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ASSESSMENT OF RISKS IN PUBLIC PRIVATE PARTNERSHIP HIGHWAY PROJECTS IN INDIA USING FUZZY SYNTHETIC EVALUATION

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ABSTRACT

There is an enhanced need of Public Private Partnership applications in worldwide infrastructure development. While this brings a good opportunity for efficient and quality public service and management, large risks often arise due to varying cultural, political, socio- economic, environmental problems and local issues in the project. Diverse stakeholders in Public Private Partnership can also bring about conflicts that usually hinder the smooth implementation of the highway projects. Fuzzy synthetic evaluation is a method to evaluate the multiple criteria decision making. PPP risk assessment usually involves a large number of Critical Risk Factors (CRFs) and critical risk group (CRGs). During the evaluation process, all the CRFs and CRGs have to be scrutinized in order to ensure effectiveness. Hence, it is required to synthetically evaluate to solve multi- attribute and multi-level problem. As an application of fuzzy set theory, fuzzy synthetic evaluation has been adopted in risk assessment in PPP highway projects. The risk assessment in Public Private Partnership is often multi-layered and fuzzy in nature which requires evaluator's subjective judgment; it is appropriate to adopt the fuzzy synthetic evaluation method to develop a fuzzy risk assessment model. This paper aims to develop a fuzzy synthetic evaluation model for assessing the risk level of a particular and the overall risk index associated with Public Private Partnership Highway Projects in India.

Keywords: Public Private Partnership, Risk assessment, Risk management, Fuzzy synthetic evaluation

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1. INTRODUCTION

There is an enhanced need of PPP applications in worldwide infrastructure development. While this brings a good opportunity for efficient and quality public service and management, large risks often arise due to varying cultural, political, socio- economic, environmental problems and local issues in the project. The risk assessment in PPP is usually multi-layered and fuzzy in nature which requires subjective judgment hence fuzzy synthetic evaluation method can be a tool to assess the critical risks associated with PPP highway projects in India.

The fuzzy set theory was introduced by Zadeh (1965). Fuzzy theory was designed to interpret the uncertainties of the real situations. Simple Fuzzy Classification (SFC), Fuzzy Similarity Method (FSM) and Fuzzy Comprehensive Assessment (FCA), are all subtitles of Fuzzy Synthetic Evaluation (FSE) and have been used recently by a number of researchers in various environmental areas (Lu et al., 1999; Chang et al., 2001; Lu and Lo, 2002; Haiyan, 2002). Fuzzy evaluation methods process all the components according to predetermined weights and decrease the fuzziness by using membership functions, therefore sensitivity is quite high compared to other index evaluation techniques.

Xu et al. (2010) applied a fuzzy synthetic evaluation approach to allocate Public Private Partnership risks between the public and private sectors. From these previous research studies, it can be seen that fuzzy synthetic evaluation (FSE) has merits in handling complicated evaluation with multi attributes and multi-levels. In fact, the use of fuzzy synthetic evaluation could help evaluate more quantifiable risks such as macroeconomic risk, financial risk, and construction and operation risk, as well as the use of fuzzy numbers in the fuzzy synthetic evaluation.

In the present study fuzzy synthetic evaluation model is developed for assessing the critical risks and development of individual and overall risk index associated with Public Private Partnership Highway Projects in India. This research study will enable highway planning & construction stakeholders to better understand and evaluate the risks associated with Public Private Partnership highway projects in India.

2. FUZZY SYNTHETIC EVALUATION

Fuzzy synthetic evaluation is a method to assess multiple criteria decision making. Its purpose is to provide a synthetic evaluation of an object relative to an objective in a fuzzy decision environment with a number of factors (Hsu and Yang 1997). In this study, it is used to calculate the Risk Index (Probability and Severity) of a particular Critical Risk Group (CRG) and Overall Risk Index (ORI) of Public Private Partnership highway projects. The process of fuzzy synthetic evaluation is shown in Figure 1 A fuzzy synthetic evaluation model requires three basic elements (Xu et al, 2010).

