Risk Assessment of Power Project Development in India using Fuzzy Synthetic Evaluation

Garikipati Venkateswara Rao[a], Prof. A. Sreeram[b]

[a] 1Research Scholar, Department of Management, GITAM (Deemed to be University), GITAM-HBS, Hyderabad Campus
[b]Professor, Department of Management, GITAM (Deemed to be University), GITAM-HBS, Hyderabad Campus
Email ID: [a]jeevirao1961@gmail.com

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Abstract: Post the economic reforms of 1991, there was an enhanced participation from private sector in the development of power projects in India. Development of power projects is a complex process in India with involvement of several stakeholders. Consequently there are several risks associated with the project at varied levels. Diverse stakeholders can bring about unforeseen conflicts which can hinder the successful completion of projects. As of year 2017, about 34 coal based power projects have been identified as stressed assets. Nearly 40% of the stressed capacity is still under development. This scenario points to the need of a proper risk assessment. The risk assessment for development of power projects often involves multiple variables and is fuzzy in nature and hence, it is appropriate to adopt the fuzzy synthetic evaluation method for risk assessment. This paper used the fuzzy synthetic evaluation model for assessing the risk level in development of power projects in India by analyzing several risk factors and risk groups based on the perceptions of experienced power sector professionalsi

Keywords: Power Projects, Risk assessment, Fuzzy synthetic evaluation, India

1. Introduction

The installed capacity of power stations in India is around 382GW as on 31st March 2021 (Central Electricity Authority). Around 62% of the total installed capacity comes from thermal power plants. The 1991 economic reforms provided the much needed impetus to the pace of capacity addition. Prior to the reforms, almost the entire installed capacity was from the Government sector. The cost of electricity was always a sensitive issue both socially & politically and hence, there were very few private sector participants in the generation of power. However, the Government alone could not meet the peak demand and the generation always fell short. After private sector including foreign capital was permitted in power generation, the installed capacity has grown by more than five times (Central Electricity Authority). Most of the capacity addition had come from the private sector during this period. The notification of Electricity Act 2003 further increased the addition of capacity by bringing in the private sector. Private sector accounts for nearly 47% of the total installed capacity as on 31.03.2021 (Central Electricity Authority). Between 2007 and 2009, four Ultra Mega Power Plants (UMPPs) were awarded to private sector companies. However, after considerable delay and cost escalation, only two UMPPs could be commissioned till date (Central Electricity Authority). Many large projects have stalled during the development stage or sometimes during operational stage due to the delay encountered in development stage and consequent cost escalation. These stalled projects turn into non-performing assets. As of year 2017, about 34 coal based power projects have been identified as stressed assets (Energy, 2018). Nearly 40% of the stressed capacity is still under development. This scenario points to the need of a proper risk assessment. There can be several factors which can lead to time and cost overruns. PMI and KPMG in India, 2019 noted that 345 projects have incurred a cost overrun of INR 2.19 lakh crore and 354 projects have an average delay of 45 months in India as on January 2018 as per the Ministry of Statistics and Programme Implementation (MoSPI) project database. Multiple factors contribute to the reported overruns. Several researchers tried to identify the reasons for such overruns and suggested methods for risk assessment & mitigation.

2. Literature Review

(Yelin, C, & Y, 2010) tried to develop a fuzzy synthetic evaluation model for determining an equitable risk allocation between the government and the private sector for PPP projects. Investment in thermal power project faces many risks due to the complicated international economic environment. **(Xu, Yeung, Chan, Chan, Wang, & Ke, 2010)** developed a fuzzy synthetic evaluation model for evaluating the risk level associated with PPP highway projects in China. The risk assessment was based on analysis of 17 critical risk factors and the empirical research findings revealed that the overall risk level of PPP highway projects are risky. Government interference and corruption were found to be the major hurdle to the success of PPP highway projects in China.

(Sharma & Goyal, 2014) note that it was very difficult to develop quantitative model for Indian conditions due to the lack of data and proposed to model the risk assessment using fuzzy set theory. **(Dinakar, 2014)** focused on study of core factors that caused delays and analysed the day-to-day records in a construction project. Improper communication between the involved parties was identified as the major problem.

(Zhao & Li, 2015) studied the risk factors in UHV power construction projects in China and concluded that the risk assessment methods which are traditionally used may not yield good results due to the unforeseen issues which are common in such projects. A risk evaluation index and model was using fuzzy comprehensive evaluation method.

