0.0000	0.0000	0.0079	0.0395	0.0000
Breakdown technical	5.14%	4	0	0	0	1	0		0	0	0.5	1	0.5		0.0000	0.0000	0.0257	0.0514	0.0257
Operational & Maintenance	2.80%	4	0	0	0	1	0		0	0	0.4	1	0		0.0000	0.0000	0.0112	0.0280	0.0000
Regulatory	2.33%	5	0	0	0	0	1		0	0	0	0.2	1		0.0000	0.0000	0.0000	0.0047	0.0233
Electricity Price	5.83%	5	0	0	0	0	1		0	0	0	0.2	1		0.0000	0.0000	0.0000	0.0117	0.0583
Evaluation Techniques	5.57%	2	0	1	0	0	0		0	1	0.3	0	0		0.0000	0.0557	0.0167	0.0000	0.0000
Generation	3.34%	5	0	0	0	0	1		0	0	0	0	1		0.0000	0.0000	0.0000	0.0000	0.0334
(PPP)	4.72%	3	0	0	1	0	0		0	0	0.3	1	0.3		0.0000	0.0000	0.0142	0.0472	0.0142
Terrorism	3.43%	1	1	0	0	0	0		1	0.2	0	0	0		0.0343	0.0069	0.0000	0.0000	0.0000
															0.0098	0.0103	0.0078	0.0156	0.0146
									Risk Index (RI)(Operational)						0.0100	0.0090	0.0117	0.0151	0.0459
															A12	A23	A34	A45	AT
															2.6961				

Table 5.10 (b): Operational stage fuzzy assessment matrix

Membership degrees are final assessment matrix of attributes (from 1 to 5) for a specific project type. The membership degree of attributes for a particular project category can be plotted in attributes vs. membership degree graph and simultaneously weights for each attribute is also computed which is plotted between weight vs attributes graph. Weighted average vs attribute graph for construction and operation projects are shown in **fig. 5.10**. Similarly Membership degree for constructional & operational stage small hydro power project can be seen in **Fig. 5.11.**

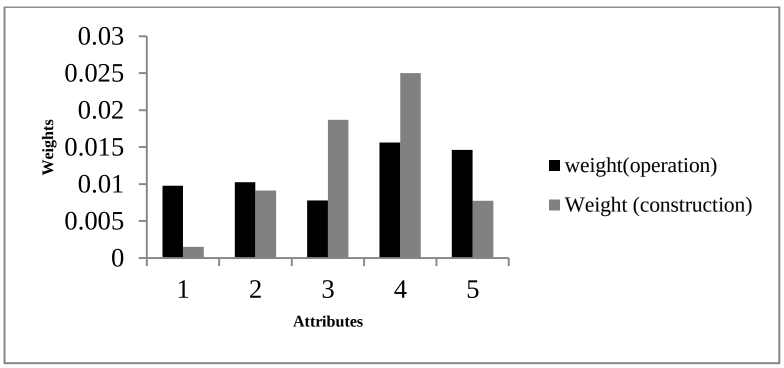


Figure 5.11: Weights Assigned As per Fuzzy Risk assessment Matrix (construction& operation stage)

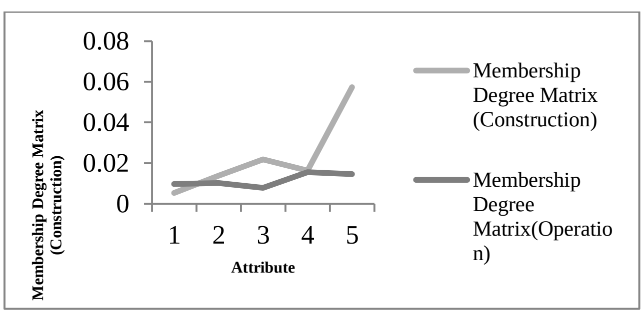


Figure 5.12: Fuzzy Membership Matrix Histogram for construction & Operation stage

A risk index computed using decision parameter computation was agreed upon from several scenarios considering membership degree versus attributes curves and formulation of Risk Index (RI) was given as per Equation 5.6.

$$RI = \frac{1 * A_{12} + 2 * A_{23} + 3 * A_{34} + 4 * A_{45}}{A_T} \qquad \textbf{(5.6)}$$

Where the area under the curve between the attributes i and j is named $\mathbf{A_{ij}}$ with: **i =1, 2, 3, 4** and **j = 2, 3, 4, 5.** the total area under the curve is $\mathbf{A_T}$. This enabled a Risk Index (***RI***) value to be calculated, establishing a **5** grade evaluation system: Low risk having **RI** values less than 0.6, medium risk between 0.6 and 1.9; High risk, between 1.9 and 3.2; very high risk, between 3.2 and 4.4; extreme risk 4.4 and above. The risk scale index represents the minimum and maximum values calculated by Eq. (5.6).

5.15 Classification of Projects

A Risk Index computation was agreed upon from several scenarios considering membership degree versus attributes curves and formulation of Risk Index (RI) and was given as (Ergin et al, 2003) The higher the RI value – the Higher the risk value

Risk Index (RI) values for 4 different projects from different phases can be seen in Table 5.11 considering the public surveys from Pathri, Mohammadpur, kaldigad, Asiganga 1 small hydro power projects.

CLASS 1: Extreme risk; it is not manageable risk cannot be transferred; having RI value above 4.4.

CLASS 2: very High Risk; risk is very high the risk is transferred using some policy implications, having RI value between 3.2 and 4.4

CLASS 3: Natural, average projects having high risk with possibility of managing probability and severity of risk factors having RI value between 1.9 and 3.2

CLASS 4: Mainly moderate risk, projects, having RI value between 0.6 and 1.9

CLASS 5: nominal low side, low risk with almost no impact having RI values between 0-0.6

Project Name	Project Phase	Risk Index	Class of risk
Pathri	**Operational**	**2.6529**	**High**
Mohammadpur	**Operational**	**3.034**	**High**
Kaldigad	**Construction**	**2.6572**	**High**
Asiganga	**Construction**	**2.4578**	**High**

Table 5.11: Risk Index and risk category based on risk assessment

5.16 Data interpretation

The Attribute values ranging from 1 to 5 signify the rating value of the risk assessment. As visually seen in weighted averages vs. attributes histograms, high weighted average on attributes (e.g. Attributes 4) reflects a high risk (high rating) value. Conversely, a high weighted average value on attributes (e.g. Attributes 1 or 2) reflects a low risk (low rating) value.

In Figure 6.3 Weighted Averages Histogram for construction stage hydro power project risk parameters it gets the highest value for attribute four and for operational stage it gets the highest value for between attribute four and five.

The graphs of membership degrees for a stage give the overall results of the risk assessment over the attributes. Interpretations of these graphs may be based on the skew of the curve where a curve skew to RHS reflects high risk value and conversely a curve skew to LHS reflects a low risk value. Here in figure 6.4 for construction stage power projects the curve is very much skewed to right hand side so it is tending to high risk. Similarly operation stage curve shows it is rightly skewed so it is also moving towards high risk.

After seeing the Risk index value the construction project risk index comes out to be 2.8582 which shows that project has high risk whereas In the case of operation power projects the risk index is 2.6961 which is also in the range of High risk.

5.17 Validation of fuzzy logic analysis

The influence of fuzzy grading matrix on result is below 5% and it has very low impact on the calculation risk index value. However the input matrix and weights of the parameters have a considerable influence on the calculation of risk index value. The sensitivity analysis has been done considering different scenarios as follows i) changing response scale of questionnaire from 5 to 4; ii) changing method for fuzzy logic calculation from triangular to trapezoid; iii) considering separately probability and severity scenarios for power project as shown in table 5.12 . In each scenario the risk index value changes from the original value with in the range of 10% to 15%. But the risk range remains the same; study signifies the result on significance scale of 5%.

Stage/operational	**Risk**	**Response Scale**			
Method		**1 to 5**	**Risk Type**	**1 to 4**	**Risk Type**
Centroid	Risk Probability	2.578	High	2.05	High
	Risk Severity	2.73	High	2.19	High
	Pro*Severity	2.652912	High	2.118844024	High
Trapezoid	Risk Probability	2.89	High	2	Moderate
	Risk Severity	2.98	High	2.149	High
	Pro*Severity	2.934655	High	2.078338279	High

Table 5.12: Scenarios of Risk with changing Fuzzy theory & Response scale

5.17.1 Out of box test

In order to validate the results of fuzzy logic the out of box test is performed. This test validates the model if out of total 119 responses if randomly supposes few respondents selected as sometime 60, 30 90 and then the same risk index is calculated for two hydro power projects Pathri & Mohammadpur small hydro power projects mentioned in table 5.13.

Power project	Respondents	Risk Index	Variation from base	Risk Type
Pathri	30	2.53352	4.50%	**High**
	60	2.73912	3.25%	**High**
	90	2.82481	6.48%	**High**
	119	2.6529	Base	**High**
Mohammadpur	30	2.98394	1.65%	**High**
	60	2.80463	7.56%	**High**
	90	3.16901	4.45%	**High**
	119	3.034	Base	**High**

Table 5.13: Out of box test on two operational stage SHP's

The interpretation of table 5.13 shows either performing the test taking out of box sample the risk is variation in pathri hydro power project with in the limit of 7% and in mohammadpur this variation occurs with 8% that but the type of risk is remains high risk only as the result estimated is proving its validity within 7 to 8% of accuracy.

5.18 Discussion

Sensitivity analysis is a tool for judging one risk parameter impact on outcome, as mentioned in paragraph 5.1 the impact of capital cost, price of electricity and cost of capital on NPV is visible but not all the risk factors are considered all together.one major thing associated with sensitivity analysis is that it is not treating any non-parametric variables MCS which is a stochastic tool and it assesses the impact of all the parametric risk factors together on outcome as NPV, IRR & PI. All the parameters that are significant to the outcome of the project thus the variables that have a negative impact on the NPV and IRR. Still, this kind of analysis is taking in consideration a change of only one variable, while taking all the other variables constant and cannot compute the change of some variables at a time. Also this analysis is ignoring any possible correlation between several risky variables. The need of fuzzy logic arises with the limitation occurring due to MCS method. The subjectivity is not avoided using MCS so the fuzzy logic which incorporates both qualitative and quantitative risk variables use for risk assessment. The reliability of this method even checked using out of box method. The operation stage risk is assessed using MCS but construction stage is avoided as less availability of quantitative risk variables so this shortcoming is covered using fuzzy logic method as many types of risk variables are covered under this study.

5.19 Conclusion

Risks associated with operational & construction stage SHP investments are identified. These risk items serve as a checklist that cover possible risks associated with SHP investments in operational & Construction phase. Risk managers or investment decision makers can be informed and be able to recognize the risks associated with SHP investments. Investment decision makers can predict the overall risk of the project investment entire as well as phase wise before start the investment. An overall risk index can be used as early indicators of project problems or potential difficulties. Evaluators can keep track to evaluate the current risk level with the progress of investments. Moreover, it was assumed that if one project in the same phase if it is more risky so all the projects have similar risk. This myth is demolished with the help of this research where in the same stage two power projects in same geographical area contains different certainties reason behind this is variables considered for risk assessment varies in their relative importance in terms of severity and probability. The greatest advantage of the applied method is that it quantifies all type of parametric and non-parametric risk factors with less computational complexity. Similarly the relative importance of all the risk factors was also identified. So even investors they get the idea that which factor is could be more problematic area as compare to others using tornado chart.

The risk managers can apply risk mitigation techniques based on those factors. Finally risk assessment was done computing Risk index values which show the phase specific risk which is not performed in this area so far. This estimation helps investors about the possibilities of risks in concerned projects. When dealing with the risk analysis problems, the predominance of new method has been showed: easier and more useful. Estimated Risk index further used for creating a new business model of investment is proposed to investors with less

risk. Risk distribution for investors performed using Optimum portfolio and business models are discussed in chapter 6 which concludes this research

CHAPTER 6

RISK DISTRIBUTION USING PORTFOLIO OPTIMIZATION & BUSINESS MODELS FOR INVESTOR IN SMALL HYDRO POWER PROJECTS OF UTTARAKHAND

6.0 Introduction

This chapter makes the previous chapters assessed risk useful for investors by applying the Nobel laureate's research in the area of portfolio theory, established by William Sharpe, Merton Miller and Harry Markowitz. This chapter helps investors of small hydro power project to distribute their investment in such proportion so that the return and risk tradeoff would generate. The two approaches work simultaneously to one using portfolio theory then by applying various business models to the assessed risk. This chapter concludes this research by providing support to investors for better investment decision making practices to choose among risky project or different business models with which they can either reduce the risk or share.

