Risks in Public and Private Partnership Projects –Identification and Prioritization

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ABSTRACT

Infrastructure is an important sector which contributes to the growth of overall development of the nation. Recently, Public Private Partnerships (PPP) has become the key factor to facilitate this development. Due to long concession periods and large investments, the risk management plays a crucial role in these types of projects.

This thesis deals with the risk quantification and risk allocation of PPP projects using a fuzzy based questionnaire survey. Fuzzy logic can express and handle vague or imprecise judgments mathematically and therefore can effectively deal with errors due to human subjectivity. 20 risk factors in PPP projects are summarized from a comprehensive literature review. Interdependencies among the main risk factors affecting PPP projects are assessed using fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach. Sub risk factors are prioritized using a fuzzy hybrid method involving fuzzy Failure Mode and Effect Analysis (FMEA) and fuzzy Analytic Hierarchy Process (AHP) method. The obtained results have shown that approvals and permits, construction cost overrun, construction time overrun and land acquisition risks are the key risks affecting PPP projects.

***Key Words*: Public Private Partnership Projects; Risk Management; Fuzzy Logic; Failure Mode and Effect Analysis; Decision Making Trial and Evaluation Laboratory; Analytic Network Process.**

1. INTRODUCTION

PPP is contractual partnership between the public and private sector agencies, specifically targeted towards financing, designing, implementing and operating infrastructure facilities and services. Moreover, PPP contributes to better quality and performance of infrastructure projects. Though PPP projects provide a good return in investment, risk involved in such projects is very significant. The risks need to be thoroughly analyzed, researched and managed to minimize disputes and costs and maximize the value for money. Risk management involves risk planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, risk monitoring and control. Quantitative analysis of risks in PPP projects provides a very clear picture on the most prominent risk groups. This study uses a fuzzy based risk assessment approach to quantify risks occurring in PPP projects. A questionnaire survey was conducted among professionals working in PPP projects and responses of 24 experts are used for the analysis.

When making decisions in a fuzzy environment, the result of decision-making is highly affected by subjective judgments that are vague and imprecise. To solve this kind of imprecision problem, fuzzy set theory was first introduced by L. A. Zadeh (1965) as a mathematical way to represent and handle vagueness in decision-making. The concepts of fuzzy set theory are essential to accounting for the uncertainty and fuzziness of realistic environments. Research subjects are allocated a value between 0 and 1 to indicate their fuzzy degree. People's subjective judgments are convertedinto numbers In particular, to tackle the ambiguities involved in the process of linguistic estimation, it is a beneficial way to convert these linguistic terms into fuzzy numbers. A linguistic variable is a variable whose values have the form of phrases or sentences in a natural language. Especially, linguistic variables are used as variables whose values are not numbers but linguistic terms. The linguistic term approach is a convenient way for decision makers to express their assessments. For dealing with the ambiguities of human assessments, the linguistic variable "influence" is used with different linguistic terms like very high, high, low etc. each of which are expressed in fuzzy numbers. A fuzzy hybrid method involving fuzzy Failure Mode and

Effect Analysis (FMEA), fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) and fuzzy Analytic Hierarchy Process (AHP) is employed for the purpose.

DEMATEL, originally developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between 1972 and 1976, is used for researching and solving the complicated and intertwined problem group. DEMATEL method allows to explore interrelationships between factors and to develop a cause effect diagram. The main advantage of fuzzy integrated DEMATEL is to consider fuzziness involved in human decision making. Fuzzy DEMATEL is used in this study to find the interdependencies between the main risk groups such as financial risks, legal risks, political risks etc.

AHP is a widely used multi-criteria decision-making tool originally developed by Prof. Thomas L. Saaty. AHP uses pair-wise comparisons which allow verbal judgments and enhances the precision of the results. It is suitable to use fuzzy AHP to assess the risks of PPP projects, which will encounter many uncertainties during the long concession contract period and have multiple objectives originating from project stakeholders (Li and Zou, 2011).