1. A set of basic criteria/ factors $\Omega = \{R_{11}, R_{12}, \ldots R_{ij}\}$ where, R_{11} = Level of demand for project, R_{12} = Error in estimation of demand, R_{21}= Liquidity crisis in market, R_{22}= Low financial attraction of project to investor, R_{23}= High financing costs, R_{24}= Adverse Market (High Competition), R_{25} = Inflation, R_{26}=Foreign exchange fluctuation, etc.
2. A set of grade alternatives $C= \{c_1, c_2, \ldots c_n\}$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 severity) In this study, risk assessment i.e. the rating of risk impact of a particular risk factor is result of the product of risk probability and risk severity. (Xu et al, 2010)
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_{ij}. With the preceding three elements, for a given v Ɛ V, its evaluation result can be derived.

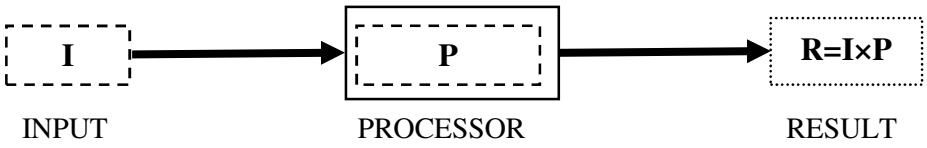

Figure 1 Process of Fuzzy Synthetic Evaluation

Where, I is the Input Information (it represents the parameters measured by expert opinion survey in this research study) (these parameters mean different alternatives c_j with respect to different criteria r_{ij})P is the Processor in which it transforms the Input into Output (i.e. it is evaluation matrix and evaluation matrix is the Model mentioned later) R is the Result Processed Information (it represents the membership function (both risk probability and risk severity) of each Critical Risk Factor (CRF) and Critical Risk Group (CRG) derived from questionnaire survey in this research study)

3. CALCULATION OF WEIGHTAGE OF CRITICAL RISK FACTORS AND CRITICAL RISK GROUPS

In the present study, 72 risks associated with PPP highway projects were identified. A total of 28 identified Critical Risk Factors (CRFs) and 7 identified Critical Risk Groups (CRGs) were used for assessment of the overall risk level of PPP highway projects in India. On the basis of the research works conducted the weightages for each of the 28 Critical Risk Factors (CRFs) and 7 Critical Risk Group (CRGs) were resolute. A set of knowledge-based fuzzy inference rules was then established to set up the membership function for the 28 Critical Risk Factors (CRFs) and 7 Critical Risk Group (CRGs). The weightage of each Critical Risk Factor (CRFs) and Critical Risk Group (CRGs) on basis of responses from the interviewer is calculated. The weightage of identified 28 risk factors and 7 groups is calculated by using the Equation 1 (Chow 2005; Yeung et al. 2007) as shown below.

$$w_i = \frac{m_i}{\sum_{i=1}^{1} m_i} \quad (1)$$

Where, w_i- weightage of a particular risk factor and risk group, m_i - mean of probability or severity of risk factors, $\sum_{i=1}^{5}$ summation of mean of probability or severity. The mean rating is calculated by the ratio of summation of all the probability/severity to the number of responses collected in questionnaire. The mean rating of each critical risk factor is calculated by above formula shown in Equation 1 whereas rating of each critical group is calculated by ratio of summation of (mean) all the factors in a group to summation of (mean) all group.

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 only identified critical risk factors were calculated, the critical risk factors were calculated by normalization. Table 1 shows the weightage of critical risk factor's and critical risk group on basis of probability whereas Table 2 shows weightage on basis of severity.

Table 1 Weightage of the Critical Risk Factors and Critical Risk Group on Basis of Probability