6.1 Risk Distribution

Once risks have been identified and quantified for an existing power project or various risk reduction alternatives, they are evaluated against tolerable risk guidelines, including the as low as reasonably practical (ALARP) principle in the case of risk reduction measures (S. A. Hosseini, 2011). These guidelines can serve a useful role in the development of the investment or business cases for addressing hydro power profit loss issues. However, power projects investment decisions should be made by those responsible for ensuring Small Hydro Power revenue and cost considerations after all the relevant factors have been appropriately assessed and weighed; they should not be the automatic result of applying a tolerable risk guideline to the outcomes of a risk analysis . (Approach, Assessment, Assessment, & Results, 1998)Thus risk assessment does not prescribe investment decisions. These decisions need to be made by the Small Hydro Power owner in conjunction with the regulator, if applicable, and other stakeholders. (Fleten et al., 2007)However, each party can expect to be in a better position to make informed decisions or to prioritize investment decision when they supplement traditional financial investment approaches with insights obtained from an appropriately conducted risk assessment.

6.1.1 Risk Control

From a business or management perspective, risk control (treatment) options can be grouped into the following categories (fig 6.1), although these are "not necessarily mutually exclusive or appropriate in all circumstances". (Chaurasiya et al., 2013). Significance or interpretation of various risk control measures are primarily “Avoid the risk” - this is a choice, which can be made before a hydro power project is built, or through decommissioning an existing project.(Heat & Nevertheless, 1993). Secondly “Reduce (prevent) the probability of occurrence” – typically through structural measures, or project safety management activities such as monitoring and surveillance, and periodic inspections. (Salling, 2005a). Further “Reduce (mitigate) the consequences” – for example, by non-structural approaches such as effective early warning systems or by relocating exposed populations at risk. (Tongtao & Cunbin, 2014a) then “Transfer the risk” – for example, by contractual arrangements, insurance or sale and lastly “Retain (accept) the risk” - “after risks have been reduced or transferred, residual risks are retained and may require risk financing (e.g. insurance).”

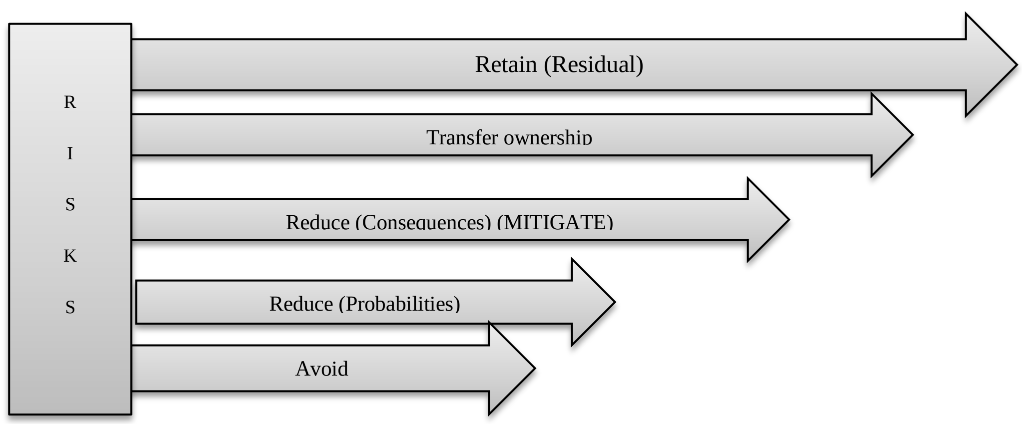


Figure 6.1: Risk Control Zones ALARP Model

6.2 Portfolio Selection Theory

There are two schools of thoughts on investment analysis, fundamental and technical. In terms of choosing equity investments, meaning which project to invest or not, it is intuitive for the project past performance as well as future business plans to be considered. In order to do so, analyses on the projects financial statements and accounting or financial records need to be conducted, and the intrinsic value of the company can be estimated and compared with its current stock price. A decision on whether to purchase or sell shares of this company can then be made. This is the fundamentalist approach of choosing investments. As it can be seen, most of the analyses focus on the business side.

Modern Portfolio Theory is Harry Markowitz's theory of portfolio choice in an uncertain future. In this theory, he quantified the difference between the risk of portfolio assets taken individually and the overall risk of the portfolio. The theory offers a solution to the problem of portfolio choice for a risk-averse investor: the optimal portfolios, from the rational investor's point of view, are defined as those that have the lowest risk for a given return. (Desai, V., 2005) These portfolios are said to be mean-variance efficient. This theory is the foundation of our Portfolio Selection discussion.

Basic concept of this theory identified that the portfolio risk came from the covariance of the assets that made up the portfolio,(Cheung & Kaymak, 2008).The contribution of an asset to the portfolio return variance is thus measured by the covariance between the assets return and the portfolio's return rather than by the variance (risk) of the individual asset itself. This theory also established the risk of a portfolio is lower than the average of the risks of each asset taken individually and gave quantitative evidence of the contribution of diversification, (Parandin et al., 2013)

In Small hydro power project due to high front end capital cost once projects are chosen and portfolio formed, it needs to be managed in order to maximize the benefits (minimize the losses). This gives rise to the idea of portfolio management. Portfolio management consists of constructing portfolios with proper allocation of assets and then making them evolve in order to reach the return objectives defined by the investor, The investment methods used to reach the objectives range from quantitative investment, which originated from modern portfolio theory, to more traditional methods of financial analysis as we previously defined. In this research, we introduce and demonstrate methods of managing portfolios using modern portfolio theory. In this chapter, researcher applies Markowitz's theory to small hydro power projects selection and assesses the observed results.

6.3 Optimum Portfolio Selection in SHP (Two Risky Projects)

The process of constructing an investor portfolio can be viewed as a sequence of two steps:

(1) Selecting the composition of individuals portfolio of risky alternatives in this case operational or construction phases, two operational projects or two construction phase project and;

(2) Deciding how much to invest in risky project.

An investor decide to allocate investment funds between the two projects after knowing its expected return and degree of risk (Tongtao & Cunbin, 2014b), so a fundamental part of the capital allocation problem is to characterize the risk–return trade-off for this portfolio. The theme of portfolio allows to quantify investors' personal trade-offs between portfolio risk and expected return using weighting function, (Salling, 2005b).

Portfolios of two alternatives (operational projects Pathri & Mohammadpur) are analyzed through estimation of expected return and risk of alternatives, where risk of two alternatives is assessed using fuzzy logic and mote carlo simulation discussed in previous section.

Returns of two alternatives are considered using DPR of projects from each alternative. Here in this case the two operational stage projects Mohammadpur and Pathri are considered. Subsequently the expected return and risk are considered using equation 6.1 & 6.2.

The risk and return of two projects are shown in table 6.1. A pathri operational project denoted using Pat, and mohammadpur project using mod, for computation of portfolio expected return and risk weight of each alternative is required. A proportion denoted by $\boldsymbol{\omega_{pat}}$ is invested in the pathri and the remainder for Mohammadpur, **1-** $\boldsymbol{\omega_{pat}}$, Symbolized $\boldsymbol{\omega_{mod}}$. The rate of return on this portfolio, $\mathbf{R_p}$, will be computed using equation 6.1.

$$R_p = \omega_{pat} R_{pat} + \omega_{mod} R_{mod} \quad \textbf{(6.1)}$$

Where $\mathbf{R_{pat}}$ is the rate of return on pathri SHP and R_{mod} *is* the rate of return on the Mohammadpur project.

The variance of the two-alternative portfolio is computed using equation 6.2.

$$\sigma_p{}^2 = \omega^2{}_{pat} \ \ \sigma^2{}_{pat} + \omega^2{}_{mod} \ \ \sigma^2{}_{mod} + 2\omega_{pat}\omega_{mod}cov(R_{pat}, R_{mod}) \quad \textbf{(6.2)}$$

$$\sigma_p{}^2 = \omega^2{}_{pat} \ \ \sigma^2{}_{pat} + \omega^2{}_{mod} \ \ \sigma^2{}_{mod} + 2\omega_{pat}\omega_{mod}\sigma_{mod}\sigma_{pat}cor(R_{pat}, R_{mod}) \quad \textbf{(6.3)}$$

$\boldsymbol{\sigma_{mod}}$ **&** $\boldsymbol{\sigma_{pat}}$ are standard deviation or risk with projects mohammadpur and pathri respectively, interchangeably the other form of equation for calculating portfolio risk is equation 6.3 where in spite of using covariance correlation is used. Though in all above mentioned equations weights are required so randomly weights values are varied between 0 to 100% for generating optimum portfolio. The optimum portfolio is the need for investors so minimum variance portfolio is created via estimation of optimum weights using equation 6.4 & 6.5.

$$\omega_{Mod} = \frac{\sigma_{pat}}{\sigma_{pat} + \sigma_{mod}} \quad \textbf{(6.4)}$$

$$\omega_{pat} = 1 - \omega_{mod} \quad \textbf{(6.5)}$$

Optimum portfolio thus created using above estimated weights at different correlation values varies between +1 to -1.

6.4. Portfolio Selection based on assessed risks

If considering different risk and return values, the portfolio has variations, so different portfolio's consisting of numerous combination of weights, combining all possibility curve arrives.

Having realization for the same amount of risk, there is always possibility of higher yield returns in some other portfolio. These portfolios are called “efficient portfolios” and they lie on the so-called “efficient frontier”. Intuitively, these portfolios are more desirable. In this picture, the efficient frontier corresponds to the top half portion of the portfolio possibilities area. Here risk assessed for pathri & Mohammadpur power projects from chapter 5 using Monte Carlo Simulation & Fuzzy logic approach is summarized in table 71.where the expected returns of the projects are directly taken from DPR and risk used considering chapter 5.

Pathri Small Hydro Power project		Mohammadpur Small Hydro Power project	
Expected Return	18.83%	Expected Return	11.13%
Risk Assessed (Monte Carlo Simulation)	65.82%	Risk Assessed (Monte Carlo Simulation)	51.13%
Risk Index assessed (Fuzzy Logic Approach)	53.06%	Risk Assessed (Fuzzy Logic Approach)	60.08%

Table 6.1: Summary sheet for optimum Portfolio Preparation

6.4.1 Determination of optimum Investor’s portfolio

To achieve optimal diversification, a mathematical portfolio selection model was developed by Markowitz. This model finds the composition of all the portfolios that correspond to the efficiency criterion defined for a given set of securities, and construct the corresponding efficient frontier. Simply put, the portfolio selection model involves minimizing the variance (risk) for a given return or maximizing the return for a given risk, which can be written as follows:

In order to create an optimum portfolio, optimum weights for both stages are estimated using Equation 6.4 & 6.5. Capital investment proportion for Mohammadpur project computed as 44.05% using risk assessed based on using Monte Carlo simulation assessed risk and for pathri hydro power project the proportion comes out to as 55.95%. However the proportion for capital investment for pathri Hydro power project based on Fuzzy logic approach assessed risk is 46.9% and for mohammadpur it is 53.1%. These weights are varied randomly between 0 to 100% for both the stages shown in table 6.2 (a) & (b). Randomly 11 different scenarios are generated using different proportions of weight moves between 0to 100%. Scenario 7 shows the optimum portfolio corresponding to above estimated weights in both the tables.