(Deshpande & Rokade, 2017) assessed the overall risk index associated with Public Private Partnership Highway Projects in India by using a fuzzy synthetic evaluation model. Diverse stakeholders can cause hindrances in the smooth implementation of such highway projects.

Construction projects are the fuel for economic growth of any nation. Construction projects in India too face time overruns which is a global phenomenon **(Prasad, Vasugi, Venkatesan, & Bhat, 2018)**. Financial related causes were found to be the most critical causes of delay in different type of projects. **(Kage, Mane, Chougule, Kadam, & Majale, 2018)** write that delays and escalation in cost are the major issues encountered by construction projects in India and the most influential factors in India for overruns are poor monitoring and communication, improper estimation of cost, lack of experience of contractor etc.

(Baruah & Kakati, 2019) developed fuzzy logic modules for finding the risk probabilities is large projects executed through the Public Private Partnership (PPP) mode in India.

3. Research Gap

These research studies indicate that adoption of fuzzy synthetic evaluation (FSE) methodology for risk assessment has merits in handling complex risk environment with multiple attributes at multiple levels. A fuzzy synthetic evaluation model has been used in the present study for identification of overall risk index associated with development of Power Projects in India. This research study will enable the power sector stakeholders to better understand and evaluate the risks associated with development of power projects in India.

4. Research Methodology

Based on the literature survey, a list of risks was prepared. The risk list was shared with other experts and after consultation, a total of 67 risks were identified for inclusion in the survey. The risks were grouped under seven categories as in Table-4.1. The study covered the lifecycle of the power project from conceptualization to commissioning.

For each of the 67 risks, the respondents were asked to rate the probability of occurrence of the risk or the risk frequency on a Likert scale of 1 to 5. Similarly, the respondents were also asked to rate the impact of the risk if it occurs on the cost and time aspects of the project on a scale of 1 to 5. The survey questionnaire was developed online using the Google Forms tool. The questionnaire was forwarded to power sector professionals with differing backgrounds in order to capture the perceptions holistically. More than 500 professionals were approached for taking the survey and at the closing of the survey, 319 responses were received. After cleaning the data, 310 valid responses were recorded and used for the fuzzy analysis. The respondents were from all power sector professionals with varying backgrounds and experience. The details of respondents are summarized in Table-4.2. The respondents are a group with a good mix of managerial capabilities which is beneficial for the research study and can present a truthful picture of the risk perception at across the different management levels.

Table 4.1: List of risks identified for the survey

Design Risks	Construction Risks	Financial Risks	Legal Risks	Procurement Risks	Regulatory Risks	Safety Risks
D.1 Incomplete or inaccurate cost estimate	C1. Tight project schedule	F.1 Price inflation of construction materials	L.1 Occurrence of disputes/litigation	P.1 Equipment quality/Defective manufacturing of main components of the plant	R.1 Excessive approval procedures in administrative government departments/ Bureaucracy of government	S.1 General safety accident occurrence
D.2 Inadequate or insufficient site information/investigation	C.2 Inadequate project scheduling	F.2 Fluctuation in interest rates	L.2 Labour strike/disputes	P.2 Material Delivery	R.2 Serious noise pollution caused by construction	S.2 Natural disasters/ adverse environmental conditions