Failure Mode and Effect Analysis (FMEA) is a tool for identifying potential modes of failure in asystem, evaluating the main causes, determining the impact of failures and formulating preventive measures (Mohammadi and Tavakolan, 2013). In this system, a Risk Priority Number(RPN) for each risk is calculated as the product of the probability of risk occurrence (O), severity (S) and detection (D). In traditional FMEA, the relative importance ofO, S and D is not taken into account and RPN value may not truly represent the actual scenario. Fuzzy FMEA is used to overcome these drawbacks. Results of both fuzzy FMEA and fuzzy AHP technique are taken to rank the risk factors.

2. REASEARCH METHODOLOGY

The research methodology adopted is demonstrated in Fig. 1 and is based on a comprehensive literature review, and comprehensive questionnaire survey for data collection.

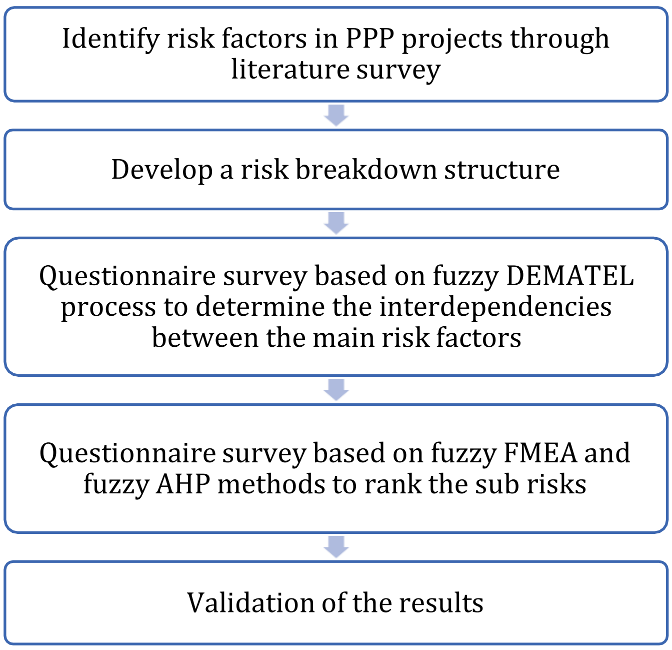

Fig.-1: Research Methodology

3. RISK IDENTIFICATION AND RISK BREAKDOWN STRUCTURE

The main risk factors and sub risk factors under each main risk in PPP projects identified were through literature survey Those factors that have been repeatedly identified in the literature as critical were only taken up for further analysis. 5 projects are taken to correlate the results of the literature review with the actual scenario in India. The projects were taken from Public Private Partnership Projects in India: Compendium of Case Studies. The case studies provided a representation across various locations and various types of PPP projects. The risk breakdownstructure formed is given in Fig.2.