Scenario's	Wpat	Wmod	E(Rp)	σpcor1	σpcor0.75	σpcor0.5	σpcor0.25	σpcor0	σpcor-1
scenario 1	1	0	18.83%	65.92%	65.92%	65.92%	65.92%	65.92%	65.92%
scenario 2	0.9	0.1	18.06%	64.52%	59.55%	62.09%	60.83%	59.55%	54.14%
scenario 3	0.8	0.2	17.29%	63.12%	53.75%	58.62%	56.24%	53.75%	42.35%
scenario 4	0.7	0.3	16.52%	61.72%	48.70%	55.60%	52.26%	48.70%	30.57%
scenario 5	0.6	0.4	15.75%	60.32%	44.67%	53.08%	49.06%	44.67%	18.78%
scenario 6	0.5	0.5	14.98%	58.93%	41.96%	51.15%	46.78%	41.96%	7.00%
optimum Scenario	0.514492754	0.4854	14.52%	58.09%	41.08%	50.31%	45.93%	41.08%	0.00%
scenario 7	0.4	0.6	14.21%	57.53%	40.82%	49.88%	45.57%	40.82%	4.79%
scenario 8	0.3	0.7	13.44%	56.13%	41.38%	49.31%	45.52%	41.38%	16.58%
scenario 9	0.2	0.8	12.67%	54.73%	43.59%	49.47%	46.62%	43.59%	28.36%
scenario 10	0.1	0.9	11.90%	53.33%	47.20%	50.36%	48.80%	47.20%	40.15%
scenario 11	0	1	11.13%	51.93%	51.93%	51.93%	51.93%	51.93%	51.93%

Table 6.2 (a): optimum portfolio scenario's for investors using assessed risk based on MCS

Scenario's	Wpat	Wmod	E(Rp)	σpcor1	σpcor0.75	σpcor0.5	σpcor0.25	σpcor0	σpcor-1
scenario 1	1	0	18.83%	53.06%	53.06%	53.06%	53.06%	53.06%	53.06%
scenario 2	0.9	0.1	18.06%	53.76%	48.13%	51.02%	49.60%	48.13%	41.75%
scenario 3	0.8	0.2	17.29%	54.46%	44.12%	49.56%	46.92%	44.12%	30.43%
scenario 4	0.7	0.3	16.52%	55.17%	41.28%	48.72%	45.16%	41.28%	19.12%
scenario 5	0.6	0.4	15.75%	55.87%	39.89%	48.54%	44.43%	39.89%	7.80%
scenario 6	0.5	0.5	14.98%	56.57%	40.08%	49.02%	44.77%	40.08%	3.51%
optimum Scenario	0.514492754	0.4854	15.22%	56.35%	39.85%	48.80%	44.55%	39.85%	0.00%
scenario 7	0.4	0.6	14.21%	57.27%	41.83%	50.15%	46.18%	41.83%	14.82%
scenario 8	0.3	0.7	13.44%	57.97%	44.97%	51.88%	48.55%	44.97%	26.14%
scenario 9	0.2	0.8	12.67%	58.68%	49.22%	54.16%	51.75%	49.22%	37.45%
scenario 10	0.1	0.9	11.90%	59.38%	54.33%	56.91%	55.64%	54.33%	48.77%
scenario 11	0	1	11.13%	60.08%	60.08%	60.08%	60.08%	60.08%	60.08%

Table 6:2(b): optimum portfolio scenario's for investors using assessed risk based on Fuzzy Logic

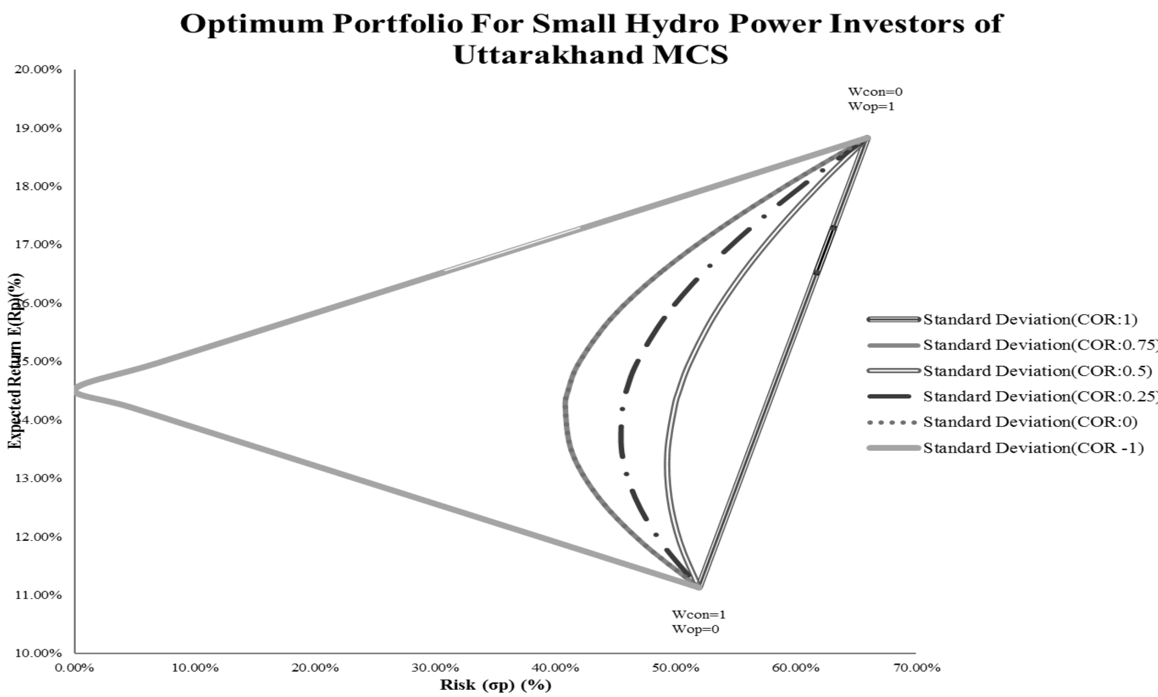


Figure 6.2 (a): Optimum portfolio for investor's using MCS based assessed risk

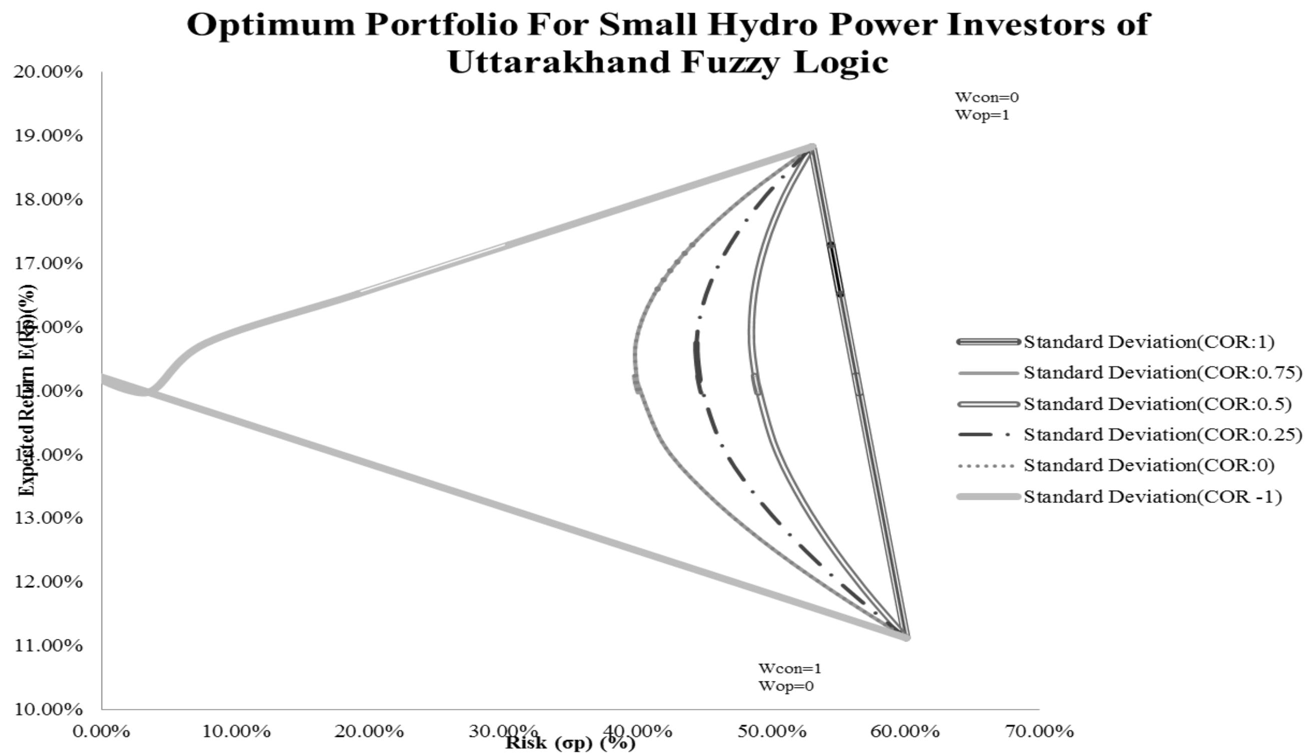


Figure 6.2 (b): Optimum portfolio for investor's using Fuzzy based assessed risk

The expected return of optimum portfolio comes out as 14.52% using risk based on Monte Carlo Simulation and 15.22% which is enhanced using Fuzzy logic approach. whereas risk value varies between 0 to 58.09% with correlation values -1 and +1 respectively in the case of risk assed comes from Monte Carlo simulation Shown in table 6.2(a) and the optimum risk varies between 0-56.35% using assessed risk based on Fuzzy logic approach which is again reduced shown in Fig 6.2(b). Although getting 0% risk is a speculation but with reference to each portfolio minimum risk is achieved (Figure 6.1 a & b). While checking the significance of estimated weights several other scenarios are created via changing risk and return values of projects, the variation is within the range of 5% which is not so significant, hence these weights are considered to be the optimum distribution of capital investment by investors between alternatives.

6.4.2 Scenario Analysis for optimum Portfolio Selection (Model Testing)

Scenario analysis gives model testing involves estimating how the portfolio would have performed under some of the most extreme moves seen in the same area. To test the impact of extreme movements in the small hydro power sector investment, a project might set the percentage changes in all variables, If this is considered to be too extreme, the highest and lowest.

These scenarios can also be artificially generated. Stress testing can be considered as a way of taking into account extreme events that do occur from time to time but that are virtually impossible according to the probability distributions assumed for variables thus with this stress testing the result would come out as under 95% significance level and risk and return values are not varied more than 6% from base value, so validity of this stress testing is confirmed.

6.5 Business Models in Hydro power investment

Privatization is the process of reducing government role or increasing private sector role in production of goods and services in line with public interest and market demand.

"Privatization is the transfer of ownership of assets from the public to private sector or application of private capital to fund investment in the port facilities, equipment's and systems". Privatization can be classified into two categories (World Bank, 2001)

Comprehensive privatization: privatization in which successor company takes the ownership of hydro power infrastructures including land within project domain, superstructures and equipment's, and responsible for all hydro power activities.

Partial privatization: privatization where a part of project activities usually operational activities transferred to private sector with the right of investment in project superstructures, equipment and somewhat in operational infrastructures.

The investors of hydro power project as mentioned in chapter 1 could be either public or private sector. Though in large infrastructure projects, due to huge capital requirement it is not feasible with public or private investor to continue and maintain it properly so the concept of public private partnership comes in a picture. Any arrangement made between a state authority and a private partner to perform functions within the mandate of the state authority, and involving different combinations of design, construction, operations and finance is termed as Ireland's PPP model. The PPP is sometimes referred to as a joint venture in which a government service or private business venture is funded and operated through a partnership of government and one or more private sector companies.

Thus, the PPP combines the development of private sector capital and sometimes, public sector capital to improve public services or the management of public sector assets (Michael, 2001). The PPP may encompass the whole spectrum of approaches from private participation through the contracting out of services and revenue sharing partnership arrangement to pure non-recourse project finance, while sometime it may include only a narrow range of project type.

According to Ministry of Finance Government of India the PPP project means a project based on a contract or concession agreement, between Government or statutory entity on the one side and a private sector company on the other side, for delivering infrastructure service on payment of user charges. This is a narrower definition as compared to world best practices where the private sector participation in any form of concession agreement, divestiture of the public sector, Greenfield projects and management and lease contract are considered as PPP. The Planning Commission of India has defined the PPP in a generic term as "the PPP is a mode of implementing government programmes/schemes in partnership with the private sector. It provides an opportunity for private sector participation in financing, designing, construction, operation and maintenance of public sector programme and projects". In addition, Greenfield investment in the infrastructure development has also been given more encouragement in India. The PPP has two important characteristics:

1) There is an emphasis on service provision as well as investment by the private sector.
2) Significant risk is transferred from the Government to the private sector.

Private- public partnership falls into partial privatization category, within partial privatization, a number of alternative modes have been existed. These alternative modes are as Management contract; Leasehold agreement; Concession agreement

(BOT, BOOT etc.) & · Joint venture. Though all has its own significance the major alignment in this thesis is on concession agreement.

6.6 Concession Agreement

Concession agreement is the contract by which private sector takes over the management of power project activities with the obligation of investment in construction and rehabilitation of hydro power basic and operational infrastructures, superstructures and equipment for specific period after which hydro power facilities will be conveyed to Hydro power authority. Concession agreement is a temporary privatization under which concessionaire creates, operates and delivers public services. Therefore, the primary objective of concession agreement is to reduce the national deficit and promote private financing of public infrastructures. It is also known as "Greenfield project"

"*Greenfield project: A private entity or a public-private joint venture builds and operates a new facilities for the period specified in the project contract. The facility may return to the public sector at the end of the concession period" (world Bank Website).*

There are different kinds of modes namely BOT (Build-Operate-Transfer), BOOT (Build-Own-Operate-Transfer), BROT (Build-Rehabilitate-Operate-Transfer), BTO (Build-Transfer-Operate), ROT (Rehabilitate-Operate-Transfer), EOT (Equip- Operate-Transfer) existed under the concession agreement. BOT, BOOT and BTO are major arrangements of concession agreement. Under the concession agreement, private investors become the owner of power project facilities during the effective terms of concession period and at the expiration of concession period facilities are transferred to public authority or government.

a) BOT (Build-Operate-Transfer)

It is the common mode of concession agreement applied in most of the projects in the world. Private sector is assigned to right to build and operate the power project facilities (basic and operational infrastructure, superstructures and equipment) for specified (long) period afterwards facilities are transferred to power project authority. Under this arrangement, hydro power facilities never belong to (ownership) the private sector so at the expiration of concession agreement private sector is not able to receive compensation for the transfer of the facilities. After cessation of contract, hydro power authority can lease out the facilities or, grant other concession with different objects, or make management contract.