D.3 Improper project feasibility study	C.3 Making variations in construction program	F.3 Low credibility of shareholder & lender	L.3 Land acquisition	P.3 Material shortage	R.3 Delay in permits and licenses	S.3 Material theft & damage
D.4 Time constraint (Too little time is provided for design and estimation)	C.4 Low management competency of sub-contractors	F.4 Change in bank formalities and lenders	L.4 Resettlement & rehabilitation	P.4 New technology	R.4 Changes in laws and regulations	S.4 Accidents during commissionin g
D.5 Inadequate design due to improper selection of consultants/engin eering team	C.5 Site location	F.5 Insurance Risk	L.5 Pollution and safety rules	P.5 Nominated vendors/poor supplier base	R.5 Political conflicts	
D.6 Incomplete specifications	C.6 Design changes)	F.6 Payment delay/Invoice delay	L.6 Bribery/Corrup tion	P.6 No past experience in similar project	R.6 Fuel allocation risk	
D.7 Effect on terrestrial flora & fauna which can impact the design freedom	C.7 Change in top management	F.7 Owner financial capacity/Paucity of funds/Funding risk	L.7 Law and order/social unrest	P.7 Short tender time	R.7 Environmental clearances.	
D.8 Poor design for construction	C.8 Quality of work	F.8 Tax rate/Exchange rate variation	L.8 Lack of enforcement of legal judgment/Unce rtainty and unfairness of court justice	P.8 Type of contract	R.8 Change in fiscal schemes	
	C.9 Damage of major equipment	F.9 Market risk/ Reduction in Power Demand/ Economic crisis: Impact on energy consumption	L.9 Local laws/customs	P.9 Improper verification of contract document	R.9 Change in policy	
	C.10 Contractual risks	F.10 PPA Risk	L.10 Right of way issues	P.10 Order of wrong specifications from manufacturers		
	C.11 Linkages of rail, road, water, fuel and power evacuation	F.11 Financial market instability/Credit risk		P.11 Contractors capacity		
	C.12 Force-majeure conditions	F.12 Financial Closure		P.12 Obsolescence of infrastructure		

Table 4.2: Background details of survey respondents

1) Position in the Organization			
Category	Top management/Strategic decision	Senior Management/Project In-	Line Manager

	making			charge				
Percentage	27.7			49			23.3	
2) Educational Qualification								
Category	Graduate			Post graduate			Doctorate	
Percentage	47.7			47.7			4.6	
3) Number of years of work experience								
Category	Less than 10 years		10 to 20 years		20 to 30 years		More than 30 years	
Percentage	2.9		22.6		33.9		40.6	
4) Type of organization								
Category	Project Developer	Lender/ Financial Institution	EPC Contractor	Government authority/ regulatory authority	State Utility	Social Sector/ NGO	Project Engineering Consultant	Others
Percentage	19.0	1.9	23.5	5.2	9.4	1.0	14.5	25.5
5) Type of projects								
Category	Coal based power projects	Renewable Energy Projects (Solar/Wind)		Gas based Power Projects		Combination of all three projects		Others
Percentage	35.5	3.9		1.3		31.9		27.4

5. Fuzzy Synthetic Evaluation

Fuzzy synthetic evaluation is a method to assess multiple criteria decision making. In this study, it is used to calculate the Risk Index (Probability and Impact) of a particular Risk Group and Overall Risk Index (ORI) of power project development. The process of fuzzy synthetic evaluation is shown in Figure 5.1. A fuzzy synthetic evaluation model requires three basic elements (Xu, Yeung, Chan, Chan, Wang, & Ke, 2010).

1. A set of basic criteria/ factors $\Omega = \{r_1, r_2, r_3, \ldots, r_j\}$. In the present study, the basic criteria are the risk factors such as D1 = Incomplete or inaccurate cost estimate, C1 = Tight project schedule, F1= Price inflation of construction materials etc.

2. A set of grade alternatives $C = \{c_1, c_2, c_3, c_4, c_5\}$e.g c_1= very low; c_2=low; c_3=moderate; c_4=high; c_5=very high. (for both risk probability and risk impact). In this study, risk assessment i.e. the rating of risk severity of a particular risk factor is result of the product of risk probability and risk impact (Xu, Yeung, Chan, Chan, Wang, & Ke, 2010). Sl.No.1 & 2 form the inputs.

3. For every object v Ɇ V (which means fuzzy subset v does not belong to fuzzy set V), there is an evaluation matrix $E = (e_{ij})_{mxn}$. In the fuzzy environment, e_{ij} is the degree to which alternative c_j satisfies the criteria r_j. With the preceding three elements, for a given v Ɇ V, its evaluation result can be derived. This model is the processor.