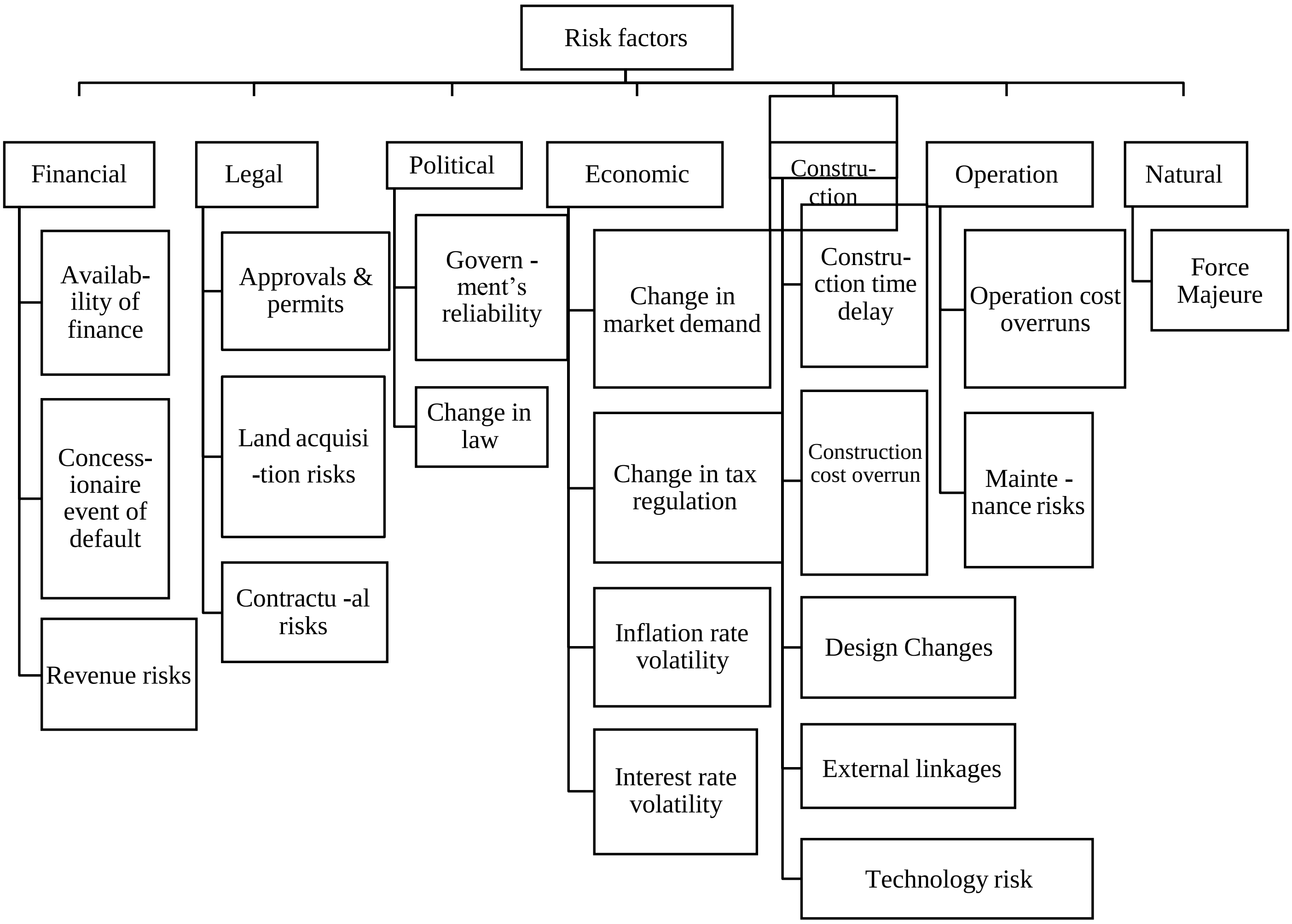

Fig.- 2: Risk Breakdown Structure

4. ANALYSIS OF MAIN RISK FACTORS

DEMATEL is applied to determine effect and cause criteria, and to obtain the model in terms of linguistics parameterized with fuzzy numbers. Fuzzy DEMATEL method can be applied to problems that require group decision-making in a fuzzy environment. The procedure for fuzzy DEMATEL analysis to find the cause and effectrelationship between the main factors is given below (Tzeng *et al.*, 2007 and Luthra *et al.*, 2016).

Step 1: Respondents are asked to indicate the direct influence that they believe each main risk factor exerts on each of the others according to an integer scale ranging 0 - 4 and then the responses are entered into a matrix asfuzzy numbers.

Step 2: Defuzzify the TFNs in the matrices into crisp scores (center of area method) to obtain defuzzified DEMATEL response matrix.

Step 3: Compute the average matrix,X from all 24 responses Each element of this average matrix will be in this case the mean of the same elements in the different defuzzified response matrices of the respondents.

Step 4: Calculate the initial direct relation matrix. The initial direct relation matrix, N can be obtained by normalizing the average matrix X. The initial influence which an element exerts and receives from another can be read from matrix N. Matrix N portrays the interrelationships among the elements.

Step 5: Calculate the direct/indirect relation matrix T, which is also called the total relation matrix. A continuous decrease of the indirect effects of problems along the powers of the matrix N (N^2, N^3, . . . , N^∞) guarantees convergent solutions to matrix inversion.

$$T = \lim (N + N^2 + \cdots + N^k) = (1 - N)^{-1} \quad (1)$$

Step 6: Calculate the sum of the values in each column and each row. This step entails summing the values of each column and row in the total relation matrix, where D_i is the sum of the i^{th} row and Rj is the sum of the j^{th} column.

Step 7: Let i=j; D_i = D and R_i = R. A causal diagram can be acquired by mapping the dataset of (D + R, D - R), where the horizontal axis (D + R) is made by adding D to R, and the vertical axis(D - R) is made by subtracting D from R. In this step, (D + R) is defined as prominence and (D –R) is defined as relation. "Prominence" shows how important the criterion is, whereas "Relation" may divide the criteria into the cause and effect groups. When the value (D-R) is positive, the criterion belongs to the cause group. If the value (D-R) is negative, the criterion belongs to the effect group. Prominence and Relation values are provided in Table 5.7.