"A project based on the granting of a concession by a principal, usually a government, to a promoter, sometimes known as the concessionaire, who is responsible for the construction, financing, operation and maintenance of a facility over the term of the concession before finally transferring at no cost or at a predetermined price, a fully operational facility to the principal. During the concession period, the promoter owns and operates the facility and collects revenues in order to repay the financing and investment costs, maintains and operates the facility and makes a margin of profit

Under the BOT arrangement, private sector charges the power tariff and collects all project dues. Payment to hydro power authority can be fixed or revenue sharing basis. In some cases, private sector and hydro power authority agree to share the profit (after deducting fixed and other costs) in the form of a royalty or a percentage on the net income BOT scheme can be apply either to dam or to entire hydro power project. Typical example of BOT agreement

b) BOOT (Build-Own-Operate-Transfer)

BOOT is similar concept of the concession to BOT. Under the BOOT arrangement, land and facilities are conveyed to private operator. Private operator takes the ownership of entire hydro power project facilities during the term of contract period. At the end of the contract, facilities are transferred to port authority at agreed price. BOOT is different from BOT with regard to ownership of land and assets, and transfer of hydro power project facility at agreed price.

C) BTO (Build-Transfer-Operate)

Under this arrangement, private sector receives the right to build infrastructure facilities but he is required to transfer immediately all new power project to hydro power authority or government after completion of construction and then operates project on the contractual basis for specified period. The reason behind such arrangement is that private sector receives the loan from lenders on concession agreement to build the hydro power project. Here, concession agreement is collateral for securing loan. BTO is applied.

India has a huge installed power generation capacity of 1,43,061 MW (end-March 2008), of which the private sector projects constituted at 14.0 per cent only. Given the fiscal constraints, private participation in the power sector development has been considered essential for meeting this capacity addition and to meet the growing demand for power. However, there is no PPP model power project in the central sector and in the states also, it is very limited as the power projects have either been developed by the public sector or by the private sector as Independent Power Producers (IPP), Captive Power Plants (CPP) and Merchant Power Plants (MPP). Though the power sector reform has encouraged private power project, the response in this regard is not much encouraging. According to Power Ministry sources, about 7366 MW capacity (5 per cent of total installed capacity) consisting of 37 projects has been fully commissioned so far in the IPP segment. Five private power projects have been completed with a capacity of 718 MW and about 5776 MW capacity is under execution. There are about nine hydro power projects with an installed capacity of 30,825 MW have been cleared/appraised by the Central Electricity Authority (CEA), but there is no sign of their early execution. India has an estimated unutilized hydro power potential of more than 1,50,000 MW. Ultra Mega Power Projects with each having a capacity of minimum 4,000 MW through private sector funding have also been considered by the Government to augment the capacity addition to meet the power requirement in the country. However, there are certain issues that come in the way of private sector participation need attention to augment the private investment.

The initial response of the domestic and foreign investors to the private participation in the power sector was extremely encouraging. However, many projects have encountered unforeseen delays. There have been delays relating to finalization of power purchase agreements, guarantees and counter-guarantees, environmental clearances, matching transmission networks and legally enforceable contracts for fuel supplies. Continuous losses by State Electricity Boards (SEBs) arising both from inadequate tariff and from Aggregated Technical and Commercial losses of as high as 40 per cent discouraged the private investors in power generation as they faced insecurity of payment and hence expansion of private investment in this sector was constrained. In this regard, policy issues such as inability of SEBs and State Governments to provide acceptable payment security to the private power suppliers, delay in finalization of power purchase agreement (PPA), fuel supply agreement, fuel transportation agreement and problems in sourcing coal supply to thermal power stations need a relook to encourage private participation.

Focusing of small projects under private participation may be viable, bankable, and easily executable and above all, the gestation period will also be minimal. On the other hand, big projects like Dabhol, which encountered with many problems, have also been a discouraging factor for the private participation in mega projects. Reducing the risk is a better option than allocating it. Therefore, minor power projects in the private sector or on PPP basis should be encouraged. An important factor which discourages private participation is the reluctance of lenders to finance large IPPs.

Countries	**Business Model used**
Sri Lanka	BOT
Vietnam	BLT

India	BOT, BOOT
South Korea & Costa Rica	BTO
Denmark	BTO

Table 6.3: Globally Accepted Concession Agreement in HEP's

		Risk Distribution		Preferred Risk allocation
Business Model	**Total Risk**	**Private Sector**	**Public Sector**	
BOT(Build Operate transfer)	**100%**	**29.65%**	**70.35%**	**Largely to government**
BOOT (Build own operate transfer)	**100%**	**82.11%**	**17.89%**	**Solely to private sector**
BOO(Build own operate)	**100%**	**100%**		**Either could be the investors private or public sector**
BTO (Build transfer operate)	**100%**	**46.87%**	**56.10%**	**shared**
BROT (Build Rehabilitate Operate transfer)	**100%**	**55.13%**	**43.25%**	**shared**

Table 6.4: Risk sharing with different Concession Agreements of Public private partnership

Existing practices of India shows that public private partnership models are not applicable in small hydro power projects though there are few large hydro power projects are working in this direction. Based on analysis the different concession agreement mentioned in table 6.4 show that applicability of BROT & BTO model are good for risk distribution among public and private investors. The risk share almost equal, even the portfolio theory discussed in the next chapter gives appropriate distribution of investors in power projects. The distribution of private investors is only around 47% and in BROT agreement it is only 55% and the government risk is also 56% & 44% respectively which is better than BOO, BOOT, & BOT concession agreements.

6.7 Discussion

The portfolio theory is a bench mark for investors to take right decision using risk analysis in any of the above two methods either Monet Carlo or fuzzy logic. This theory even gives investors a holistic overview to invest simultaneously in two or more projects either from the same phase or different phase. Investors return and risks are optimized and better investment practices will be visible. This is an approach to catch more investors to show them real scenario with their investment. The transition from Monte Carlo to fuzzy logic approach applying on the same type of projects shows the enhancement in the value of return as well as reduction in the risk values which considered being the good practice. The concession agreements are also considered to be valuated using different business models and among those models BTO & BROT is preferred over others as it distribute or share risk almost equally among private and public investors.

6.8 Conclusion

Conclusion of this chapter has been concentrated on the Modern Portfolio theory and its foundations, the mean-variance model and the efficient frontier applied for investors of small hydro power project. The goal behind preparing an efficient and optimum portfolio for the investors of hydro power project to minimizes the risks of the investment and maximizes their return on that. Researcher hope to use the acquired knowledge on portfolio theory help investors to choose among different small hydro power projects and select the best one with estimated qualitative and quantitative risk analysis. Similarly using different concession agreements the investors can distribute their risk among private and public investors based on authority and power given to investors.

CHAPTER 7

SUMMARY CONCLUSION

7.0 Introduction

This chapter summaries the whole thesis and conclude with major findings, providing limitations of study and finally highlights future scope of work. This chapter presents concluder remark and creates a platform for other researchers to continue the work further in hydro power investment direction.

7.1 Findings

This section presents the major finding of the study which offers a big picture, for person who wants to take the summary of this work.

- Major Investment attributes of Risks in SHP's are technical, construction; financial; legal; business Environment & Socio Economic.
- Fuzzy logic approach major five construction stage risk factors identified as approvals, construction Budget, Machinery, and river flow and soil erosion. And in operation stage as machinery, breakdown, regulatory, electricity price and capital cost.

- The construction and operation stage risk index is estimated as 2.85 & 2.69 around 57.16% & 53.92% but risk index of operational phase SHP projects are higher as compare to operation phase SHP projects.
- The aggregate risk between constructions to operation stage is 2.789 around 55.97%.
- Optimum portfolio is created for investors as per risk assessed using Fuzzy Logic where using fuzzy logic approach the return increased to 15.5% and risk is also varies between 0-56.61%.
- A business model is suggested to investors for SHP's of Uttarakhand as those are BROT & BTO which distribute risk among public and private investors as in BROT the risk distribute in the proportion of 46.87% & 53.13% in private & public investors. Whereas in BTO this sharing is 53.93% & 43.07%.
- This thesis presents a big picture to investors, policy makers, and government of uttarakhand about small hydro power project risks, their impact and also aware investors about risk distribution methodology in risky projects.

7.2 Limitations of study

The major limitations the researcher comes across in this risk assessment analysis are as mentioned below:

- The current research has considered the broader dimension of risks in the assessment of climatic conditions causing seasonal variation and geographical factors owing to the vast track of Uttarakhand region. Though various subs (Variables) factors i.e. earthquakes and treamours etc. under the mentioned major and broader issues pertaining to risks are not directly considered and discussed, however fall under these larger issues of risk assessment and has been mentioned in the research. Since the climatic conditions and geographical factors play a pivotal role in evoking the sub variables such as earthquakes etc., these variables are resultant of the variants mentioned above in the broader needs a full length study because this area is yet to be explored and researched upon owing to sudden and swift transition in seasonal variation causing these sub variables which has already been discussed.

- Similarly, stay by the NGO's and civil societies, one of the major risk variables only mentioned in the category of clearances has not been discussed in detail as a full length study.
- This research is based on the study of 4 major projects, i.e. 2 operational and 2 constructions, a part of the three major geophysical variables Ganga, Yamuna and Bhagirathi, which perhaps is one of its limitations, as it fails to cover the entire three geophysical variables. However, the research does not fail to cover two out of the three geophysical variables Ganga & Yamuna basin in both operational & construction stages, but fails to cover the operational phase of Yamuna basin, which is 40% of the total. Above all, it should be understood that the risk pertaining to one basin may be easily aligned with the other two basins as well. Therefore, if some of the

risks assessed in the construction levels of Ganga & Yamuna basin bear points and ratio of commonality, it can be understood and postulated that there might be some points of commonality in the risk assessment at the operational level in the Yamuna Basin as well. As, a research is a standard frame which is put to analysis and test, so as to verify therefore, if there arouses any discrepancy in risk assessment of Ganga & Yamuna basin at operational level, which it may, it is left as a new and fresh area of research concern to be applied for future scope.

7.3 Future scope of Work

- This study may be further applied to Renovation & Modernization and preconstruction stages of SHP's of Uttarakhand.
- The scope of applying real option analysis to the risk assessment in the sector of hydro power may be further investigated.

7.4 Suggestions

- Hydro power investors should follow subjective risk assessment in order to avoid major investment risks.
- Investors can distribute their risks using portfolio theory and PPP model.

7.5 Contribution to literature

In the literature there are several studies considering risk analysis in construction projects (Zavadskas et al., 2010). However, risk analysis in renewable energy projects, especially for hydro- power plants, is very limited. In classical project risk analysis techniques, risk rating values are calculated by multiplying impact and probability values, but direct analysis of these linguistic factors is often neglected (Dikmen et al., 2007). Most existing risk analysis models, such as Monte Carlo simulation and tornado chart, are based on quantitative techniques, which require numerical data. Kangari and Riggs (1989) note that probabilistic models suffer from detailed quantitative information, which is not normally available in the real construction world. However, much of the information related to risk analysis is not numerical (Mustafa and Al-Bahar, 1991). Rather, this information is expressed as words or sentences in a natural language. These conceptual factors can be expressed in linguistic terms, so-called fuzzy information (Kucukali and Baris, 2010; Kucukali). Uncertainty factors such as ‘‘poor geology’’ or ‘‘unstable policy’’ fall into this category. In this section the major potential risks associated with investments in these SHP plants were identified according to a literature review (Carneiro and Ferreira, 2012, Agrawal 2012, Cucchiella et al. 2012, Leach et al. 2011, Nikolic et al. 2011, Rangel 2008, and Cleijne and Ruijgroks 2004). Thus, the following types of risks were considered to be relevant for the project: construction/completion, technological, geological, hydrological, economic, financial, political, environmental, nature, and sociocultural.

