PERCEPTION AND MANAGEMENT OF RISK IN HYDROPOWER PROJECTS

G.P. Patel  Sandeep Singhal
Managing Director  Director (Projects)
UJVN Limited  UJVN Limited
gppatel@ujvnl.com  sandysinghal14@hotmail.com

ABSTRACT

Hydroelectric Projects have often been accused of indulgence in time and cost overrun resulting ultimately in delay in availability of power as well as in higher cost of power. Main contributing factors to the alleged ubiquitous over-run include delay in timely availability of statutory approvals, resettlement & rehabilitation factors, land acquisition problems and project management & implementation decisions. These factors are the risks involved in the development of hydropower projects.

Hydroelectric power plant has complex structures and involves large amounts of capital with a long-running construction period. This situation imposes uncertainty factors with considerably high risks. There are several phases from investigation and planning to O & M of the project which can be identified as critical phases in hydropower projects where many unforeseen factors occur. Failure to manage project risks leads to significant problems for the client such as completion time delays and cost overruns.

The purpose of this paper is to identify the risks involved in the development of hydropower projects and their management.

Key words: Hydropower, risk management

1. INTRODUCTION

Renewable energy projects life cycle is full of various risks which will cause cost and schedule overrun or project failure. The data gathered for identification of the highest risk as political and regulatory changes for renewable energy projects in developing countries like India. Similarly, the most important business risk involved is of regulation and compliance. Construction of hydropower plants involves uncertainties because of various external factors such as site geology, grid connection, paucity of funds and environmental issues. These factors increase the construction costs and duration. For example, in one of the hydropower plant in India, namely Maneri Bhali stage-2, the cost of civil works increased because of closure of project due to paucity of funds. Unpredicted geologic structure at the tunneling sites also contributes to the increase in cost. In another example, the Government of India closed two major hydroelectric power projects under construction stage in Uttarakhand, canceling the construction altogether because of the environmental issues namely Lohari Nag Pala and Pala Maneri.
In literatures, there are several examples considering the risk analysis in construction projects but risk analysis in renewable energy projects, especially for hydropower plants is very limited. In classical project risk analysis techniques, risk rating values are calculated by multiplying impact and probability values and direct analysis of these linguistic factors is often neglected. Most existing risk analysis models, such as Monte Carlo simulation and tornado chart, are based on quantitative techniques which require numerical data which is not normally available in the real construction world. However, much of the information related to risk analysis is not numerical. Rather, this information is expressed as words or sentences in a natural language. These conceptual factors can be expressed in linguistic terms that are, so called fuzzy information. Uncertainty factors such as “poor geology” or “unstable policy” fall into this category. The aim of this paper is to introduce a new approach for hydropower projects risk assessment through the fuzzy set concepts.

2. RISK ASSESSMENT

The classes of risk factors, which are mentioned below are based on the expert input, field studies and literature review. The risk factors and their evaluation criteria are listed in Table 1. The risk factors are:

(i) Site geology (geotechnical properties of the construction site),
(ii) Hydrological
(iii) Land use (right to use of the land for the construction of hydropower scheme),
(iv) Environmental issues (impact on ecosystem),
(v) Grid connection (connection to the power system),
(vi) Social acceptance (impact on local community who use the river or the surrounding lands),
(vii) Financial (the status of the inflation and interest rate),
(viii) Natural hazards (earthquake, flooding and landslide),
(ix) Political/regulatory changes (level of political stability),
(x) Terrorism (human-made disasters),
(xi) Access to infrastructure (road, electricity and water),
(xii) Technological
(xiii) Revenue (cash flow).