Risk No.	Critical Risk Factors & Critical Risk Group	Mean Value for Risk Probability	Weightage for each Risk factor	Total Mean Value of each Risk Group	Weightage of each Risk Group
R1	**Feasibility Stage**			11.13	0.12
R11	Level of demand for project	4.07	0.36		
R12	Error in Estimation of Demand	2.93	0.26		
R13	Public Participation & Community Consultation	4.13	0.37		
R2	**Financing Stage**			18.93	0.21
R21	Liquidity Crisis in Market	3.07	0.16		
R22	Low financial attraction of project to investor	3.00	0.16		
R23	High financing costs	3.07	0.16		
R24	Adverse Market (High Competition)	2.87	0.15		
R25	Inflation	2.87	0.15		
R26	Foreign Exchange Fluctuation	4.07	0.21		
R3	**Design Stage**			8.07	0.10
R31	Scope Change Risk	3.00	0.37		
R32	Unproven Engineering Technique	3.07	0.38		
R33	Design deficiency	2.00	0.25		
R4	**Pre-Construction Stage**			30.53	0.33
R41	Poor Interdepartmental Co-ordination	4.67	0.15		
R42	Delay in R&R of Project Affected Persons	4.27	0.14		
R43	Delay in Land Acquisition & Compensation Problem	4.07	0.13		
R44	Delay in shifting/ relocation of utilities	4.13	0.14		
R45	Delay in Payment to Project Affected Persons	4.20	0.14		
R46	Delay in Environment Clearance	3.07	0.10		
R47	Delay in Tree cutting	3.00	0.10		
R48	Legal Dispute during Pre- Construction Stage	3.13	0.10		
R5	**Construction Stage**			9.07	0.1
R51	Too many changes in scope of work	3.07	0.34		
R52	Construction Cost Overrun	3.00	0.33		
R53	Legal Dispute during Construction Stage	3.00	0.33		
R6	**Operation & Maintenance Stage**			10.47	0.11
R61	Inadequate Service Quality	3.33	0.32		
R62	Legal Dispute during O & M Stage	3.13	0.30		
R63	Negligence of Operation by Concessionaire	3.20	0.31		
R64	Risk of higher vehicle operation cost of road users	3.07	0.29		
R7	**Transfer Stage**			3.07	0.03
R71	Low Residual Value	3.07	1.00		
				= 91.27	

Table 2 Weightage of the Critical Risk Factors and Critical Risk Group on Basis of Severity

Risk No.	Critical Risk Factors & Critical Risk Group	Mean Value for Risk Probability	Weightage for each Risk factor	Total Mean Value of each Risk Group	Weightage of each Risk Group
R1	**Feasibility Stage**			9.07	0.1
R11	Level of demand for project	4.07	0.45		
R12	Error in Estimation of Demand	3.07	0.34		
R13	Public Participation & Community Consultation	1.93	0.21		
R2	**Financing Stage**			19.00	0.21
R21	Liquidity Crisis in Market	3.93	0.21		
R22	Low financial attraction of project to investor	4.00	0.21		
R23	High financing costs	3.00	0.16		
R24	Adverse Market (High Competition)	3.07	0.16		
R25	Inflation	3.00	0.16		
R26	Foreign Exchange Fluctuation	2.00	0.11		
R3	**Design Stage**			9.93	0.11
R31	Scope Change Risk	3.07	0.31		
R32	Unproven Engineering Technique	2.93	0.30		
R33	Design deficiency	3.93	0.40		
R4	**Pre-Construction Stage**			30.34	0.33
R41	Poor Interdepartmental Co-ordination	4.67	0.15		
R42	Delay in R&R of Project Affected Persons	4.27	0.14		
R43	Delay in Land Acquisition & Compensation Problem	4.13	0.14		
R44	Delay in shifting/ relocation of utilities	4.07	0.13		
R45	Delay in Payment to Project Affected Persons	4.00	0.13		
R46	Delay in Environment Clearance	3.07	0.10		
R47	Delay in Tree cutting	3.07	0.10		
R48	Legal Dispute during Pre- Construction Stage	3.07	0.10		
R5	**Construction Stage**			9.14	0.1
R51	Too many changes in scope of work	3.07	0.34		
R52	Construction Cost Overrun	3.07	0.34		
R53	Legal Dispute during Construction Stage	3.00	0.33		
R6	**Operation & Maintenance Stage**			11.47	0.12
R61	Inadequate Service Quality	3.07	0.27		
R62	Legal Dispute during O & M Stage	2.47	0.22		
R63	Negligence of Operation by Concessionaire	3.00	0.26		
R64	Risk of higher vehicle operation cost of road users	2.93	0.26		
R7	**Transfer Stage**			3.07	0.03
R71	Low Residual Value	3.07	1.00		
				= 92.01	

4. EVALUATION OF THE MEMBERSHIP FUNCTION FOR EACH CRITICAL RISK FACTOR AND CRITICAL RISK GROUP

As recognized by earlier research, a total of 28 identified Critical Risk Factors (CRFs) were used for assessment of the overall risk level of Public Private Partnership highway project in India.