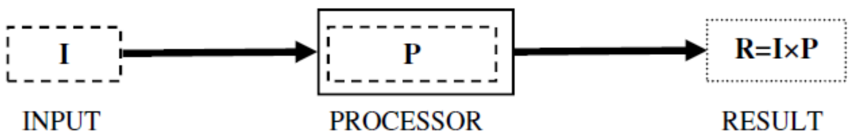

Figure 5.1: Fuzzy synthetic evaluation model (Xu, Yeung, Chan, Chan, Wang, & Ke, 2010)

5.1 Calculation of Weightages

In the present study, 67 risks associated with power project development were identified. All the 67 risks were grouped into 7 identified Risk Groups for assessment of the overall risk level of power project development in India. On the basis of the research conducted the weightages for each of the 67 Risk Factors and 7 Risk Group were calculated. A set of knowledge-based fuzzy inference rules was then established to set up the membership function for the 67 Risk Factors and 7 Risk Group. The weightage of each Risk Factor and Risk Group on basis of responses from the survey is calculated. The weightage of the identified 67 risk factors and 7 groups is calculated by using the Eqn.1 ((Chow, 2005); (Yeung, Chan, Chan, & Li, 2007)).

$$Wi = \frac{Mi}{\sum_{i=1}^{5} Mi} \qquad \text{...Eqn.(1)}$$

Where, Wi- weightage of a particular risk factor and risk group,

Mi - mean of probability or severity of risk factors, ΣMi - summation of mean of probability or severity.

The mean rating is calculated by the summation of the individual ratings provided by the survey respondents divided by the total number of respondents who provided the ratings. The mean rating is calculated for both probability and impact separately. The mean rating of each critical risk factor is calculated by Eqn.(1) whereas rating of each critical group is calculated by ratio of summation of mean of all the factors in a group to summation of the mean of all groups.

The weightage of each risk factor is used to determine the membership function of each risk group and weightage of each risk group is used to determine the membership function of overall risk index. The weightage of each risk factor is on the basis of its probability of occurrence and severity and weightage of the identified risk factors were calculated and normalized. Table 5.1.1 shows the weightage of risk factor's and risk group on basis of probability whereas Table 5.1.2 shows weightage on basis of severity for Construction risk group. Similarly, the weightage for all the risk factors and risk groups is derived.

Table 5.1.1: Weightage of risk factors and critical risk groups on the basis of probability of occurrence

Risk	Risk Probability Mean	Risk Weight	Risk Group	Risk Group Weight
C.10 Contractual risks	2.4774	0.08	30.7516	0.19
C.11 Linkages of rail, road, water, fuel and power evacuation	2.6548	0.09		
C.12 Force-majeure conditions	2.1548	0.07		
C.2 Inadequate project scheduling	2.7968	0.09		
C.3 Making variations in construction program	2.8226	0.09		
C.4 Low management competency of sub-contractors	2.9903	0.10		
C.5 Site location	2.4419	0.08		
C.6 Design changes	2.5097	0.08		
C.7 Change in top management	2.1355	0.07		
C.8 Quality of work	2.6129	0.08		
C.9 Damage of major equipment	2.2484	0.07		
C1. Tight project schedule	2.9065	0.09		

Table 5.1.2: Weightage of risk factor's and critical risk groups on the basis of impact

Risk	Risk Impact Mean	Risk Weight	Risk Group	Risk Group Weight
C.10 Contractual risks	3.1935	0.09	37.2258	0.19
C.11 Linkages of rail, road, water, fuel and power evacuation	3.4161	0.09		
C.12 Force-majeure conditions	3.0935	0.08		
C.2 Inadequate project scheduling	3.1839	0.09		
C.3 Making variations in construction program	2.9387	0.08		
C.4 Low management competency of sub-contractors	3.3613	0.09		

C.5 Site location	2.8355	0.08
C.6 Design changes	2.8419	0.08
C.7 Change in top management	2.5452	0.07
C.8 Quality of work	3.2548	0.09
C.9 Damage of major equipment	3.2839	0.09
C1. Tight project schedule	3.2774	0.09

5.2 Developing the Membership functions

Now, assume $\Omega = \{r_1, r_2, r_3, \ldots, r_j\}$ as set of basic criteria in fuzzy risk model and the scale selected were defined as C= $\{c_1, c_2, c_3, c_4, c_5\}$ where c_1= very low; c_2=low; c_3=moderate; c_4=high; c_5=very high.

The risk factors and rating for both risk probability and risk impact were considered. Now, for each risk factor the membership functions were evaluated using the responses from the survey.