Table-1: Prominence and Relation Values

Factors	D	R	minenceD+R	lationD-R
Financial Risks	2.356	3.259	5.615	-0.903
Legal Risks	1.879	1.990	3.869	-0.111
Political Risks	3.010	1.646	4.656	1.364
Economic Risks	2.813	1.993	4.806	0.820
Construction Risks	2.139	3.217	5.356	-1.078
Operation Risks	2.053	2.229	4.282	-0.176
Natural Risks	2.357	2.273	4.630	0.084

As we move along the horizontal axis of the cause effect diagram the prominence of the factors increases. From the causal diagram (Fig 5.2), it can be inferred that financial risks are the most prominent risk group closely followed by construction risks. The horizontal axis separates the cause group risks and effect group risks. Fig.

5.2 reveals that political risks, economic risks and natural risks are the cause group risks and financial risks, legal risks, construction risks and operation risks are the effect group risks. The cause group risks trigger the other risks. Political risks are the major cause group risks and hence political risks should be given due considerations in the risk management process. Construction risks and political risks are easily affected by other risks.

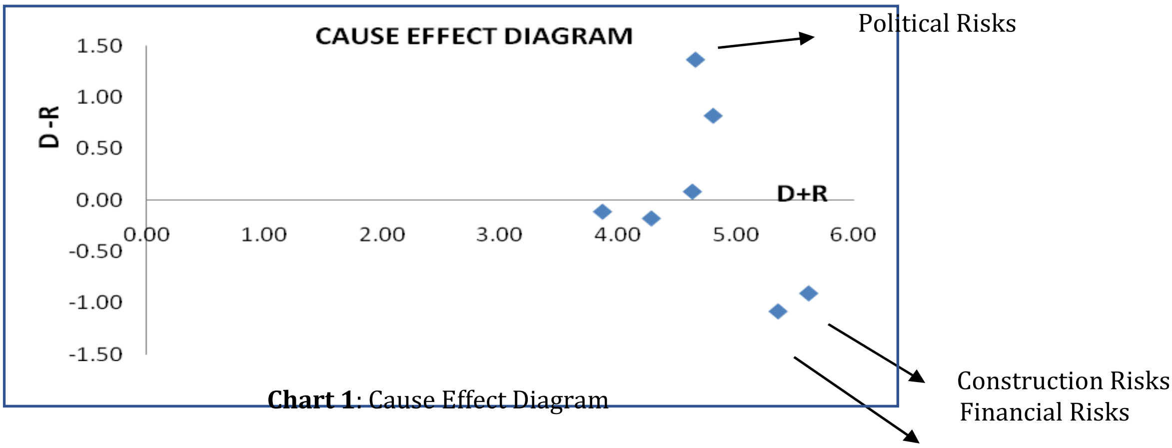

Chart 1: Cause Effect Diagram

5. ANALYSIS OF SUB RISK FACTORS

A fuzzy hybrid method involving Fuzzy FMEA and Fuzzy AHP (FAHP) methods was adopted to prioritize sub riskfactors in PPP projects. FMEA takes into consideration the severity, frequency of occurrence and likelihood of detection of a particular risk factor while AHP explores the relative importance of the risk factors. The integration of fuzzy theory will help to reduce errors due to human subjectivity. The weights obtained by two method, fuzzyFMEA and FAHP, are multiplied to arrive at a final weight for each risk factor.

5.1 Fuzzy FMEA

In Failure Mode and Effect Analysis (FMEA) a Risk Priority Number(RPN) for each risk is calculated as the product of the probability of risk occurrence (O), severity (S) and detection (D). The O rating refers to the frequency of the occurrence of a particular risk factor. The S rating is used to represent the potential effects associated with the occurrence of a risk factor. D rating considers the likelihood of detection of a particular risk factor. The RPN represents the level of a particular risk, i.e. a higher value of RPN means higher level of risk FMEA integrated with fuzzy theory allows risk prioritization to be handled more efficiently.