Now, assume $\Omega = \{R_{11}, R_{12}, \ldots . R_{71}\}$ 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 $c_1 - \text{very low}$; $c_2 - \text{low}$ $c_3 - \text{moderate}$; $c_4 - \text{high}$; $c_5 - \text{very high}$.

The risk factors and grade for both risk probability and risk severity were considered. Now, for each critical risk factor the membership functions were evaluated using the responses of the Public Private Partnership expert interviewed.

For example, risk probability of the survey result of R13 – Public Participation & Community Consultation indicated that 7% of the respondent opined the probability of occurrence of particular risk is very low whereas 33% as low; 47% as moderate; 7% as high and 7% as very high therefore the membership function of Feasibility Stage is given by Equation 2

$$R_{13} = \frac{0.07}{\text{very low}} + \frac{0.33}{\text{low}} + \frac{0.47}{\text{moderate}} + \frac{0.07}{\text{high}} + \frac{0.07}{\text{very high}} \quad (2)$$

$$= \frac{0.07}{1} + \frac{0.33}{2} + \frac{0.47}{3} + \frac{0.07}{4} + \frac{0.07}{5} \text{ It can be written as (0.07, 0.33, 0.47, 0.07, 0.07)}$$

Similarly, risk severity of the survey result of R 13 – Public Participation & Community Consultation indicated that 7% of the respondent opined the probability of occurrence of particular risk is very low whereas 27% as low; 47% as moderate; 13% as high and 7% as very high therefore the membership function of Feasibility Stage is given by Equation 3

$$R_{13} = \frac{0.07}{\text{very low}} + \frac{0.27}{\text{low}} + \frac{0.47}{\text{moderate}} + \frac{0.13}{\text{high}} + \frac{0.07}{\text{very high}} \quad (3)$$

$$= \frac{0.07}{1} + \frac{0.27}{2} + \frac{0.47}{3} + \frac{0.13}{4} + \frac{0.07}{5} \text{ It can be written as (0.07, 0.27, 0.47, 0.13, 0.07)}$$

Similarly, the membership functions of all CRFs for all the other factor were derived which were shown in Table 3 for probability and Table 4 for severity and Figure 2 shows membership function of risk probability/severity.

Table 3 Membership Function of all CFs on the Basis of Risk Probability

Risk No.	Critical Risk Factor	Weightage	Membership function of all CFs	MF of all CGs
R1	**Feasibility Stage**			
R11	Level of demand for project	0.37	(0, 0, 0, 0.47, 0.53)	(0.02, 0.12, 0.38, 0.23, 0.24)
R12	Error in Estimation of Demand	0.26	(0, 0, 0.8, 0.13, 0.07)	
R13	Public Participation & Community Consultation	0.37	(0.07, 0.33, 0.47, 0.07, 0.07)	
R2	**Financing Stage**			
R21	Liquidity Crisis in Market	0.16	(0, 0, 0, 0.53, 0.47)	(0.03, 0.11, 0.38, 0.30, 0.19)
R22	Low financial attraction of project to investor	0.16	(0, 0, 0, 0.60, 0.40)	
R23	High financing costs	0.16	(0, 0, 0.47, 0.47, 0.07)	