7.6 Specific conclusion

The current research aimed to identify, quantify & distribute risks so as to reduce it for the investor benefit and concern from the angle of economy and inclination for further investment in the region of Uttarakhand small hydro power projects. This research helps investors to assess and distribute their risks in small hydro power projects.

In this research, a methodology is applied for risk rating of small hydropower plant projects. The relative importance of the risk factors was determined from the expert judgments and questionnaire survey. The survey results showed that the most concerned risks are Capital cost, Construction Schedule, Machinery, Precipitation.

This research concludes that ignorance and improper assessment of risk for selection of a project for investment may not give clear path to the investors. So with the aim of improved realistic investment decisions strategic approach may work as bonus for most of investors with more considerate.

Applicability of the applied methodology has been tested on a real case. Findings of the case study demonstrate that the proposed methodology can be easily applied by the professionals to quantify risk ratings. The advantage of the applied methodology is will give investors a more rational basis on which to make decisions and it can prevent cost and schedule overruns. Forecasting the measure of risk of a river-type hydropower plant can be made by any decision maker with the help of the Fuzzy Logic.

CHAPTER 8

REFERENCES

1. ADB report, 2012. (2012). Disguised attempt to fund large hydro projects, 1–8.
2. Agrawala, S., Moehner, A., Hemp, A., Aalst, V., Hitz, S., Smith, J., Mwaipopo, O. U. (2003). Environment Directorate Development Co-Operation Directorate Working Party on Global and Structural Policies Working Party on Development Co-operation and Environment Development And Climate Change In Tanzania .
3. Arid, S. C. (2000). China's Three Gorges : The Impact of Dam Construction on Emerging Human Rights, *6*(2).
4. Angulo-fernández, I. P., Aguilar-lasserre, A. A., González-huerta, M. A., & Moras-sánchez, C. G. (2011). Investment Decision based on a Genetic Algorithm to Optimize the Profitability of Fattening-sheep Farming, *I*, 5–9.
5. Approach, T., Assessment, R., Assessment, P. R., & Results, P. (1998). Chapter 31 Probabilistic Risk Assessment.
6. Kumar, A . (2008). Hydropower Plants, (July).

7. Assistance, A. J. O. / O. / O. R. of the W. B. G.' s. (2003). Private Sector Development in the Electric Power Sector.

8. Banerjee, R. (2006). Comparison of options for distributed generation in India. *Energy Policy*, *34*(1), 101–111. doi:10.1016/j.enpol.2004.06.006

9. Bank, A. D. (2006). *Report and Recommendation of the President to the Board of Directors Proposed Multitranche Financing Facility India : Uttaranchal Power Sector Investment Program*.

10. Bansal, A. (2012). A Study on Recent Trends in Risk Management of Non-Performing Assets (NPA's) by Public Sector Banks in India, *3*(1), 50–57.

11. Barajas, M., & Agard, B. (2010). Improved fuzzy ranking procedure for decision making in product design. *International Journal of Production Research*, *48*(18), 5433–5453. doi:10.1080/00207540903117873

12. Basu, I., & Garg, R. (2012). Indian Power Sector : The Need for Demand.

13. Bazmi, A., & Zahedi, G. (2011). Sustainable energy systems: Role of optimization modelling techniques in power generation and supply—A review. *Renewable and Sustainable Energy Reviews*, *15*(8), 3480–3500. doi:10.1016/j.rser.2011.05.003

14. Berchmans, H. J. (2013). UNDERSTANDING RISKS of MINI & SMALL HYDRO Indonesia Clean Energy Development (ICED) Project.

15. Bertani, R. (2012). Geothermal power generation in the world 2005–2010 update report. *Geothermic*, *41*(2012), 1–29. doi:10.1016/j.geothermics.2011.10.001

16. Bhanu, S. (2011). Effect of Pay Satisfaction in Information Technology Enabled Sector in India, *11*(2), 112–128.

17. Bhattacharyya, S. S. (2007a). Chamera Hydro-Electric Power Project (Chep-1), Khairi: Looking beyond the Horizon of Hydroelectricity and Profit, Giving New Meaning to Life. *Vision: The Journal of Business Perspective*, *11*(1), 79–93. doi:10.1177/097226290701100107

18. Bloom, N., Bond, S., & Van Reenen, J. (2007). Uncertainty and Investment Dynamics. *Review of Economic Studies*, *74*(2), 391–415. doi:10.1111/j.1467-937X.2007.00426.x

19. UJVNL; (2010). Uttarakhand Electricity Regulatory Commission, *9*(I).

20. Castaldi, D., Chastain, E., Windram, M., Ziatyk, L., & Sciences, M. (2003). A Study of Hydroelectric Power : From a Global Perspective to a Local Application.

21. Chaklader, B., & Aggarwal, P. (2010). Declaration of Bonus Debenture : A Case of Britannia Industries Limited Effect of Issue of Bonus Debentures on the Share Prices of BIL, *II*(02), 93–108.

22. Chan, A. P. C., Chan, D. W. M., Asce, M., & Yeung, J. F. Y. (2009). Overview of the Application of "Fuzzy Techniques" in Construction Management Research, (November), 1241–1253.

23. Chaurasiya, P. K., Prasad, V., & Khare, R. (2013a). Scenario and Risk of Hydro Power Projects In India, *5*(2), 1068–1075.

24. Cheung, W. M., & Kaymak, U. (2008a). A Fuzzy Logic Based Trading System.

25. Chhabra, N., & Mishra, B. C. K. (2011). A paradigm shift in Investment Decision modelling considering small Hydel power sector of India.

26. Confederation of Indian Industry (CII). (2009). Uttarakhand Vision 2022.

27. Deng, Y., Su, X., Jiang, W., Xu, J., & Xu, P. (2010a). Risk Analysis Method : A Fuzzy Approach, (July), 146–150.

28. Desai, V. (2005). *Risk Analysis in Port Finance*. Eramus University Rotterdam.

29. Dhillion, S. S. (2012). Benefit Sharing Mechanisms Sweco Norway and ENVIRO-DEV Consultants, *2012*.

30. Diduck, A., Sinclair, J., Pratap, D., & Hostetler, G. (2007). Achieving meaningful public participation in the environmental assessment of hydro development: case studies from Chamoli District, Uttarakhand, India. *Impact Assessment and Project Appraisal*, *25*(3), 219–231. doi:10.3152/146155107X217299

31. *Energy statistics 2011*. (2011).

32. Filippini, M., & Luchsinger, C. (2002). Deregulation of the Swiss Electricity Industry : Implication for the Hydropower Sector, (13).

33. Finke, G. R. (2010). Operational Risk Quantification – A Risk Flow Approach.

34. Firestone, M., Fenner-crisp, P., Chang, S., & Callahan, M. (1997). Guiding Principles for Monte Carlo Analysis, (March).

35. Fischer Black; Myron Scholes. (1973). The Pricing of Options and Corporate Liabilities, *81*(3), 637–654.

36. Fleten, S., Fuss, S., Heggedal, A. M., Szolgayova, J., & Christian, O. (2010). Evaluation of Hydropower upgrades projects- a real option approach, (23005).

37. Fleten, S., & Heggedal, A. M. (2009). Climate Policy Uncertainty and Investment Behavior : E Vidence From Small.

38. Fleten, S., Juliussen, E., & Revdal, I. (2007). Investment Timing And Optimal Capacity Choice For Small Hydropower Projects, (7491), 1–21.

39. Fluctuations, D. (1988). Discussion Paper on risk and uncertainity (39).

40. For, A., & Technologies, H. (2002). Environmental and Health Impacts Of Electricity Generation A Comparison of the Environmental Impacts of Hydropower, (June).

41. Fougère, M., & Moulettes, A. (2006). The Construction of the Modern West and the Backward Rest in Hofstede ’ s Culture ' s Consequences Published in the Journal of Multicultural Discourses The Construction of the Modern West and the Backward Rest in Hofstede ' s Culture ' s Consequences.

42. Gains, A. , Belgian, U., & Data, P. (2002). National Bank Of Belgium Working Papers - Research Series Finance, Uncertainty And Investment : Assessing The Gains And Losses Of A Generalized Non Linear Structural Approach This Paper Is Part Of The Research Program On " New Views On Firms’ Investment, (26).

43. Gajewska, E., & Ropel, M. (2011). Risk Management Practices in a Construction Project – a case study.

44. Geetanjali Mittal. (2004). Real Options Approach to Capacity Planning Under Uncertainty by Geetanjali Mittal.

45. Ghosh, A., & Kaur, A. (2010). Steady growth in small hydro power ; however significant challenges remain ..., 1–11.

46. Girmay, Y. (2006). Assessing the Environmental Impacts of a Hydropower Project : The case of Akosombo / Kpong Dams in Ghana Assessing the Environmental Impacts of a Hydropower Project : The case of Akosombo / Kpong Dams in Ghana.

47. Soni, G.; (2006). Financial Modelling of Small Hydro Project (3x750 Kw), (03).

48. Han, S.-Y., Kwak, S.-J., & Yoo, S.H. (2008). valuing environmental impacts of large dam construction in Korea: An application of choice experiments. *Environmental Impact Assessment Review*, *28*(4-5), 256–266. doi:10.1016/j.eiar.2007.07.001

49. Harinarayana, T., Abdul Azeez, K. K., Murthy, D. N., Veeraswamy, K., Eknath Rao, S. P., Manoj, C., & Naganjaneyulu, K. (2006a). Exploration of geothermal structure in Puga geothermal field, Ladakh Himalayas, India by magneto telluric studies. *Journal of Applied Geophysics*, *58*(4), 280–295. doi:10.1016/j.jappgeo.2005.05.005

50. Harrison, G. P., Whittington, H. W., Gundry, S. W., & Management, R. (2010). Climate Change Impacts On Hydroelectric Power, (1).

51. He, Y. (2010). Modeling Electricity Prices for Generation Investment and Scheduling Analysis, (February).

52. Heat, J., & Nevertheless, C. (1993). Geothermal systems and resources.

53. Heggedal, A. M., & Linnerud, K. (2008.). Climate policy uncertainty and investment behaviour : Evidence from small hydropower plants, (September 2009), 1–24.

54. Heggedal, A. M., Linnerud, K., & Fleten, S.-E. (2011). Uncertain Policy Decisions and Investment Timing: Evidence from Small Hydropower Plants. *SSRN Electronic Journal*, (1), 1–32. doi:10.2139/ssrn.1987701

55. Heitsch, H., & Römisch, W. (2007). Scenario tree modelling for multistage stochastic programs. *Mathematical Programming*, *118*(2), 371–406. doi:10.1007/s10107-007-0197-2

56. Hossain, M. A. (2006). Tipaimukh Dam of India : Probable Disaster for Bangladesh, 1–23.

57. Hosseini, S. A. (2011). Archive of SID Dam in Iran Using Multi-Attribute Decision Making Method Archive of SID, *36*(56), 7–9.

58. Hosseini, S. M. H., Forouzbakhsh, F., & Rahimpoor, M. (2005). Determination of the optimal installation capacity of small hydro-power plants through the use of technical, economic and reliability indices. *Energy Policy*, *33*(15), 1948–1956. doi:10.1016/j.enpol.2004.03.007

59. Hussain Ahmed Siddiqui & javed Iqbal Mufti. (2005). Government to Provide Guarantee for 50mw Power Projects Developing Hydel Power Projects : Risks And Constraints.

60. Hydro Power in Uttarakhand. (2012).

61. Hydro Power Project Financing Scenario in India – A Case Study on Hydro Power Projects in India Publication Details : (2013), (225).

62. I, C. A. (2007). Chep-1, Khairi: Looking beyond the Horizon of Hydro-Electricity and Profit. *Vision: The Journal of Business Perspective*, *11*(1), 95–101. doi:10.1177/097226290701100108

63. International Energy Agency. (2003). *Power Generation Investments*.

64. Ikonnikova, S. (2011). Impact of Regulation on the Power Sector : Opportunities for Natural Gas *, *70100*.

65. Indian Institute of Technology, R. (2007). Water Resources Development (Hydropower Development), (July).

66. Jain, S. (2010). Cost Benchmarking of Generation Utilities Using DEA: A Case Study of India. *Technology and Investment*, *01*(04), 229–234. doi:10.4236/ti.2010.14028

67. Jal, U., & Nigam, V. (2010). Uttarakhand - India Water to Wire Modernisation and Upgrading of Hydroelectric Projects Phase II – Feasibility Study Detailed Project Report Cluster 1 – Tons River Valley Main Report – Chibro Hep, *1*(May).

68. Jalsrot Vikas Sanstha, N. (2012). *Hydropower Pricing In Nepal*.

69. Jayant Sathaye (USA), Oswaldo Lucon (Brazil), A. R. (Bangladesh). (2012). *Renewable Energy in the Context of Sustainable Development*.