It should be noted that the financial, political/regulatory changes and terrorism were regarded as risks related to country conditions. In view of experts site geology and environmental issues are the most important risks for hydropower plants.
<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Score (1)</th>
<th>Score (2)</th>
<th>Score (3)</th>
<th>Score (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Geology</td>
<td>Rock mass quality is very good-good: RQD=%60-100</td>
<td>Rock mass quality is fair: RQD=%40-60</td>
<td>Rock mass quality is poor-very poor: RQD=%0-50</td>
<td>Soil with high ground water level</td>
</tr>
<tr>
<td>Hydrological</td>
<td>Project has detailed Hydrological data</td>
<td>Project has Hydrological data</td>
<td>Project has no Hydrological data</td>
<td>Project is in Cloud burst zone</td>
</tr>
<tr>
<td>Land use</td>
<td>Forest property:</td>
<td>Private property:</td>
<td>Agricultural land</td>
<td>Private Residential area</td>
</tr>
<tr>
<td>Project of Treasury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Issues</td>
<td>Project has detailed Environmental Impact Report</td>
<td>Project has Environmental Impact Report</td>
<td>Project has no Environmental Impact Report</td>
<td>Project is in an ecological sensitive area</td>
</tr>
<tr>
<td>Grid Connection</td>
<td>Close to power system</td>
<td>Near to power system</td>
<td>Far to power system</td>
<td>Connection to the power system has some limitations</td>
</tr>
<tr>
<td>Social Acceptance</td>
<td>Project has detailed Social Impact Report</td>
<td>Project has Social Impact Report</td>
<td>Project has no Social Impact Report</td>
<td></td>
</tr>
<tr>
<td>Local community benefit</td>
<td>Financial Economic performance of country is very high</td>
<td>Economic performance of country is high</td>
<td>Economic performance of country is medium</td>
<td>Economic performance of country is low</td>
</tr>
<tr>
<td>benefit from the river or the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>surrounding lands</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Hazards Change in Laws</td>
<td>Low risk Political risk of country is low</td>
<td>Medium risk Political risk of country is medium</td>
<td>High risk Political risk of country is high</td>
<td>Very high risk Political risk of country is very high</td>
</tr>
<tr>
<td>and Regulations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terrorism</td>
<td>Terror risk index of country is low</td>
<td>Terror risk index of country is medium</td>
<td>Terror risk index of country is high</td>
<td>Terror risk index of country is extreme</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Very easy</td>
<td>Easy</td>
<td>Access to Difficult</td>
<td>Very difficult</td>
</tr>
<tr>
<td>Technological</td>
<td>Technical capability is high</td>
<td>Technical capability is Good</td>
<td>Technical capability is low</td>
<td>No Technical capability</td>
</tr>
<tr>
<td>Revenue</td>
<td>Design discharge is high reliable</td>
<td>Design discharge is medium reliable</td>
<td>Design discharge is low reliable</td>
<td>Design discharge is unreliable</td>
</tr>
</tbody>
</table>
3. MANAGEMENT OF RISK

Risk management cycle has been shown in figure 1 below. Risk Management consists of three basic steps:

i. Risk Identification: As discussed above identification can be done by following a structural approach of risk identification into economical, technical, socio-economic and environmental risks.

ii. Risk Analysis: Probabilistic risk analysis, although more complex and costly in terms of analysis time and effort compared to the point estimates, provides a plausible scientific tool to identify and quantify the uncertainties of risk estimates.

iii. Risk Resolution: Risk assessment including risk identification and risk analysis can be used for developing efficient resolution strategies to obtain investor confidence.

![Risk Management Cycle Diagram](image)

**Fig. 1:**

3.1 Risk identification

Risk identification can start with the source of the problem, or with the problem itself. There are a number of techniques which can be used to assist in the identification of risk. Four typical methods are available which are as follows (Hall, 1997):

a) Physical inspection – involving an actual visit to the location of the risk.
b) Flow Charts – used to describe any form of “process” within a project.
c) Fault trees – diagrammatic representations of all the events which may result in loss. They also show the way in which individual events can combine together to produce potentially dangerous situations.
d) Hazard indices – techniques which express the likelihood of a loss as a number, so as to allow the comparison with other similar types of risk.
The identification activities are critical, for any risks that are not discovered are risks accepted. The risk identification process is sufficient when it uncovers the risks and its sources while there is time to take action (Hall, 1997).

![Diagram of Types of Risk](image)

**Fig. 2:**

There are many different risks existing which should be subdivided into tangible (quantitative) and intangible (qualitative) features. 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). Figure 2 shows the classification of risks and it is important to mention that this is a selection – and not a complete list – of possible risks facing 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.

At project selection stage concern lies with the reliability of feasibility studies, economic forecasts and environmental impacts, for example flood risk, noise risk, water quality issues or fish impact. In the financing stage the risks are political and economic stability, government commitment to policy, reliability of cost estimates and revenue projections; and financial measures, for instance currency and interest rate. After necessary permissions for development there are further risks during the construction period including completion risk, cost overruns risk, meeting environmental obligations, political and other forces majeures, changes in taxation and in law. In the operation and maintenance stage, risks include weather risk, for example the availability of water, price risk, breakdown risk, inflation risk, changes in taxation and in law, political and other forces majeures, technical performance risk, damage to third party, risk of innovation and finding costs higher than planned. To sum up, it is important to consider risks through all stages of the product life-cycle.

### 3.2 Risk analysis

After the risks are identified they must be individually assessed as to their potential probability and consequence (Borge, 2001). If historical data is available, the projections made are more likely to reflect what could actually happen. However, it is important to handle this information with care, as many forecasts based solely on past data have been inaccurate or inadequate. If there is no historical information, estimates must be based on experience,
knowledge or comparisons with similar cases, or effort must be expended to increase the certainty of the information (Vose, 1996).