Table 2: Fuzzy linguistic scale (Nazeri and Naderikia, 2017)

SEVERITY	
Rating	Fuzzy Number
Extremely significant effect	(4, 5, 6)
Very significant effect	(3, 4, 5)
Significant effect	(2, 3, 4)
Slight effect	(1, 2, 3)
No effect	(1, 1, 2)

DETECTION	
Rating	Fuzzy Number
Extremely significant effect	(4, 5, 6)
Very significant effect	(3, 4, 5)
Significant effect	(2, 3, 4)
Slight effect	(1, 2, 3)
No effect	(1, 1, 2)

OCCURRENCE	
Rating	Fuzzy Number
Very high	(4, 5, 6)
High	(3, 4, 5)
Medium	(2, 3, 4)
Low	(1, 2, 3)
Very low	(1, 1, 2)

The Fuzzy FMEA procedure employed for the present study is provided below (Nazeri and Naderikia, 2017).

Step 1: A fuzzy linguistic scale is adopted from Nazeri and Naderikia, 2017 and provided in Table-2 is selected, and respondents are asked to rate O, S and D according to it.

Step 2: The mean responses are found by taking the average of the fuzzy ratings from the 24 respondents.

Step 3: The mean response in TFN form is defuzzified into crisp score by center of area method.

Step 4: The Risk Priority Number (RPN) is found by, RPN = $O \otimes S \otimes D$. The RPN gives the FMEA weights ofeach risk.

Table 3: Sample FRPN Calculation for Risk Factor "Revenue Risks"

Parameter	Average response	Crisp score	FRPN
Occurrence	(3.13, 4.04, 5.04)	4.07	FRPN=4.07 ×4. 09 ×3.25= 54.100
Severity	(3.09, 4.09, 5.09)	4. 09	
Detection	(2.40, 3.18, 4.18)	3.25	

Similarly, FRPN values for all sub risks are calculated and listed in Table 4.

Table 4: Fuzzy RPN Values

Sub Risk Factors	FRPN	Sub RiskFactors	FRPN
Design changes	78.001	Change in law	36.452
Land acquisition risks	72.560	Force Majeure	32.541
Availability of finance	71.624	Interest ratevolatility	29.108
Construction time delay	69.231	Operation costoverruns	28.462
Approvals and permits	64.142	Technologyrisk	26.144
Revenue risk	54.112	Maintenancerisks	19.313
Contractual risks	53.451	Inflation ratevolatility	19.142
Change in market demands	48.674	Government's reliability	17.251
Concessionaire event of default	48.213	Change in taxregulation	15.464
Construction cost overruns	39.13	Externallinkages	10.254

The risks are listed in Table 4 according to their priority order from the FMEA results. Design changes, Land acquisition risks, availability of finance, construction time delay and approvals and permits are the major risk according to the results obtained from fuzzy FMEA analysis. Change in tax regulation and external linkages are the least important ones. The FRPN values are multiplied by FAHP weights to obtain the final weights of each sub factor.

5.2 Fuzzy AHP

Developed by T. L. Saaty in 1970, and refined continuously to date, the AHP breaks down the main problem into more comprehensible sub-problems. The AHP model is a tree diagram, which in its simplest form, consists of a goal at the top, a set of alternates for reaching the goal at the lowest level, and a set of criteria connecting the alternates to the goal. For the present study, project success is the goal. The set of risk factors are taken as the set of criteria forming the last level.

If uncertainty (fuzziness) of human decision making is not taken into account in an AHP problem, the results can be misleading. FAHP overcomes the inability of AHP to deal with human subjectiveness in the pair wise comparison process. Instead of a single value, the FAHP generates a range of values to incorporate the decision- makers uncertainty.

The steps employed to find the FAHP weights of risk factors are found from the procedure described below (Li and Zou, 2011;Ayhan, 2013).