R24	Adverse Market (High Competition)	0.15	(0.07, 0.13, 0.67, 0.07, 0.07)	
R25	Inflation	0.15	(0.07, 0.20, 0.60, 0.07, 0.07)	
R26	Foreign Exchange Fluctuation	0.21	(0.07, 0.27, 0.53, 0.07, 0.07)	
R3	**Design Stage**			
R31	Scope Change Risk	0.37	(0, 0, 0.53, 0.40, 0.07)	(0.03, 0.11, 0.57, 0.21, 0.05)
R32	Unproven Engineering Technique	0.38	(0, 0.07, 0.73, 0.07, 0.07)	
R33	Design deficiency	0.25	(0.13, 0.33, 0.40, 0.13, 0)	
R4	**Pre-Construction Stage**			
R41	Poor Interdepartmental Co-ordination	0.15	(0, 0, 0, 0.07, 0.93)	(0, 0, 0.08, 0.34, 0.58)
R42	Delay in R&R of Project Affected Persons	0.14	(0, 0, 0, 0.20, 0.80)	
R43	Delay in Land Acquisition & Compensation Problem	0.13	(0, 0, 0, 0.27, 0.73)	
R44	Delay in shifting/ relocation of utilities	0.14	(0, 0, 0, 0.33, 0.67)	
R45	Delay in Payment to Project Affected Persons	0.14	(0, 0, 0, 0.40, 0.60)	
R46	Delay in Environment Clearance	0.10	(0, 0, 0.20, 0.60, 0.20)	
R47	Delay in Tree cutting	0.10	(0, 0, 0.60, 0.33, 0.07)	
R48	Legal Dispute during Pre- Construction Stage	0.10	(0, 0, 0, 0.73, 0.27)	
R5	**Construction Stage**			
R51	Too many changes in scope of work	0.34	(0, 0, 0.27, 0.6, 0.13)	(0, 0, 0.55, 0.36, 0.09)
R52	Construction Cost Overrun	0.33	(0, 0, 0.67, 0.26, 0.07)	
R53	Legal Dispute during Construction Stage	0.33	(0, 0, 0.73, 0.20, 0.07)	
R6	**Operation & Maintenance Stage**			
R61	Inadequate Service Quality	0.32	(0, 0, 0, 0.67, 0.33)	(0.02, 0.10, 0.22, 0.46, 0.20)
R62	Legal Dispute during O & M Stage	0.18	(0.13, 0.40, 0.33, 0.13, 0)	
R63	Negligence of Operation by Concessionaire	0.31	(0, 0, 0.07, 0.67, 0.27)	
R64	Risk of higher vehicle operation cost of road users	0.19	(0, 0.13, 0.73, 0.07, 0.07)	
R7	**Transfer Stage**			
R71	Low Residual Value	1.00	(0, 0, 0.40, 0.53, 0.07)	(0, 0, 0.40, 0.53, 0.07)

Table 4 Membership Function of all CFs on Basis of Risk Severity

Risk No.	Critical Risk Factor	Weightage	Membership function of all CFs	MF of all CGs
R1	**Feasibility Stage**			
R11	Level of demand for project	0.45	(0, 0, 0, 0.40, 0.60)	(0.01, 0.06, 0.35, 0.28, 0.31)
R12	Error in Estimation of Demand	0.34	(0, 0, 0.73, 0.20, 0.07)	
R13	Public Participation & Community Consultation	0.21	(0.07, 0.27, 0.47, 0.13, 0.07)	
R2	**Financing Stage**			
R21	Liquidity Crisis in Market	0.21	(0, 0, 0, 0.47, 0.53)	(0.04, 0.08, 0.30, 0.36, 0.22)
R22	Low financial attraction of project to investor	0.16	(0, 0, 0, 0.67, 0.33)	
R23	High financing costs	0.16	(0, 0, 0.40, 0.53, 0.07)	
R24	Adverse Market (High Competition)	0.16	(0.07, 0.13, 0.60, 0.13, 0.07)	
R25	Inflation	0.16	(0.07, 0.20, 0.53, 0.07, 0.13)	
R26	Foreign Exchange Fluctuation	0.11	(0.13, 0.27, 0.53, 0.07, 0)	
R3	**Design Stage**			
R31	Scope Change Risk	0.31	(0, 0.07, 0.47, 0.40, 0.07)	(0.05, 0.22, 0.51, 0.20, 0.04)
R32	Unproven Engineering Technique	0.30	(0.07, 0.13, 0.67, 0.07, 0.07)	
R33	Design deficiency	0.40	(0.07, 0.40, 0.40, 0.13, 0)	
R4	**Pre-Construction Stage**			
R41	Poor Interdepartmental Co-ordination	0.16	(0, 0, 0, 0.13, 0.87)	(0, 0, 0.1, 0.31, 0.58)
R42	Delay in R&R of Project Affected Persons	0.14	(0, 0, 0, 0.20, 0.80)	
R43	Delay in Land Acquisition & Compensation Problem	0.14	(0, 0, 0.07, 0.20, 0.73)	
R44	Delay in shifting/ relocation of utilities	0.12	(0, 0, 0.07, 0.27, 0.67)	
R45	Delay in Payment to Project Affected Persons	0.13	(0, 0, 0.07, 0.33, 0.60)	
R46	Delay in Environment Clearance	0.10	(0, 0, 0.13, 0.67, 0.20)	
R47	Delay in Tree cutting	0.10	(0, 0, 0.53, 0.33, 0.13)	
R48	Legal Dispute during Pre- Construction Stage	0.08	(0, 0, 0.07, 0.67, 0.27)	
R5	**Construction Stage**			
R51	Too many changes in scope of work	0.34	(0, 0, 0.20, 0.67, 0.13)	(0, 0, 0.54, 0.36, 0.11)
R52	Construction Cost Overrun	0.34	(0, 0, 0.73, 0.20, 0.07)	
R53	Legal Dispute during Construction Stage	0.33	(0, 0, 0.67, 0.20, 0.13)	
R6	**Operation & Maintenance Stage**			
R61	Inadequate Service Quality	0.38	(0, 0, 0.07, 0.60, 0.33)	(0.04, 0.15, 0.4, 0.54, 0.25)