For example, for the risk factor C10- Contractual Risks, 21% respondents in the survey opined that there is 10% probability of occurrence, 32% opined that there is 30% probability of occurrence, 30% opined that there is 50% probability of occurrence, 12% opined that there is 70% probability of occurrence and 5% opined that there is 90% probability of occurrence. Therefore the membership function of risk factor C10- Contractual Risks for risk probability is given by Eqn.(2)

$$C10 = \frac{0.21}{very\ low} + \frac{0.32}{low} + \frac{0.30}{moderate} + \frac{0.12}{high} + \frac{0.05}{very\ high} \quad \text{....Eqn.(2)}$$

$$= \frac{0.21}{1} + \frac{0.32}{2} + \frac{0.30}{3} + \frac{0.12}{4} + \frac{0.05}{5}$$

It can be written as {0.21,0.32,0.30,0.12,0.05}

Similarly, for the risk factor C10- Contractual Risks, 7% respondents in the survey opined that there is negligible impact, 20% opined that there is minor impact, 31% opined that there is moderate impact, 28% opined that there is high impact and 13% opined that there is very high impact. Therefore the membership function of risk factor C10- Contractual Risks for risk impact is given by Eqn.(3)

$$C10 = \frac{0.08}{very\ low} + \frac{0.20}{low} + \frac{0.31}{moderate} + \frac{0.28}{high} + \frac{0.13}{very\ high} \quad \text{...Eqn.(3)}$$

$$= \frac{0.08}{1} + \frac{0.20}{2} + \frac{0.31}{3} + \frac{0.28}{4} + \frac{0.13}{5}$$

It can be written as (0.08, 0.20, 0.31, 0.28, 0.13)

Similarly, the membership functions of all risk factors were derived which are shown in Table 5.2.1 for probability and Table 5.2.2 for impact.

Table 5.2.1: Fuzzy membership function for construction risk probability

Risk	**Membership Function**
C.10 Contractual risks	(0.21,0.32,0.30,0.12,0.05)
C.11 Linkages of rail, road, water, fuel and power evacuation	(0.21,0.29,0.24,0.17,0.09)
C.12 Force-majeure conditions	(0.37,0.29,0.20,0.09,0.05)
C.2 Inadequate project scheduling	(0.11,0.29,0.34,0.21,0.05)
C.3 Making variations in construction program	(0.11,0.28,0.33,0.22,0.05)
C.4 Low management competency of sub-contractors	(0.10,0.23,0.35,0.21,0.11)
C.5 Site location	(0.26,0.31,0.19,0.19,0.04)

C.6 Design changes	(0.18,0.34,0.29,0.16,0.03)
C.7 Change in top management	(0.34,0.35,0.19,0.11,0.02)
C.8 Quality of work	(0.18,0.29,0.32,0.15,0.06)
C.9 Damage of major equipment	(0.35,0.29,0.17,0.15,0.05)
C1. Tight project schedule	(0.10,0.26,0.31,0.26,0.06)

Table 5.2.2: Fuzzy membership function for construction risk impact

Risk	**Membership Function**
C.10 Contractual risks	(0.07,0.20,0.31,0.28,0.13)
C.11 Linkages of rail, road, water, fuel and power evacuation	(0.09,0.15,0.24,0.28,0.24)
C.12 Force-majeure conditions	(0.11,0.21,0.31,0.22,0.15)
C.2 Inadequate project scheduling	(0.06,0.22,0.31,0.31,0.10)
C.3 Making variations in construction program	(0.11,0.24,0.33,0.24,0.08)
C.4 Low management competency of sub-contractors	(0.06,0.16,0.29,0.34,0.15)
C.5 Site location	(0.16,0.24,0.28,0.24,0.08)
C.6 Design changes	(0.12,0.27,0.33,0.22,0.06)
C.7 Change in top management	(0.19,0.34,0.29,0.17,0.07)
C.8 Quality of work	(0.08,0.19,0.28,0.29,0.15)
C.9 Damage of major equipment	(0.11,0.15,0.28,0.30,0.17)
C1. Tight project schedule	(0.06,0.18,0.30,0.34,0.12)

The membership functions of all risk groups are derived with the help of the model in Eqn.(4). This model is suitable when many criteria are considered and the difference in the weighting of each criterion is not great (Xu, Yeung, Chan, Chan, Wang, & Ke, 2010).