Jensen et al. (2000) presented a selection of diverse methods of risk analysis which can be classified as follows:

1. Intuitive approach: Add an item for “unforeseen costs” (the traditional approach for accounting risk)
2. Sensitivity analysis (probably the most common way of handling project risk in practice)
3. Statistical methods, for example probabilistic risk analysis using the Monte-Carlo Simulation (MCS) method.

The obvious disadvantage of the “Intuitive approach” is that the estimate depends solely on subjectivity and refers to just one item which is inaccurate. The disadvantages of the second approach “Sensitivity analysis” are the assumption of linearity and the limitation of modeling dependency and interactions. An advantage is that the analysis shows easily those items which may strongly affect the profitability of the project or not. On the other hand, the different parameters or assumptions are treated one by one but the sum of effects is seldom considered (Vose, 1996). In contrast, the third approach “Statistical methods” is able to resolve the shortcomings of the sensitivity analysis by the joint consideration of a series of possible variations for each and every variable that affects the profitability. White et al. (1998) stressed that this approach gives a measure of the variability around the investment outcome based on the expected cash flow, which is an important consideration in the comparison of alternative investments. Furthermore, they stated that the use of probability distribution assuming uncertainty approximates the “real world” conditions better rather than just the single-estimate approach, which implies that conditions of certainty exist.

The profitability of the hydropower plant is highly sensitive regarding the running hours per year and the total investment cost. These factors both depend on the availability of water. Therefore, we focus on weather risk through variation of rainfall and the choice between alternative technologies.

When using a risk analysis method with the Monte-Carlo-Simulation (MCS), it is possible to take interdependency into account. Before the simulation can be carried out the analyst must make a model of the project. This model must include all relevant cost and revenue items and their interdependency. The real problem is to assess the expected value and probability distribution of each item, and to evaluate their interdependency. If it is assumed that all variables are independent.

The three steps of probabilistic risk analysis using the MCS method are as follows:

1. Identification of the variables that determine profitability. In the case of the qualitative consideration of investing in run of river type hydropower project, the key variable is the weather risk measured as variability around the mean value of the flow data.
2. Calculation of the probability functions of the aforementioned variable. Begin with available historical flow data and describe the flow variation by using the log-normal or the Gumbel distribution.

3. Starting the Simulation: A risk analysis model provides information on the relationship between the parameters, showing the distributions of possible outcomes by using randomly selected sets of values as input parameters to simulate possible outcomes.

3.3 Risk resolution

Once the risks have been identified and analysed, a decision needs to be taken as to how they are to be controlled. Possible courses of action to reduce risk should be identified along with the benefits and costs of each course of action. Several risk resolution strategies includes risk acceptance, avoidance, reduction, research and transfer. Applications of the aforementioned strategies are:

As an example for risk transfer, which is a strategy to shift the risk to another person, group, or organization, they explained that construction risks can best eliminated by a `fixed timescale turnkey contract. Another strategy is risk reduction through mitigation, prevention, or anticipation. In the case of hydropower projects, the risk of price uncertainty can be reduced through power purchase agreements, for example the feed-in tariff (EEG) in Germany reduces risk and stimulates development. Further dynamic performance risk can be mitigated by analysing the present performance of previous projects of a chosen project developer. This risk strategy is called risk research which helps to obtain more information through investigation.

As shown in Figure 2, some of the risks facing a hydropower project can be resolved through insurance cover. However, for weather risk there is no insurance cover available. Therefore, it is important to analyse and to reduce this type of risk by an accurate planning process.

During geological clearances strict measures should be taken to avoid construction of any project in geological unstable area.

Sometimes these risks are taken knowingly and technical experts try to compensate it with the increased cost of project but that is calculated and should be strictly adhere to the technical standards. In case of economic risk funds can be arranged from different financial institutions.

4. CONCLUSIONS AND DISCUSSION

The risks affect, what is most important to owners and operators alike, the profitability. Detail planning of risk identification, analysis and their resolution can eliminate the chances of time and cost over-run in a hydropower project. The planning should cover the entire project life cycle i.e. from investigation till operation & maintenance. Proper contract agreement can eliminate losses due to risks involve during construction stage. Power purchase agreement
should be based on availability base tariff i.e. higher will be tariff in peaking hours. Proper site selection can eliminate chances of damage due to extreme weather conditions because most of the hydropower projects are located in hilly regions.

The statistical simulation methods are better suited to analyse risks of hydropower projects as they allow us to calculate the density function of profitability directly from the probability distributions for historical flow data. This method provides comprehensive knowledge on the projects; improve the quality of the decisions that are made and increase confidence in the decision. The key to risk management is to be aware of all kinds of risk and to develop a plan to eliminate or minimise them in a cost-effective manner.

All risk mentioned in this paper can be managed with the WILL of all stakeholders such as developer, contractor, local administration and local people.

5. REFERENCES