R62	Legal Dispute during O & M Stage	0.24	(0.07, 0.40, 0.40, 0.13, 0)	
R63	Negligence of Operation by Concessionaire	0.38	(0, 0, 0.13, 0.60, 0.27)	
R64	Risk of higher vehicle operation cost of road users	0.38	(0.07, 0.13, 0.60, 0.13, 0.07)	
R7	**Transfer Stage**			
R71	Low Residual Value	1.00	(0, 0, 0.33, 0.60, 0.07)	(0, 0, 0.33, 0.60, 0.07)

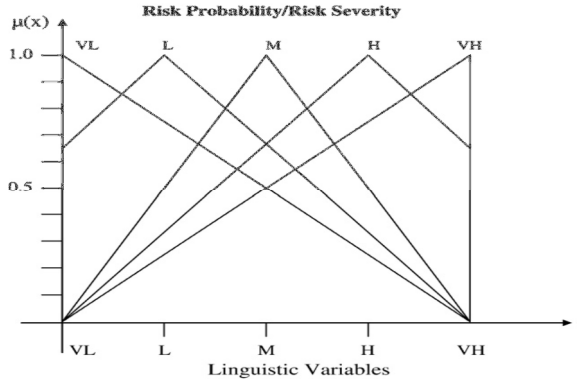

Figure 2 Membership Function of Risk Probability/ Risk Severity (Source: Xu et al, 2010)

The membership function of all CRGs were derived with the help of Model (Lo 1999)

Model 4: M (◦,*) $c_j = \min\left(1, \sum_{i=1}^{m} w_i * r_{ij}\right) \nabla\, c_j \in C$

For example, The membership Function of Feasibility Stage (which include Level of demand for project, Error in Estimation of Demand, Public Participation & Community Consultation) for Risk Probability is evaluated as

(0.37×0+0.26×0+0.37×0.07; 0.37×0+0.26×0+0.37×0.33; 0.37×0+0.26×0.8+0.37×0.47; 0.37×0.47+0.26×0.13+0.37×0.07; 0.37×0.53+0.26×0.07+0.37×0.07) = (0.02, 0.12, 0.38, 0.23, 0.24)

Similarly, Membership Function of Feasibility Stage for Risk Severity is evaluated as

(0.45×0+0.34×0+0.21×0.07;0.45×0+0.34×0+0.21×0.27; .45×0+0.34×0.73+0.21×0.47 ;0.45×0.40+0.34×0.20+0.21×0.13 ; 0.45×0.60+0.34×0.07+0.21×0.07) = (0.01, 0.06, 0.35, 0.28, 0.31)

5. DEVELOPING A FUZZY SYNTHETIC EVALUATION MODEL FOR PUBLIC PRIVATE PARTNERSHIP HIGHWAY PROJECTS

The appropriate Weightage of the 28 CRFs and 7 CRGs were developed for Public Private Partnership highway Project, followed by establishment of membership function for each CRFs and CRGs for both probability of occurrence and severity of risks respectively.