$M(*,\emptyset), bj = \min\,(1, \sum_{i=1}^{m} wi\ x\ rij)\ \forall bj \in B$ ...Eqn.(4)

Where, b_j is the jth member (c1,c2,c3,c4,c5)

wi is weight of the ith risk factor

rij is the jth member of ith risk factor

The symbol Φ in the model represents the summation of product of weighting and membership function. Membership function of each risk group is determined by applying the weights of each risk factor to their membership functions. For example, Membership Function of Construction Risk group(which contains 12 risks) for Risk Probability is evaluated by applying the weights of each risk factor in Table 5.1.1 to their membership functions in Table 5.2.1.

{0.08x0.21+0.09x0.21+0.07x0.37+0.09x0.11+0.09x0.11+0.10x0.10+0.08x0.26+0.08x0.18+0.07x0.37+0.08x0.18+0.07x0.35+0.09x0.10;

0.08x0.32+0.09x0.29+0.07x0.29+0.09x0.29+0.09x0.28+0.10x0.23+0.08x0.31+0.08x0.34+0.07x0.35+0.08x0.29+0.07x0.29+0.09x0.26;

0.08x0.30+0.09x0.24+0.07x0.20+0.09x0.34+0.09x0.33+0.10x0.35+0.08x0.19+0.08x0.29+0.07x0.19+0.08x0.32+0.07x0.17+0.09x0.31;

0.08x0.12+0.09x0.17+0.07x0.09+0.09x0.21+0.09x0.22+0.10x0.21+0.08x0.19+0.08x0.16+0.07x0.11+0.08x0.15+0.07x0.15+0.09x0.26;

0.08x0.05+0.09x0.09+0.07x0.05+0.09x0.05+0.09x0.05+0.10x0.11+0.08x0.04+0.08x0.03+0.07x0.02+0.08x0.06+0.07x0.05+0.09x0.06**}** = **{**0.20,0.29,0.27,0.18,0.06**}**

Similarly, Membership Function of Construction Risk group for Risk Impact is evaluated by applying the weights of each risk factor in Table 5.1.2 to their membership functions in Table 5.2.2

{0.09x0.07+0.09x0.09+0.08x0.11+0.09x0.06+0.08x0.11+0.09x0.06+0.08x0.16+0.08x0.12+0.07x0.19+0.09x0.08+0.09x0.11+0.09x0.06;

0.09x0.20+0.09x0.15+0.08x0.21+0.09x0.22+0.08x0.24+0.09x0.16+0.08x0.24+0.08x0.27+0.07x0.34+0.09x0.19+0.09x0.15+0.09x0.18;

0.09x0.31+0.09x0.24+0.08x0.31+0.09x0.31+0.08x0.33+0.09x0.29+0.08x0.28+0.08x0.33+0.07x0.37+0.29x0.28+0.09x0.28+0.09x0.30;

0.09x0.28+0.09x0.28+0.08x0.22+0.09x0.31+0.08x0.24+0.09x0.34+0.08x0.24+0.08x0.22+0.07x0.17+0.09x0.29+0.09x0.30+0.09x0.34;

0.09x0.13+0.09x0.24+0.08x0.15+0.09x0.10+0.08x0.08+0.09x0.15+0.08x0.08+0.08x0.06+0.07x0.07+0.09x0.15+0.09x0.17+0.09x0.12**}** = **{**0.20,0.29,0.27,0.18,0.06**}**

The membership functions for all the risk groups have been computed similarly in Table 5.2.3 for Risk probability and Table 5.2.4 for Risk Impact.

Table 5.2.3: Fuzzy membership function of risk groups for risk probability

Risk Group	Weightage	Membership Function for Risk Probability
Design Risks	0.12	(0.27,0.29,0.24,0.15,0.06)
Construction Risks	0.19	(0.20,0.29,0.27,0.18,0.06)
Financial Risks	0.18	(0.23,0.33,0.27,0.13,0.05)
Legal Risks	0.15	(0.29,0.30,0.23,0.13,0.05)
Procurement Risks	0.17	(0.29,0.33,0.23,0.11,0.03)
Regulatory Risks	0.13	(0.27,0.30,0.25,0.13,0.05)
Safety Risks	0.05	(0.38,0.32,0.19,0.08,0.03)