70. Jenab, K., & Ahi, P. (2010a). Fuzzy quality feature monitoring model. *International Journal of Production Research*, *48*(17), 5021–5030. doi:10.1080/00207540903117907

71. Joshi, M. C. (2007a). Hydro Power Potential in Uttarakhand, (October), 22–24.

72. Júnior, W. de S., & Reid, J. (2010). Uncertainties in Amazon hydropower development: Risk scenarios and environmental issues around the Belo Monte dam. *Water Alternatives*, *3*(2), 249–268.

73. Kai, L., & Tiong, R. (2008a). Economic Internal Rate of Return (EIRR) Estimation in Vietnam Hydro Power Project, 1–7.

74. Kalantzopoulos, N. A., Hatzigeorgiou, A. M., & Spyridis, T. C. (2008). Modeling Uncertainty and Risk In Investment Appraisal Decisions : A Monte Carlo Simulation, *58*(3), 167–183.

75. Kesharwani, M. K. (2006). Overview Of Small Hydro Power Development, 44–57.

76. Khcherem, F., & Bouri, A. (2009). Fuzzy Logic and Investment Strategy. *Global Economy & Finance Journal*, *2*(2), 22–37.

77. Knutsen, L. H., & Poulsen, T. (2010a). Investment Strategy for Small Hydropower Generation Plants in Norway Supervisor :, 0–76.

78. Kolberg, T. (1990). Master thesis. *Mycotoxin Research*, *6*(2), 100. doi:10.1007/BF03192151

79. Kristiansen, T. (2005). Risk Management in Electricity Markets Emphasizing Transmission Congestion.

80. Kucukali, S. (2011a). Risk assessment of river-type hydropower plants using fuzzy logic approach. *Energy Policy*, *39*(10), 6683–6688. doi:10.1016/j.enpol.2011.06.067

81. Lamech, R., Saeed, K., Energy, T., & Board, M. S. (2003). What International Investors Look For When Investing In Developing Countries.

82. Lundmark, R., & Patterson, P. (2010). Investment decision & uncertainty in the Power Generation Sector. *Scientific Research*, *12*(3), 14–67.

83. Lundmark, R., & Pettersson, F. (2007). Investment Decisions and Uncertainty in the Power Generation Sector, 1–14.

84. Madlener, R., & Ediger, V. (2004). Modeling Technology Adoption as an Irreversible Investment Under Uncertainty: The Case of the Turkish Electricity Supply Industry, (30).

85. Madlener, R., & Wickart, M. (2006). Optimal Technology Choice and Investment Timing : A Stochastic Model of Industrial Cogeneration vs . Heat-Only Production, *18*.

86. Maingi, J. K., & Marsh, S. E. (2002). Quantifying hydrologic impacts following dam construction along the Tana River, Kenya. *Journal of Arid Environments*, *50*(1), 53–79. doi:10.1006/jare.2000.0860

87. Mckinsey. (2010). Energy efficiency : A compelling global resource.

88. Mcleish, D. L. (2004). Monte Carlo Simulation.

89. Mcveigh, J., & Cohen, J. (2007). Preliminary Technical Risk Analysis for the Geothermal Technologies Program Preliminary Technical Risk Analysis for the Geothermal Technologies Program, (March).

90. Meeting, E. A., Ggf, T., Workshop, T., & Power, S. H. (2012a). Financing hydropower Introduction to the Specifics of Small Hydro Power Plants, (May), 0–35.

91. Mittal, G. (2004). *Real Options Approach to Capacity Planning Under Uncertainty by Geetanjali Mittal*.

92. Montgomery, V. (2009). New statistical methods in risk assessment by probability bounds, (February).

93. Möst, D., & Keles, D. (2009). European Journal of Operational Research A survey of stochastic modelling approaches for liberalised electricity markets.

94. Naik, H., & Rathod, T. G. (2008). Impact of Availability-Based Electricity Tariffs (ABT) on the Power Sector : Case Study of Karnataka.

95. Nandy, M., & Bhattacharya, S. (2012). Energy Issues in India and South Africa.

96. *National hydroelectric power corporation limited*. (2007) (Vol. 2007).

97. Nilsen, T., & Aven, T. (2003a). Models and model uncertainty in the context of risk analysis. *Reliability Engineering & System Safety*, *79*(3), 309–317. doi:10.1016/S0951-8320(02)00239-9

98. Noor-E-Alam, M., & Doucette, J. (2010a). Stochastic Investment Decision Making with Dynamic Programming. *Iieom.org*, (2009).

99. Parandin, N., Seidzadeh, M., & Hamedi, S. (2013a). Using Fuzzy Risk Analysis Based on Similarity Measure of Generalized Fuzzy Numbers for Ranking Factories, *3*(1), 499–504.

100. (Published in the Gazette of India, Extraordinary, Part-II, and Section 3, Sub-section (ii) Ministry Of Environment And Forests New Delhi 14. (2006), (ii), 1–43.

101. Partici, T., Ceo, T., & Crc, T. (2003). Investment Decision-Making under Risk (Reliability) and Uncertainty for Infrastructure Asset Management.

102. Pasha, A., & Nasab, Z. (2012a). Financial Analysis of Small-Hydro Power Project in Malaysia from the Investor Perspective, *33*, 149–153.

103. Pejovic, S., Karney, B. W., Zhang, Q., & Kumar, G. (2007a). Smaller Hydro, Higher Risk. *2007 IEEE Canada Electrical Power Conference*, 91–96. doi:10.1109/EPC.2007.4520312

104. Pereira, M., Campodónico, N., & Kelman, R. (1998). Long-term Hydro Scheduling based on Stochastic Models, 1–22.

105. Personal, M., Archive, R., Fleten, S., Fuss, S., Heggedal, A. M., Szolgayova, J., & Christian, O. (2010). Mp r a, (23005).

106. Pharlia, G. K. (2007). Steps to Enhance Private Investment in Hydro Sector, (October), 22–24.

107. Phuyal, T. P. (2006). Small hydropower and headworks modelling, 84–95.

108. Pillai, I. R., & Banerjee, R. (2009). Renewable energy in India: Status and potential. *Energy*, *34*(8), 970–980. doi:10.1016/j.energy.2008.10.016

109. Pindyck, R. (1990a). Robert Pindyck. *Irreversibility,Uncertainity & Investment*, (3307).

110. Planning commision. (2011). *Power 8.2.1.*

111. Popovski, K., Gnjezda, G., Niederbacher, P., Naunov, J., & Milutinovic, I. (2000). O p t i m i z a t i o n of the g e o t h e r m a l d i s t r i c t heat- ing system “geoterma” - kocani, macedonia, 310–313.

112. Producers, I. P. (2006). Nepal India Cooperation on Hydropower (NICOH) By : Independent Power Producers ’ Association Nepal Confederation of Indian Industry SARI / E Small Grants Program, (January).

113. Prasad, R. (2007). Risk Insight Series Developing a Risk Profile.

114. R.V.Shahi. (2006). Investment Opportunities in Indian Power Sector and Cooperation with International Energy Agency R . V . Shahi Secretary , Ministry of Power Government of India, 1–9.

115. Ralph, B. M., Harvey, B., Ph, D., Lewis, B., Engineers, P., & Box, P. O. (2000a). Report from the Field : A New Generation of Geothermal Turbine-Generator Plants for Baseload Utility Service Table 1 " Summary of Recent MHI Geothermal Projects i ~ Proiect i Location il Owner / Utility ~ i, 318–321.

116. Rana, A. (2003). Evaluation of a Renewable Energy Scenario in India For Economic and Co2 Mitigation Effects. *Review of Urban & Regional Development Studies*, *15*(1), 45–54. doi:10.1111/1467-940X.00063

117. Renovation and Modernization for Hydro Power Stations. (2007).

118. Ralph, F. (2007). Risks to Biodiversity from Hydropower in the 6 the Power Development Plan.

119. Report, I. E. A. T. (2013). IEA Technical Report.

120. Risk, Uncertainty and Investment Decision- Making in the Upstream Oil and Gas Industry Fiona Macmillan MA Hons (University of Aberdeen) October 2000 A thesis presented for the degree of Ph . D . at the University of Aberdeen. (2000), (October).

121. Rode, D. C., & Dean, S. R. (n.d.). Monte Carlo Methods for Appraisal and Valuation : A Case Study of a Nuclear Power Plant.

122. Salling, K. B. (2005a). Risk Analysis and Monte Carlo Simulation within Transport Appraisal, 1–25.

123. Salmon, J. P., Meurice, J., Wobus, N., Stern, F., & Duaime, M. (2011). Guidebook to Geothermal Power Finance Guidebook to Geothermal Power Finance. *Energy*, *303*(March), 275–3000.

124. Saxena, P. (2006). Overview of Small Hydro Power Development In India.

125. Schaefli, B., Hingray, B., & Musy, A. (2007). Climate change and hydropower production in the Swiss Alps : quantification of potential impacts and related modelling uncertainties Methodology : overview, *11*(3), 1191–1205.

126. Schwartz, B. K. (2012a). Big Reputation .

127. Secretariat, W., & Roorkee, I. I. T. (2005). Risk and uncertainty modelling.

128. Shang, K., & Hossen, Z. (2013a). Applying Fuzzy Logic to Risk Assessment and Decision-Making Sponsored by CAS / CIA / SOA Joint Risk Management Section Prepared by, 1–59.

129. Simu, K. (2008). *The Construction Site Manager ' s Impact on Risk Management Performance* (Vol. 4).

130. Smith, J. (1999). Harvard Business Review ,.

131. Sørensen, B. (1974). Eothermal and ocean - thermal energy conversion 7.1, 30–32.

132. Swainson, L., & McGregor, A. (2008). Compensating for development: Orang Asli experiences of Malaysia's Sungai Selangor dam. *Asia Pacific Viewpoint*, *49*(2), 155–167. doi:10.1111/j.1467-8373.2008.00367.x

133. Swider, D. J., & Weber, C. (2005). The Effects of Stochastic Electricity Market Modelling on Estimating Additional Costs of Intermittent RES-E Integration, (August 2005).

134. The Indian Power Sector : Investments , Growth And Prospects. (2013), (January).

135. Tongtao, M., & Cunbin, L. (2014). The Electricity Portfolio Decision-making Model Based on the CVaR under Risk Conditions, *7*(3), 570–575.

136. Tuna, M. C. (2013). Feasibility Assessment of Hydroelectric Power Plant in Ungauged River Basin: A Case Study. *Arabian Journal for Science and Engineering*, *38*(6), 1359–1367. doi:10.1007/s13369-013-0590-5

137. Uhlmann, W. (1965). *[Introduction in the Monte Carlo methods]*. *Biometrische Zeitschrift* (Vol. 7, pp. 116–9). Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12387918

138. Uhr, M. (2006). Optimal Operation of a Hydroelectric Power System Subject to Stochastic Inflows and Load Supervisor : Kristian Nolde.

139. Vespucci, M. T., Maggioni, F., Bertocchi, M. I., & Innorta, M. (2010). A stochastic model for the daily coordination of pumped storage hydro plants and wind power plants. *Annals of Operations Research*, *193*(1), 91–105. doi:10.1007/s10479-010-0756-4

140. Walke, R. C. (2012). Risk Quantification Model for Construction Projects using Score Model and EV Analysis approach, *2*(3), 2312–2317.

141. Wang, T. (2003). Analysis of Real Options in Hydropower Construction Projects -- A Case Study in China by.

142. Wiemann, P. (2011). Risk Management And Resolution Strategies For Established And Novel Technologies In The Low Head ,, (1).

143. Wittwer, G. (2009a). The Economic Impacts of a New Dam in South-East Queensland. *Australian Economic Review*, *42*(1), 12–23. doi:10.1111/j.1467-8462.2009.00506.x

144. Woksepp, S.,(2005). An Evaluation Model Construction Projects for Investments In, (1992), 1–19.

145. Wong, T., & Kelley, S. (2010a). Mekong hydropower development : a review of governance and sustainability challenges, 1–68.

146. Yang, M. (2007a). International Energy Agency Working Paper Series Modeling Investment Risks and Uncertainties with Real Options Approach Modeling Investment Risks and Uncertainties with Real Options Approach.

147. Zelenakova, M., Zvijakova, L., & Purcz, P. (2013a). Small Hydropower Plant – Environmental Impact Assessment – Case Study, *3*(4).