For this a total of 4 models were considered (Yelin et al, 2010)

Where, Model 1:M $(\cap,\cup), c_j = {}_{i=1}^{m}\cup \left(w_i \cap r_{ij}\right) \nabla c_j \in C$,

Model 2:M $(°,\cup), c_j = {}_{i=1}^{m}\cup \left(w_i \times r_{ij}\right) \nabla c_j \in C$

Model 1 and 2 consider only the major criteria and ignore other minor criteria therefore suitable for single-item problem and cannot be used for multi-criteria which were done in this study for calculation of Overall Risk Index (ORI).

Model 3:M $(\cap, +), c_j = \sum_{i=1}^{m}\left(w_i \cap r_{ij}\right) \nabla c_j \in C$,

Model 4: M (◦,*) $c_j = \min\left(1, \sum_{i=1}^{m} w_i * r_{ij}\right) \nabla\, c_j \in C$

Here * represents the summation of product of weightage and membership function. This model is used when wide range of criteria is used and the difference in weightage is not enormous. Therefore, this model is suitable for calculating Overall Index of the Public Private Partnership Highway Project.

Here, in these study three levels of membership function is there. Level 3 represents the membership function of critical risk factors, Level 2 represents membership function of critical risk group and Level 1 refers to Overall Risk Index.
Table 5 represents the Weightage of Overall Risk Index for probability and Table 6 shows Overall Risk Index for severity

Table 5 Weightage of Overall Risk Index for Probability of Occurrence of Risk

Risk No.	Critical Risk Group	Weightage	Level 2	Level 1
Risk Probability from Level 3 to Level 2				
R1	Feasibility Stage	0.12	(0.02, 0.12, 0.38, 0.23, 0.24)	(0.01, 0.05, 0.31, 0.33, 0.30)
R2	Financing Stage	0.21	(0.03, 0.11, 0.38, 0.30, 0.19)	
R3	Design Stage	0.10	(0.03, 0.11, 0.57, 0.21, 0.05)	
R4	Pre-Construction Stage	0.33	(0, 0, 0.08, 0.34, 0.58)	
R5	Construction Stage	0.10	(0, 0, 0.55, 0.36, 0.09)	
R6	O&M Stage	0.11	(0.02, 0.10, 0.22, 0.46, 0.20)	
R7	Transfer Stage	0.03	(0, 0, 0.40, 0.53, 0.07)	

The membership function of Overall Risk Level for Probability (includes Feasibility, Financing, Design, Pre-Construction, Construction, Operation & Maintenance and Transfer Stage) is as follows

(0.12×0.02+0.21×0.03+0.10×0.03+0.33×0+0.10×0+0.11×0.02+0.03×0;

0.12×0.12+0.21×0.11+0.10×0.11+0.33×0+0.10×0+0.11×0.10+0.03×0;

0.12×0.38+0.21×0.38+0.10×0.57+0.33×0.08+0.10×0.55+0.11×0.22+0.03×0.40;

0.12×0.23+0.21×0.30+0.10×0.21+0.33×0.34+0.10×0.36+0.11×0.46+0.03×0.53;

0.12×0.24+0.21×0.19+0.10×0.05+0.33×0.58+0.10×0.09+0.11×0.20+0.03×0.07)

= (0.01, 0.05, 0.31, 0.33, 0.30)

Table 6 Weightage of Overall Risk Index for Severity of Risk

Risk No.	Critical Risk Group	Weightage	Level 2	Level 1
Risk Probability from Level 3 to Level 2				
R1	Feasibility Stage	0.10	(0.01, 0.06, 0.35, 0.28, 0.31)	(0.02, 0.07, 0.25, 0.35, 0.31)
R2	Financing Stage	0.21	(0.04, 0.08, 0.30, 0.36, 0.22)	
R3	Design Stage	0.11	(0.05, 0.22, 0.51, 0.20, 0.04)	
R4	Pre-Construction Stage	0.33	(0, 0, 0.1, 0.31, 0.58)	
R5	Construction Stage	0.10	(0, 0, 0.54, 0.36, 0.11)	
R6	O&M Stage	0.12	(0.04, 0.15, 0.4, 0.54, 0.25)	
R7	Transfer Stage	0.03	(0, 0, 0.33, 0.60, 0.07)	