Table 5.2.4: Fuzzy membership function of risk groups for risk impact

Risk Group	Weightage	Membership Function for Risk Impact
Design Risks	0.13	(0.12,0.17,0.25,0.28,0.17)
Construction Risks	0.19	(0.10,0.21,0.29,0.27,0.13)
Financial Risks	0.18	(0.14,0.23,0.30,0.21,0.11)
Legal Risks	0.14	(0.17,0.24,0.29,0.19,0.10)
Procurement Risks	0.18	(0.13,0.24,0.33,0.21,0.10)
Regulatory Risks	0.13	(0.15,0.22,0.29,0.20,0.14)
Safety Risks	0.06	(0.18,0.24,0.28,0.20,0.10)

<u>The membership function for the overall risk probability is similarly evaluated as</u>
{0.12x0.27+0.19x0.20+0.18x0.23+0.15x0.29+0.17x0.29+0.13x0.27+0.05x0.38;
0.12x0.29+0.19x0.29+0.18x0.33+0.15x0.30+0.17x0.33+0.13x0.30+0.05x0.32;
0.12x0.24+0.19x0.27+0.18x0.27+0.15x0.23+0.17x0.23+0.13x0.25+0.05x0.19;

0.12x0.15+0.19x0.18+0.18x0.13+0.15x0.13+0.17x0.11+0.13x0.13+0.05x0.08;
0.12x0.06+0.19x0.06+0.18x0.05+0.15x0.05+0.17x0.03+0.13x0.05+0.05x0.03} = {0.26,0.31,0.25,0.13,0.05}.

The membership function for the overall risk impact is similarly evaluated as {0.13x0.12+0.19x0.10+0.18x0.14+0.14x0.17+0.18x0.13+0.13x0.15+0.06x0.18;
0.13x0.17+0.19x0.21+0.18x0.23+0.14x0.24+0.18x0.24+0.13x0.22+0.06x0.24;
0.13x0.25+0.19x0.29+0.18x0.30+0.14x0.29+0.18x0.33+0.13x0.29+0.06x0.28;
0.13x0.28+0.19x0.27+0.18x0.21+0.14x0.19+0.18x0.21+0.13x0.20+0.06x0.20;
0.13x0.17+0.19x0.13+0.18x0.11+0.14x0.10+0.18x0.10+0.13x0.14+0.06x0.10} = {0.14,0.22,0.29,0.23,0.12}.

From the membership function, the overall risk index for probability and overall risk index for impact are evaluated as below.

- ☐ Overall Risk Index for probability = 0.26*1 + 0.31*2 + 0.25*3 + 0.13*4 + 0.05*5 = 2.40
- ☐ Overall Risk Index for impact = 0.14*1 + 0.22*2 + 0.29*3 + 0.23*4 + 0.12*5 = 2.97

The Overall Risk Index for the project is evaluated by taking the product of risk probability and risk impact as in Eqn.(5).

$$Overall\ Risk\ Index = \sqrt{Risk\ Probability\ \times Risk\ Impact} \qquad \text{--- Eqn(5)}$$

The Overall Risk Index for the project is thus calculated as √2.40*2.97 which is equal to 2.67. The Risk indices for the risk groups are also similarly calculated and given in Table 5.2.5.

Table 5.2.5: Risk Index for different risk groups

Risk group	Risk Index (Probability)	Risk Index (Impact)	Overall Risk Index
Design risks	2.47	3.18	2.80
Construction risks	2.61	3.12	2.85
Financial Risks	2.47	2.89	2.67
Legal Risks	2.35	2.78	2.56
Procurement Risks	2.23	2.94	2.56
Regulatory Risks	2.39	2.96	2.66
Safety Risks	2.06	2.80	2.40

The analysis was also carried out for the various respondent groups to verify whether there is any difference in the overall risk perception. The results are given in Table 5.2.6.

Table 5.2.6: Risk Index for different groups of respondents

Respondents' group	Overall Risk Probability	Overall Risk Impact	Overall Project Risk Index
Coal based power plants	2.36	2.87	2.60
Project Developer	2.51	3.12	2.80
EPC Contractor	2.47	3.05	2.74
Project Engineering Consultant	2.41	3.02	2.70
10 to 20 years work experience	2.45	2.97	2.70
20 to 30 years work experience	2.44	3.05	2.73
More than 30 years work experience	2.29	2.83	2.55

6. Conclusion

The Fuzzy synthetic evaluation of the overall risk level for the project, based on the responses from the survey, is arrived as 2.67 which indicate a slightly moderate level of risk in undertaking the projects. It can be seen from Table 5.2.5 that the risk level is the highest for construction risk group followed by design risks and financial risks. Safety risks carry the lowest level of risk compared to other risk groups. This indicates a greater confidence amongst power sector professional with respect to safety aspects. Project developers and investors have to concentrate on design risks and construction risks in order to ensure success of the project. From table 5.2.6, it can be understood that the Project Developers perceive higher risk level compared to other groups of respondents. The risk assessment by people with greater work experience is lower. The results show that development of power projects involves only moderate level of risk and the projects can be successfully completed if a proper risk management exercise is conducted with the involvement of experienced professionals.