148. Zhang, X., Yang, M., Xue, Y., Liang, H., Boulton, W. R., Working, T., Mwaipopo, O. U. (2010a). No Title. *International Journal of Production Research*, *25*(1), 1–11. doi:10.1080/00207540903117907

ANNEXURE A1

Review of Literature and road map for problem formulation: Current Approaches

s.no	Authors-Year	Theme	Context	Inference	Gap Identified
1	(Lundmark & Pettersson, 2007b); (Noor-E-Alam & Doucette, 2010a);(Zhang et al., 2010a); (Chhabra & Mishra, 2011);(He, 2010b); (Nilsen & Aven, 2003b); (Banerjee, 2006); (Knutsen & Poulsen, 2010);(S. M. H. Hosseini et al., 2005a);(Maingi & Marsh, 2002b); (Möst & Keles, 2009); (Lundmark & Pettersson, 2007b)	Challenges in Realizing Investment Potential	**Global**	Different Investment issues i.e. policy deregulation, DPR Reliability, evaluation techniques etc. were studied as a causative factor affecting investment related decision making power of the investors in small hydro power sector.	In Uttarakhand investment risks pertaining to small hydro power investment are yet to be identified and assessed.
2	(Fleten & Heggedal, 2009b); (Zhang et al., 2010a);(Soni, 2002);(Zhang et al., 2010a)(Heggedal & Linnerud, 2005); (Pereira, Campodónico, & Kelman, 1998); (He, 2010b); (Maingi & Marsh, 2002b);(S. M. H. Hosseini et al., 2005a); (Madlener & Ediger, 2004); (Zhang et al., 2010a); (Mittal, 2004); (Pindyck, 1990a);(Kumar R., 2012). (Madlener & Wickart, 2006);(Hossain, n.d.-a);(Arid, 2000);(Schwartz, 2012b); (Girmay, 2006a); (Zhang et al., 2010a)	Risk identification in small hydro power project	**Global**	Many risks addressed so far globally in hydro power projects were identified primarily as environmental, legal, market, financial, business etc.	In global scenario though the investment risks have been identified, but the investment risks pertaining to operational & construction stages of SHP's have not been identified.
3	Oliveira and Silva (2004);Sun and van Kooten (2005);Cai at el. (2009); (Madlener & Ediger, 2004)Tucha and Brem (2006); Dow and (Ghosh & Kaur, n.d.)	Risk identification in small hydro power project	**Uttarakhand**	Identification of risks practiced so far, have been found to be based on assumptions, thereby leading to inefficient risk treatment.	Investment risk pertaining to construction and operation stages of SHP's in the state of Uttarakhand has not been identified.

4	Gitanjali Mittal(2001);Ingersoll & Ross(1992); Munn(2002); Deepashree Raje a, P.P. Mujumdar(2009);Fritz(1984); Fuquitt(1999); Morimotto(2001); Shibl(1971); Morimotto & Hopes(2002); deNeufville(1990); Watkins, Kirlby &Lawrey(1984);Stein-Erik Fleten,1 Ane Marte Heggedal,Kristin Linnerud(2009);T. Nilsen and T. Aven(2001);Anders Gjelsvik, Gjelsvik, Birger Mo, and Arne Haugstad(2006);Md. Noor-E-Alam1 and John Doucette;Michael Bruch, Volker Münch, Markus Aichinger(2011);	Practice of Global Risk assessment	**Global**	Globally deterministic, probabilistic, stochastic & strategic risk assessment practices are used for risk assessment	Investment risk assessment in Construction & operation stage SHP's, has not been performed.
5	(Diduck, Sinclair, Pratap, & Hostetler, 2007)	Practices of Risk Assessmen t	**Uttarakhand**	Risk assessment is assumption based in current practices of Uttarakhand.	Investment risk assessment **in Construction** & operation stage SHP's, in Uttarakhand has not yet been done.
6	(Cheung & Kaymak, 2008b);Lahsasna (2009);Matsatsinis at el. (2003); Li at el. (2011);Cherubini and Lunga (2001); Horgby (1999); Caleiro (2003); Blavatksyy (2011); Ng at el. (2002); Xu at el. (2011	Use of Fuzzy Logic in Risk assessment	**Global**	Globally Fuzzy logic has been used as an advance approach for subjective risk assessment in various sectors.	A fuzzy logic approach has not been applied so far for subjective risk assessment especially in SHP's of Uttarakhand.
7	(McLoughlin, Basilian 2006); (Arnesano et al 2012) &(Bhattacharya, 2010);(Arnesano et al 2012); (Ferreira, Cunha 2011); Awerbuch (2003); (Ferreira, Cunha 2011).	Risk Distributio n	**Global**	It was observed that the current practices followed for Risk Distribution in different projects other than SHP's were predominantly the Portfolio theory & PPP Model.	Investment Risk Distribution for investor's is lacking in SHP's of Uttarakhand.

Annexure A2

Small Hydro Power Risk Identification & Taxonomy

Risk Identification For SHP's In Uttarakhand (operation & Construction Stage)					
Name of the Respondent					
Experience Of Respondents					
Organization name of the respondent					
Designation of Respondent					
Qualification of Respondent					
How Related to Hydro Power			**Stage in which this risk Variable is Existing**		
Are these Risk Factors Available In SHP's Of Uttarakhand?	**Yes(1)**	**No(2)**	**Operations(1)**	**Construction(2)**	**Construction/Operation(3)**
Exchange rate					
Delay of supplies of technology, buildings and/or raw material					
Approval by authorities					
Financial resources					
clearance					
Relocation					
Human factor					
local Community					
Relocation cost					
Employment					
Tourist Places					
dam site					
Tourist Revenue					
flora and fauna					
Financing					
Interest rate					
tax rate					

inflation rate					
Climate					
Noise pollution					
drinking water quality					
River Flow					
soil erosion					
precipitation					
construction time					
Competency					
Budget Construction					
Cost Overrun					
machinery					
breakdown					
Preventive maintenance					
Regulatory					
clearances					
Electricity Price					
System procedures					
Competitors					
evaluation techniques					
Financial Resources					
generation					
Public private partnership					
terrorism					
Communication					
Fund Blockage					

Annexure A3

Small Hydro Power Risk Analysis (Construction Stage)

1. **Name of the respondents**

2. **Age of the respondent**

3. **Qualification of the respondent**

4. **Organization Name of the Respondent**

5. **Designation of the Respondent**

6. **Gender of the Respondent**
   Male Female

7. **How Related With Hydro Power?**

   Approver
   Developer
   Investors
   Researcher
   Other ( )

Question No.	Risk Factor	score 1 (very Low)	score 2 (Medium)	score 3 (High)	score 4 (very High)	score 5 (Extreme)	Respondent Score
8	Clearances	Getting clearances is very Easy	Getting clearances is Easy	Getting clearances is Moderate	getting clearances is Difficult	Getting clearances is very Difficult	
9	Climate	no landslide and cloud bursting in the Uttarakhand area	landslide and cloud bursting occurs in 10 years in the Uttarakhand area	Landslide and cloud bursting occurs every 5 year in the Uttarakhand area.	landslide and cloud bursting occurs within 2-3 years in the Uttarakhand area	landslide or cloud bursting occurs many times in a year in the Uttarakhand area	

10	Capital Cost	no extra money required as per estimation	10% budget exceed from estimated cost	more than 10 %-30% budget exceed from estimated cost	more than 30 %-50% budget exceed from estimated cost	more than 50% budget exceed from estimated cost	
11	Construction Schedule	Project Constructed within estimated time	project exceed within 6 months from estimated time	project exceed 6 months to 1 year from estimated time	project exceed more than 1 year to 3 year from estimated time	project exceed more than 3 year from estimated time	
12	Delay from Suppliers	immediate supply	supply delay by 15 days to 1 month	supply delay by 1 month to 3 months	supply delay by 3 month to 6 months	supply delay by more than 6 Months	
13	technical Breakdown	No Breakdown occurs in power plant and no impact	Breakdown occurs once in a year but manageable	Breakdown occurs Twice in a year creates cost overrun	Breakdown occurs 2-4 times in a year creates high cost overrun	Breakdown occurs frequently and cost overrun exceed severity	
14	Employment	employment given to all local community people and permanent profile is given	employment given to few educated local community people and rest are on contractual bases	employment given to people in moderate number	employment given to few local community people on contractual basis	No employment given to local community people and for other it is contractual	
15	Financing Resources	Very Easily Accessible from Financial Institution	Easily Accessible with less formalities	Available with more paper work and clearances	Finance available but takes much time and efforts	Not Available projects are stopped due to finance non availability	
16	Flora fauna	Flora fauna is not available near the power project area	flora &fauna is not so much affected as area is quite less	flora &fauna is less affected and measures are taken for prevention	flora &fauna is affected and preventions are in the implementation stage	flora &fauna affects so much that environment clearance stop	
17	Fund Blockage	Fund is never Blocked by Financing Sources	fund blockage released within 7 days to 15 days	fund blockage released within 15 days to 1 Month	fund blockage released within 1 Month to 3 months	fund blockage released after 3 months	
18	Inflation	No inflation increment	No revision in one year	Revised twice in a year	Revised two to three times in a year	inflation changes frequently	
19	Interest Rate	Fixed interest rate	No revision in one year	Revised twice in a year	Revised two to three times in a year	Inflation changes frequently	
20	Machinery	machinery used as generators and turbines give 100% efficiency	machinery used as generators and turbines give 70%-80% efficiency	Machinery used as generators and turbines give 50%-70% efficiency	machinery used as generators and turbines give 20%-50% efficiency	machinery used as generators and turbines give less than 20% efficiency	
21	Modeling Techniques	no modeling techniques used for assessment based on tariff calculation	obsolete methods used for assessment as PBP	Moderate methods used for evaluation as NPV,IRR	Moderate methods used for evaluation as Sensitivity analysis, Scenario	Very Advanced Techniques used for assessment	

					manager		
22	Noise Pollution	Hydro project not creates any sound	Hydro power project creates moderate sound as near to isolated places so no impact	Hydro power project creates moderate sound as near to industrial area so less impact	Hydro power project creates sound but sound proof measures are initiated	Hydro power project creates very high sound pollution and local community affected	
23	PPP	for SHP PPP agreement not required	PPP agreement Depends on Investor desire	PPP agreement feasible only for certain stages	PPP agreement is mandatory only few stages	PPP agreement is mandatory	
24	Precipitation	No Precipitation from river	precipitation accumulates once in a year	precipitation accumulates seasonal	precipitation accumulates 15 days or 1 Month	precipitation accumulates every 7 days to 15 days	
25	Regulatory	Government is stable norms are not changing frequently	Government norms remain same for 2-3 years	Government norms are changing once in year	Government norms are not changing 2-3 times in a year	Government is unstable norms are not changing monthly basis	
26	Relocation	Local community benefit from the river or the surrounding lands	Project has no Social Impact Report	Project has Moderate Social Impact Report	Project has Social Impact Report	Project has detailed Social Impact Report	
27	River Flow	river flow uniform throughout the year	river flow is monsoonal but under controlled	river flow is monsoonal but partly controlled	river flow is monsoonal but damage controller available	river flow is very high so damage power project	
28	Soil Erosion	Rock mass quality is very good:70%-100%	Rock mass quality is Good:55%-70%	Rock mass quality is not so good:40%-55%	Rock mass quality is poor :20%-40%	Soil with high groundwater level	
29	Tax Rate	No changes in tax	No revision in one year	Revised twice in a year	Revised two to three times in a year	Tax changes frequently	
30	Terrorism	terrorism risk index of the state is very low	terrorism risk index of the state is low	terrorism risk index of the state is Moderate	terrorism risk index of the state is High	terrorism risk index of the state is very High	
31	Construction Budget	no extra money required as per estimation	10% budget exceed from estimated cost	more than 10 %-30% budget exceed from estimated cost	more than 30 %-50% budget exceed from estimated cost	more than 50% budget exceed from estimated cost	
32	Water Quality	Drinking water quality is not creating health issues	Drinking water quality creates minor health issues	Drinking water quality creates major health issues	Drinking water quality creates severe health issues	Drinking water quality creates epidemic	

Annexure A4

Small Hydro Power Risk Analysis (Operational Stage)

1. **Name of the respondents?**

2. **Age of the respondent**

3. **Qualification of the respondent**

4. **Organization Name of the Respondent.**

5. **Designation of the Respondent.**

6. **Gender of the Respondent**
   Male Female

7. **How Related With Hydro Power?**

   Approver
   Developer
   Investors
   Researcher
   Other ( )