After driving membership function from Level 2 to Level 1, the Overall Risk Index (ORI) for Public Private Partnership Highway Project can be evaluated using Equation 4 and were tabulated in Table 7.

$$ORI = \sum_{i=1}^{m}(w \times r_i) \times l \quad (4)$$

Where, ORI is Overall Risk Index, w is Weightage of each CRF, r is degree of membership function of each CRF (for both risk probability and risk severity), l is linguistic variable

Where, 1= very low, 2 = low, 3 = moderate, 4 = high, 5 = very high

Therefore, Probability for R1 i.e. Feasibility Stage

0.02×1+0.12×2+0.38×3+0.23×4+0.24×5 = 3.52

And Severity for R1 i.e. Feasibility Stage

0.01×1+0.06×2+0.35×3+0.28×4+0.31×5 = 3.85

Where, ORI (for Probability) =0.01×1+0.05×2+0.31×3+0.33×4+0.30×5 = 3.86

ORI (for Severity) =0.02×1+0.07×2+0.25×3+0.35×4+0.31×5 = 3.86

Final Risk Index is, $\text{Impact} = \sqrt{\text{Probability} \times \text{Severity}}$

To have an in-depth analysis, the Risk Index of a particular Critical Risk Group can also be calculated using the same method. The results were shown in Table 7.

Table 7 Risk Index of Critical Risk Group and the Overall Risk Index for Public Private Partnership Highway Project

Risk No.	Critical Risk Group	Risk Probability	Risk Severity	Risk Index
R1	Feasibility Stage	3.52	3.85	3.68
R2	Financing Stage	3.54	3.64	3.59
R3	Design Stage	3.05	3.02	3.03
R4	Pre-Construction Stage	4.50	4.44	4.47
R5	Construction Stage	3.54	3.61	3.57
R6	O&M Stage	3.72	4.95	4.29
R7	Transfer Stage	3.67	3.74	3.70
ORI	Overall Risk Index	3.86	3.86	3.86

The observed research findings in Table 7 show that the Overall Risk Index (ORI) of Public Private Partnership highway projects is 3.86, which can be regarded as between "moderate risk" and "high risk". Therefore, investment in Public Private Partnership highway projects may be interpreted as risky. In addition, the Public Private Partnership Expert survey respondents perceived that " Pre-Construction Stage" is the most Critical Risk Group (CRG), with the value of Risk Index equal to 4.47; "Operation & Maintenance Stage" being the second, with the value of Risk Index equal to 4.29; "Transfer Stage" the third, with the value of Risk Index equal to 3.70; "Feasibility Stage" the fourth, with the value of Risk Index equal to 3.68; "Financing Stage" the fifth, with the value of Risk Index equal to 3.59, "Construction Stage" the sixth, with the value of Risk Index equal to 3.59 and "Design Stage" the last, with the value of Risk Index equal to 3.03.

6. CONCLUSIONS

The research findings showed that the top two risk groups of Public Private Partnership Highway Projects were: (1) Pre-Construction Stage; and (2) Operation & Maintenance Stage.

The research findings also focus light on the risk assessment in a booming Indian Infrastructure Development Industry, which can be used as an evaluation tool to assess the risk level of a Public Private Partnership project, and then to identify the areas for improvement. In fact, by using the fuzzy risk assessment model for Public Private Partnership projects, the most CRG for different types of Public Private Partnership projects could be identified and both precautionary and remedial actions could be taken as soon as possible. This research has developed a comprehensive, objective, reliable, and practical evaluation model for assessing the risk level of Public Private Partnership projects using Public Private Partnership Experts' survey and a fuzzy synthetic evaluation approach. The developed model provides an objective basis for assessing the risk level of Public Private Partnership Highway Project. The development of Overall Risk Index not only enhances the understanding of Government, Concessionaire and Consultants in implementing a successful Public Private Partnership Highway Project, but it also forms a solid base for infrastructure experts and practitioners to measure, evaluate, and improve the current performance of their Public Private Partnership Highway Projects.

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