References

1. Baruah, P., & Kakati, M. (2019). Developing some Fuzzy Modules for finding Risk Probabilities in Indian PPP Projects. World Conference on Transport Research (pp. 3939-3968). Mumbai: Elsevier B.V.
2. Central Electricity Authority. (n.d.). Detailed status of UMPP. Retrieved October 7, 2020, from Central Electricity Authority: https://cea.nic.in/reports/others/thermal/umpp/detailed_status_umpp.pdf
3. Central Electricity Authority. (n.d.). Growth of Electricity Sector in India from 1947-2019. Retrieved October 6, 2020, from Central Electricity Authority: https://www.cea.nic.in/reports/others/planning/pdm/growth_2019.pdf
4. Central Electricity Authority. (n.d.). Monthly installed capacity. Retrieved May 18, 2021, from Central Electricity Authority: https://cea.nic.in/wp-content/uploads/installed/2021/03/installed_capacity.pdf
5. Chow, L. (2005). Incorporating fuzzy membership functions and gap analysis concept into performance evaluation of engineering consultants. The University of Hong Kong.
6. Deshpande, P., & Rokade, S. (2017). ASSESSMENT OF RISKS IN PUBLIC PRIVATE PARTNERSHIP HIGHWAY PROJECTS IN INDIA USING FUZZY SYNTHETIC EVALUATION. International Journal of Civil Engineering and Technology, 401-413.
7. Dinakar, A. (2014). Delay Analysis in Construction Project. International Journal of Emerging Technology and Advanced Engineering, 4(5), 784-788.
8. Energy, S. C. (2018). Stressed /Non-performing Assets in Electricity Sector. Ministry of Power. New Delhi: Lok Sabha Secretariat.
9. Kage, S. A., Mane, M. R., Chougule, A. M., Kadam, A. V., & Majale, R. S. (2018). Time Delay and Cost Overrun in Construction Industry of India. International Journal of Innovative Research in Science,Engineering and Technology, 7(12), 11943-11948.
10. Khoshgoftar, M., Bakar, A. H., & Osman, O. (2010). CAUSES OF DELAYS IN IRANIAN CONSTRUCTION PROJECTS. The International Journal of Construction Management, 10(2), 53-69.
11. PMI and KPMG in India. (2019). Revamping Project Management. PMI and KPMG.
12. Prasad, K. V., Vasugi, V., Venkatesan, R., & Bhat, N. S. (2018). Critical causes of time overrun in Indian construction projects and mitigation measures. International Journal of Construction Education and Research.
13. Sharma, S., & Goyal, P. K. (2014). COST OVERRUN FACTORS AND PROJECT COST RISK ASSESSMENT IN CONSTRUCTION INDUSTRY - A STATE OF THE ART REVIEW. International Journal of Civil Engineering, 139-154.
14. Xu, Y., Yeung, J. F., Chan, A. P., Chan, D. W., Wang, S. Q., & Ke, Y. (2010). Developing a risk assessment model for PPP projects in China — A fuzzy synthetic evaluation approach. Automation in Construction, 929-943.
15. Yelin, X., C, C. A., & Y, Y. J. (2010). Developing a Fuzzy Risk Allocation Model for PPP Projects in China. JOURNAL OF CONSTRUCTION ENGINEERING AND MANAGEMENT, 136(8), 894-903.
16. Yeung, J., Chan, A., Chan, D., & Li, L. (2007). Development of a partnering performance index (PPI) for construction projects in Hong Kong: a Delphi study. Construction Management and Economics, 25(12), 1219-1237.

17. Zhao, H., & Li, N. (2015). Risk Evaluation of a UHV Power Transmission Construction Project Based on a Cloud Model and FCE Method for Sustainability. sustainability, 2885-2914.