Step 1: The results of all the pair wise comparisons are entered into a matrix as fuzzy numbers according to a linguistic scale

Step 2: Preferences of each respondent are averaged and is calculated to form a pair wise comparison matrix (which is average of all 24 responses)

Step 3: The local weights of sub risk factors are found using Eq. 2.

$$w_{SR_i} = \sum_{i=1}^{n} \tilde{A}_{ij}^{SR} \otimes \sum_{j=1}^{n} \sum_{i=1}^{n} \tilde{A}_{ij}^{SR} \tag{2}$$

$\tilde{A}_{ij}^{S}$ is the i^{th} row and j^{th} column fuzzy element of updated sub risk pair wise comparison matrix and w_{SR_i} is the local fuzzy weight of sub risk factor in i^{th} row of sub risk comparison matrix

Step 4: The weights of the main risk factors are found by employing Eq. 3.

$$w_{MR_i} = \sum_{i=1}^{n} \tilde{A}_{ij}^{MR} \otimes \sum_{j=1}^{n} \sum_{i=1}^{n} \tilde{A}_{ij}^{MR} \tag{3}$$

$\tilde{A}_{ij}^{M}$ is the i^{th} row and j^{th} column fuzzy element of main risk pair wise comparison matrix and w_{MR_i} is the fuzzy weight of main risk factor in i^{th} row of main risk pair wise comparison matrix. The calculations are similar to that of calculations to find the weights of sub risk factors

Step 5: The global weights of each sub risk factor is found by the following Eq. 4

$$\tilde{W}_{SR_i} = \tilde{w}_{SR_i} \otimes \tilde{W}_{MR_i} \tag{4}$$

$\tilde{W}_{SR_i}$ is the global fuzzy weight of sub risk factor in i^{th} row of sub risk pair wise comparison matrix.

Step 6: $\tilde{W}_{SR_i}$ is defuzzified into a crisp score using centre of area method. FAHP weights for the sub risks are provided in Table 5.

Table-5: FAHP Weights of Sub Risk Factors

Main Risk Factors	Weights, $\tilde{W}_{MRi}$	Sub Risk Factors	Local Weights, $\tilde{w}_{SRi}$	Global weights, $\tilde{W}_{SRi}$	FAHP Weight Crisp Score
Financial Risks	(0.10, 0.23, 0.58)	Availability of finance	(0.36,0.63, 1.17)	(0.04, 0.15, 0.67)	0.286
		Revenue risk	(0.03, 0.05, 0.09)	(0.00, 0.01, 0.05)	0.020
		Concessionaire event of default	(0.12, 0.24, 0.50)	(0.01, 0.05, 0.29)	0.116
Legal Risks	(0.05, 0.10, 0.27)	Approvals and permits	(0.33, 1.65, 1.89)	(0.01, 0.16, 0.51)	0.226
		Land acquisition risks	(0.68, 0.95, 1.08)	(0.05, 0.09, 0.18)	0.106
		Contractual risks	(0.35, 0.36, 0.58)	(0.03, 0.03, 0.16)	0.073
Political Risks	(0.01,0.02, 0.05)	Government's reliability	(0.17 ,0.57 ,0.79)	(0.00, 0.01, 0.03)	0.013
		Change in law	(0.06,0.51,0.83)	(0.00, 0.01, 0.04)	0.016
Economic Risks	(0.20,0.26,0.55)	Change in market demands	(0.09, 0.08, 0.32)	(0.01, 0.02, 0.17)	0.067
		Change in tax regulation	(0.24, 0.51, 0.73)	(0.02, 0.13, 0.40)	0.183
		Inflation rate volatility	(0.02, 0.05, 0.09)	(0.00, 0.01, 0.04)	0.016
		Interest rate volatility	(0.08,0.09, 0.20)	(0.02, 0.02, 0.11)	0.050
Construction Risks	(0.08,0.19,0.44)	Constructiontime delay	(0.32, 1.56, 1.89)	(0.02, 0.29, 0.83)	0.380
		Construction cost overruns	(1.00, 1.82, 1.98)	(0.08, 0.32, 0.87)	0.423
		Design changes	(0.52, 0.75, 0.91)	(0.04, 0.14, 0.40)	0.193
		External linkages	(0.09, 0.10, 0.14)	(0.00, 0.01, 0.06)	0.030
		Technology risk	(0.08, 0.09, 1.01)	(0.00, 0.01, 0.44)	0.150
Operation Risks	(0.06,0.14,0.31)	Operation cost overruns	(1.04, 1.16, 1.87)	(0.06, 0.16, 0.57)	0.263
		Maintenancerisks	(0.34, 0.55, 0.67)	(0.02, 0.07, 0.20)	0.096
Natura lRisks	(0.01, 0.02, 0.06)	Force Majeure	(0.16, 1.29, 1.55)	(0.00, 0.02, 0.09)	0.036

The final weights of the sub risk factors are calculated as the product of FAHP weights and FRPN values. The results are provided in Table-6.