Question No	Risk Factor	score 1 (very Low)	score 2 (Medium)	score 3 (High)	score 4 (very High)	score 5 (Extreme)	Respondent Score
8	**capital cost**	no extra money required as per estimation	10% budget exceed from estimated cost	more than 10 %-30% budget exceed from estimated cost	more than 30 %-50% budget exceed from estimated cost	more than 50% budget exceed from estimated cost	
9	**Clearances**	Getting clearances is very Easy	Getting clearances is Easy	Getting clearances is Moderate	getting clearances is Difficult	Getting clearances is very Difficult	
10	**Climate**	no landslide and cloud bursting in the Uttarakhand area	landslide and cloud bursting occurs in 10 years in the Uttarakhand area	landslide and cloud bursting occurs every 5 year in the Uttarakhand area	landslide and cloud bursting occurs within 2-3 years in the Uttarakhand area	landslide or cloud bursting occurs many times in a year in the Uttarakhand area	

11	**technical Breakdown**	No Breakdown occurs in power plant and no impact	Breakdown occurs once in a year but manageable	Breakdown occurs Twice in a year creates cost overrun	Breakdown occurs 2-4 times in a year creates high cost overrun	Breakdown occurs frequently and cost overrun exceed severely	
12	**Generation**	Electricity generated more than average capacity	Electricity generated +- 5% than average capacity	Electricity generated +- 10%to 20% than average capacity	Electricity generated +- 20-40%% than average capacity	Electricity generated less than 50% of average capacity	
13	**Electricity Price**	price fluctuates once in 10 year	price fluctuate every 5 year	price fluctuate within 2-4 years	price fluctuation once in a year	price fluctuation 3 times in a year	
14	**Operation & Maintenance cost**	Operation and maintenance c cost is 1-2% of capital cost	Operation and maintenance c cost is 2-5% of capital cost	Operation and maintenance c cost is 5%-10% of capital cost	Operation and maintenance c cost is 10%-20% of capital cost	Operation and maintenance c cost is more than 20%of capital cost	
15	**Evaluation technique**	no modelling techniques used for assessment based on tariff calculation	obsolete methods used for assessment as PBP	Moderate methods used for evaluation as NPV,IRR	Moderate methods used for evaluation as Sensitivity analysis, Scenario manager	Very Advanced Techniques used for assessment	
16	**Financing Resources**	Very Easily Accessible from Financial Institution	Easily Accessible with less formalities	Available with more paper work and clearances	Finance available but takes much time and efforts	Not Available projects are stopped due to finance non availability	
17	**Flora fauna**	Flora fauna is not available near the power project area	flora &fauna is not so much affected as area is quite less	flora &fauna is less affected and measures are taken for prevention	flora &fauna is affected and preventions are in the implementation stage	flora &fauna affects so much that environment clearance stop	
18	**Inflation**	No inflation increment	No revision in one year	Revised twice in a year	Revised two to three times in a year	inflation changes frequently	
19	**Interest Rate**	Fixed interest rate	No revision in one year	Revised twice in a year	Revised two to three times in a year	Inflation changes frequently	
20	**Machinery**	machinery used as generators and turbines give 100% efficiency	machinery used as generators and turbines give 70%-80% efficiency	Machinery used as generators and turbines give 50%-70% efficiency	machinery used as generators and turbines give 20%-50% efficiency	machinery used as generators and turbines give less than 20% efficiency	
21	**Noise Pollution**	Hydro project not creates any sound	Hydro power project creates moderate sound as near to isolated places so no impact	Hydro power project creates moderate sound as near to industrial area so less impact	Hydro power project creates sound but sound proof measures are initiated	Hydro power project creates very high sound pollution and local community affected	
22	**PPP**	for SHP PPP agreement not required	PPP agreement Depends on Investor desire	PPP agreement feasible only for certain stages	PPP agreement is mandatory only few stages	PPP agreement is mandatory	
23	**Precipitation**	No Precipitation	precipitation	precipitation	precipitation	precipitation	

		from river	accumulates once in a year	accumulates seasonal	accumulates 15 days or 1 Month	accumulates every 7 days to 15 days	
24	**Regulatory**	Government is stable norms are not changing frequently	Government norms remain same for 2-3 years	Government norms are changing once in year	Government norms are not changing 2-3 times in a year	Government is unstable norms are not changing monthly basis	
25	**River Flow**	river flow uniform throughout the year	river flow is monsoonal but under controlled	river flow is monsoonal but partly controlled	river flow is monsoonal but damage controller available	river flow is very high so damage power project	
26	**Soil Erosion**	Rock mass quality is very good:70%-100%	Rock mass quality is Good:55%-70%	Rock mass quality is not so good:40%-55%	Rock mass quality is poor :20%-40%	Soil withhighgroundwaterlevel	
27	**Tax Rate**	No changes in tax	No revision in one year	Revised twice in a year	Revised two to three times in a year	Tax changes frequently	
28	**Terrorism**	terrorism risk index of the state is very low	terrorism risk index of the state is low	terrorism risk index of the state is Moderate	terrorism risk index of the state is High	terrorism risk index of the state is very High	
29	**Tourist attraction**	Every project has tourist place near dam site and generates employment	project has tourist place near dam site and generates not so major employment	Few project has tourist place near dam site and development is going on other dam sites as well	few project has tourist place near dam site but not so developed	No tourist place near dam site	
30	**Drinking Water Quality**	Drinking water quality is not creating health issues	Drinking water quality creates minor health issues	Drinking water quality creates major health issues	Drinking water quality creates severe health issues	Drinking water quality creates epidemic	

Annexure A5

Membership Degree Matrix for operational stage Small Hydro Power project Risks

$$M_{capital\ cost} = \begin{matrix} 1 & 0.5 & 0 & 0 & 0 \\ 0 & 1 & 0.3 & 0 & 0 \\ 0 & 0.2 & 1 & 0.2 & 0 \\ 0 & 0 & 0.3 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{constrcution\ schedule} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.4 & 0 & 0 \\ 0 & 0 & 1 & 0.2 & 0 \\ 0 & 0 & 0.2 & 1 & 0 \\ 0 & 0 & 0.4 & 0 & 1 \end{matrix}$$

$$M_{Delay\ from\ Suppliers} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0.2 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{Flora\ \&\ Fauna} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{Noise} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{soil} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0.3 & 1 & 0.3 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{Water\ Quality} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0.2 & 1 & 0.2 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{financing\ resources} = \begin{matrix} 1 & 0.3 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0.2 & 1 & 0.2 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.3 & 1 \end{matrix}$$

$$M_{public\ private\ partership} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0.3 & 1 & 0.3 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{tax\ rate} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0.2 & 1 & 0.4 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{inflation} = \begin{matrix} 1 & 0.6 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0.2 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{interest\ rate} = \begin{matrix} 1 & 0.6 & 0 & 0 & 0 \\ 0 & 1 & 0.4 & 0 & 0 \\ 0 & 0 & 1 & 0.2 & 0 \\ 0 & 0 & 0.2 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{electricity\ prices} = \begin{matrix} 1 & 0.7 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0.4 & 1 & 0.4 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.5 & 1 \end{matrix}$$

$$M_{breakdown\ technical} = \begin{matrix} 1 & 0.2 & 0.3 & 0 & 0 \\ 0.2 & 1 & 0.2 & 0 & 0 \\ 0 & 0.4 & 1 & 0.5 & 0 \\ 0 & 0 & 0.5 & 1 & 0.5 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{employment} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{tourist\ attraction} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{terrorism} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{river\ flow} = \begin{matrix} 1 & 0.7 & 0 & 0 & 0 \\ 0 & 1 & 0.6 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.6 & 1 \end{matrix}$$

$$M_{machinery} = \begin{matrix} 1 & 0.6 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0.2 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{operations\ \&\ maintennance} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0.3 & 1 & 0.4 & 0 \\ 0 & 0 & 0.5 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{precipitation} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0.4 & 1 & 0.2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.4 & 1 \end{matrix}$$

$$M_{Evaluation\ technique} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.3 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{generation} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.3 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0.2 & 1 & 0.3 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{approval\ time} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0.4 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0.4 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{regulatory} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0.2 & 1 & 0.2 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0.2 & 1 & 0.2 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{relocation\ cost} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0.2 & 1 & 0.2 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{climate} = \begin{matrix} 1 & 0.5 & 0 & 0 & 0 \\ 0 & 1 & 0.3 & 0 & 0 \\ 0 & 0.2 & 1 & 0.2 & 0 \\ 0 & 0 & 0.3 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

Annexure A6

Membership Degree Matrix for Construction stage Small Hydro Power project Risks

$$M_{capital\ cost} = \begin{matrix} 1 & 0.5 & 0 & 0 & 0 \\ 0 & 1 & 0.3 & 0 & 0 \\ 0 & 0.2 & 1 & 0.2 & 0 \\ 0 & 0 & 0.3 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{constrcution\ schedule} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.4 & 0 & 0 \\ 0 & 0 & 1 & 0.2 & 0 \\ 0 & 0 & 0.2 & 1 & 0 \\ 0 & 0 & 0.4 & 0 & 1 \end{matrix}$$

$$M_{Delay\ from\ Suppliers} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0.2 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{Flora\ \&\ Fauna} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{Noise} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{soil} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0.3 & 1 & 0.3 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{Water\ Quality} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0.2 & 1 & 0.2 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{financing\ resources} = \begin{matrix} 1 & 0.3 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0.2 & 1 & 0.2 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.3 & 1 \end{matrix}$$

$$M_{public\ private\ partership} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0.3 & 1 & 0.3 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{tax\ rate} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0.2 & 1 & 0.4 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{inflation} = \begin{matrix} 1 & 0.6 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0.2 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{interest\ rate} = \begin{matrix} 1 & 0.6 & 0 & 0 & 0 \\ 0 & 1 & 0.4 & 0 & 0 \\ 0 & 0 & 1 & 0.2 & 0 \\ 0 & 0 & 0.2 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{electricity\ prices} = \begin{matrix} 1 & 0.7 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0.4 & 1 & 0.4 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.5 & 1 \end{matrix}$$

$$M_{breakdown\ technical} = \begin{matrix} 1 & 0.2 & 0.3 & 0 & 0 \\ 0.2 & 1 & 0.2 & 0 & 0 \\ 0 & 0.4 & 1 & 0.5 & 0 \\ 0 & 0 & 0.5 & 1 & 0.5 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{employment} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{tourist\ attraction} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{terrorism} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{river\ flow} = \begin{matrix} 1 & 0.7 & 0 & 0 & 0 \\ 0 & 1 & 0.6 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.6 & 1 \end{matrix}$$

$$M_{machinery} = \begin{matrix} 1 & 0.6 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0.2 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{operations\ \&\ maintennance} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0.3 & 1 & 0.4 & 0 \\ 0 & 0 & 0.5 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{precipitation} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0.4 & 1 & 0.2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.4 & 1 \end{matrix}$$

$$M_{Evaluation\ technique} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.3 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{generation} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.3 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0.2 & 1 & 0.3 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

$$M_{approval\ time} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0 & 1 & 0.4 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0.4 & 1 & 0 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{regulatory} = \begin{matrix} 1 & 0.2 & 0 & 0 & 0 \\ 0.2 & 1 & 0.2 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0.2 & 1 & 0.2 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{relocation\ cost} = \begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0.2 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0.2 & 1 & 0.2 \\ 0 & 0 & 0 & 0.2 & 1 \end{matrix}$$

$$M_{climate} = \begin{matrix} 1 & 0.5 & 0 & 0 & 0 \\ 0 & 1 & 0.3 & 0 & 0 \\ 0 & 0.2 & 1 & 0.2 & 0 \\ 0 & 0 & 0.3 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{matrix}$$

Appendices Index

About the Author

Neha Chhabra Roy has more than six years of teaching experience with bachelors and master level students. She holds bachelor's degree in Mechanical engineering and Masters in Finance. She also carries Masters of philosophy in Commerce & finance. Her area of specialization is Risk assessment, financial modeling, simulation and econometrics & investment.

She Teaches Financial Modeling & Econometrics, Corporate Finance, Project Appraisal and risk Assessment & management. She has published several national & international Papers in journals with repute. She also published two international Books on Project Appraisal and Investment & taxation.

Currently associated with Alliance university as senior Assistant Professor; Ms. Roy wants to pursue her career as Researcher in the area of risk assessment & Modeling.

List of Publications

- Roy,N.C; Pandey K K; Gupta S. (2014); Risk Identification & Impact assessment for SHP's of Uttarakhand. ICMI.
- Roy,N.C; Pandey K K; Gupta S. (2014);Risk Analysis in operational stage small hydro power project a stochastic approach. International Journal of latest technology in Management, Engineering & Applied science,III(VIII)17.
- Roy,N.C; Pandey K K; Gupta S. (2014); Optimum portfolio Estimation and risk analysis for small hydro power project investors of Uttarakhand-A Fuzzy Approach, Energy Policy 27.