Table-6: Ranking of Sub Risk Factors

Sub Risk Factors	FRPN	FAHP Weight	Final Weight	Rank
Approvals and permits	64.142	0.401	25.720	1
Construction time delay	69.231	0.356	24.646	2
Availability of finance	71.624	0.264	18.908	3
Construction cost overruns	39.139	0.468	18.317	4
Land acquisition risks	72.560	0.173	12.552	5
Design changes	78.001	0.153	11.934	6
Concessionaire event of default	48.213	0.189	9.112	7
Change in market demands	48.674	0.096	4.672	8
Operation cost overruns	28.462	0.164	4.667	9
Technology risk	26.144	0.178	4.653	10
Contractual risks	53.451	0.054	2.886	11
Revenue risk	54.112	0.042	2.272	12
Force Majeure	32.541	0.068	2.212	13
Change in tax regulation	15.464	0.113	1.747	14
Interest rate volatility	29.108	0.058	1.688	15
Maintenance risks	19.313	0.069	1.332	16
Change in law	36.452	0.014	0.510	17
Government's reliability	17.251	0.021	0.362	18
External linkages	10.254	0.022	0.225	19

From the fuzzy AHP and fuzzy FMEA analysis, the top risk factors obtained are approvals and permits, construction time delay, and availability of finance, construction cost overruns and land acquisition risks. These sub risks should be given top priority while formulating a risk management strategy. Most of the PPP projects are delayed because of delays in getting timely approvals and permits. The concessionaire will find it difficult to execute the work within the planned schedule and this may even result in cost overruns. In most cases, it is not within the concessionaire's powers to avoid such risks. However, risks such as construction time delays andcostoverruns can be avoided by proper planning for budget and cost. Risks due to unavailability offinance occur when there is an absence of a well organized financial framework. There should be provisions for alternate lenders so that there is a continuous flow of finance as and when required. Delays in obtaining land have created significant problems and even have lead to the discontinuation of many promising PPP project proposals. In some cases the government free up land before launching a PPP projects or in othercases the private sector is responsible for land acquisition. The land owners should be fairly compensated so there is no further resource consuming legal proceedings.

6. RISKS IN CASE STUDY PROJECTS

Three case study projects in Kerala were considered for the validation of the study. The major risks that occurred in Thiruvananthapuram City Road Improvement Project, Iruttukanam Small Hydro Electric Project and Thavakkara Bus Terminal Project are compared with the top ranked risks. The major risks that occurred in the above three projects are compared with the top risks obtained from the present study. Land acquisition is a majorrisk in all three of the projects while approvals and permits is a major issue in two of the projects. The rest of the top risks namely availability of finance, construction time delay and construction cost overrun occurs in at least one of the three projects taken. Thus, the major risks that occurredin the case study projects taken correlates with the results obtained from the present study.

7. CONCLUSIONS

The main objective of this study is to identify the significant risks in PPP projects in Kerala and develop a risk allocation framework. The risk factors in PPP projects are summarized from a comprehensive literature review. A risk break down structure is formulated consisting of main risks and sub risks. The main risks are divided into cause and effect group by using fuzzy DEMATEL analysis. Political risks are found to be the major cause group while financial risks and construction risks are impacted the most due to other risk factors. In addition, financialrisks are found to be the most prominent risk group closely followed by construction risks.

The key risks which affect the PPP projects are to be given due importance in order to achieve successful completion of such projects. A quantitative assessment of the risk will help to identify such key risks. The risks are assessed based on a fuzzy hybrid approach including fuzzy FMEA and fuzzy AHP approach. The obtained resultsrevealed that the top four risk factors are approvals and permits, construction time delay, availability of finance, construction cost overrun and land acquisition risks. The results obtained correlates with risks that occurred in case study projects in Kerala.

In recent years the concept of PPP is gaining much more momentum across the country justbecause it has been able to provide ample solution to the much needed projects which government cannot do on its own. The research findings presented in this report can contribute to the development and application of PPP in Kerala and enables better understanding of the risk allocation in PPP projects.

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