Critical Analysis of Risk Management and Influencing Factors in Public-Private-Partnership Infrastructure Highway Projects:-a Quantitative Approach

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***Abstract*—Public-Private Partnership (PPP) infrastructure highway projects have emerged as pivotal contributors to sustainable development, necessitating a meticulous evaluation of risk management practices and influencing factors. This paper presents an investigation into the critical aspects of risk in PPP infrastructure highway projects. The research methodology encompassed a primary factor validation survey. Subsequently, a carefully designed secondary questionnaire survey was conducted. The gathered data underwent careful analysis using the Relative Importance Index (RII) method, Cronbach's Alpha and Probability Importance Index (PII) for quantifiable measure of the significance of each identified risk factor. The application of RII, Cronbach's Alpha and PII facilitated the ranking and prioritization of these factors. The results of this study unveil pivotal insights into the risk landscape of PPP infrastructure development, offering a valuable framework for stakeholders to tailor risk mitigation strategies.**

Keywords— Public Private Partnership (PPP), Risk Category, Risk Factor, Relative Importance Index (RII), Cronbach's Alpha, Probability Importance Index (PII).

I. INTRODUCTION

Infrastructure development, particularly in the sector of highway projects, is integral to fostering economic growth and societal well-being. Public-Private Partnerships (PPPs) have emerged as a vital mechanism for financing and executing such projects, blending the strengths of public governance with private sector efficiency. However, the inherently complex nature of these ventures introduces a spectrum of risks that necessitate a systematic and nuanced approach to risk management.

This paper finds the critical analysis of risk management and influencing factors in PPP infrastructure highway projects, employing a comprehensive quantitative methodology. The imperative to understand and effectively navigate these risks becomes paramount as nations increasingly turn to PPPs as a catalyst for infrastructure development. The synergy of public and private resources, while promising, requires a thorough evaluation of the factors that can affect the project success.

The research journey begins with a primary factor validation survey, where key risk factors are identified and validated by the industry experts and stakeholders. This initial phase serves as the foundation for a structured secondary questionnaire survey, designed to capture a diverse array of perspectives on risk severity. Utilizing a scaling system ranging from Very Low to Very High, the survey elicits responses from government officials, private investors, project managers, and other key stakeholders.

The quantitative data collected is subjected to the Relative Importance Index (RII) method, Cronbach's Alpha and Probability Importance Index (PII) a robust analytical tool that affords a numerical ranking of identified risk factors. This approach not only unveils the relative significance of each factor but also provides a basis for prioritization, allowing stakeholders to focus their risk mitigation efforts strategically.

II. LITERATURE REVIEW

PPPs, or public-private partnerships, are becoming more and more well-known as a practical method of developing infrastructure., offering an alternative to traditional procurement methods. The literature reveals a broad consensus on the potential benefits of PPPs, including accelerated project delivery, cost efficiency, and the ability to tap into private sector innovation and expertise (Flyvbjerg et al., 2003). Effective risk management, particularly in the context of big highway projects where uncertainties are inevitable, is necessary for PPPs to succeed.

Numerous studies emphasize the complexity of risk management in PPPs, acknowledging the need for a nuanced understanding of risks and their potential impact on project outcomes (Grimsey & Lewis, 2004; Akintoye et al., 2003). PPPs involve a delicate balance of public and private interests, and risks can manifest at various stages, from project initiation to completion.

Understanding the specific factors contributing to risk in PPP highway projects is crucial. Factors such as political interference, regulatory changes, environmental considerations, and unforeseen technical challenges have been identified as critical risk elements (El-Sayegh, 2008; Osei-Kyei & Chan, 2015). A quantitative analysis is essential to prioritize these factors and tailor risk management strategies accordingly.

In the area of risk identification, the work of Ng et al. (2004) and Zou et al. (2007) stands out, emphasizing the need for a structured and systematic approach. This aligns with the methodology adopted in this research, commencing with a primary factor validation survey to refine and validate identified risk factors before conducting a comprehensive secondary survey. The amalgamation of primary and secondary data facilitates a holistic understanding of risk, aligning with the multifaceted nature of PPP highway projects.

III. Methodology

In order to discover proven risk variables in Public-Private Partnership (PPP) infrastructure transportation projects, a thorough literature analysis is the first step in the research approach. A thorough list of risk factors is gathered, classified, and used as the conceptual foundation for further research by drawing on this body of literature.

To ensure the relevance and applicability of these factors, Primary validation exercises are conducted with key stakeholders encompassing government representatives, private sector entities, consultants, and academic researchers. This inclusive approach gathers practical insights and refines the identified risk factors based on the real-world experiences and perspectives of these stakeholders.

The next phase involves secondary questionnaire survey. Building upon the validated risk factors, a secondary questionnaire survey is designed. The scale used in this survey goes from Very Low to Very High. The survey is distributed to a broad spectrum of respondents. The collected data undergoes analysis using the RII, Cronbach’s Alpha and PII. It provides a numerical ranking of the identified risk factors based on their perceived importance by stakeholders. This quantitative approach allows for a systematic and objective prioritization of risks.

This methodology offers valuable insights, certain limitations should be acknowledged. The study relies on the perceptions of stakeholders, which may introduce subjective biases.

A. Primary Validation

The process of evaluating risk factors connected to Public-Private Partnership (PPP) infrastructure highway projects was the main focus of this study's factor validation phase. To systematize this, a structured Category and Risk Factor Validation Form was developed, encompassing 13 overarching categories and 132 specific risk factors relevant to the PPP project context. Respondents were tasked with indicating the presence or absence of each risk factor using a binary response format 'Yes' or 'No.'

To validate the identified risk factors, Category and Risk Factor Validation Form was distributed to a panel of expert stakeholders. This panel comprised government officials, private investors, project managers, and construction experts. Their collective expertise provided valuable insights into the practical relevance and significance of each risk factor within the project context.

The responses collected through the validation form were systematically compiled and analyzed. The responses facilitated a straightforward categorization of risk factors as either validated ('Yes') or not validated ('No'). This process generated a refined list of validated risk factors.

The primary validation phase served as a critical refinement step, ensuring that the research focused on the most relevant and impactful risk factors. The validated risk factors, as endorsed by the expert panel, laid the foundation for the subsequent stages of the study, including the secondary survey and the application of the RII, Cronbach’s Alpha and PII method.

The outcome of the primary factor validation phase, resulting in the identification of 6 finalized categories and 77 validated risk factors, establishes a foundation for the subsequent stages of this research. The refined scope enhances the study's precision, ensuring that the secondary survey, RII, Cronbach’s Alpha analysis and PII are targeted towards the most pertinent risk factors in the dynamic landscape of PPP infrastructure highway projects.

B. Secondary Survey

The secondary survey phase constitutes a pivotal component of this research, involving the quantitative assessment of risk factors in PPP infrastructure highway projects. To systematize this evaluation, a Category and Risk Factor Rating Form was designed. This survey encompassed 6 categories and 77 specific risk factors, ratings from Very Low to Very High on a scale provided by the respondents. The survey engaged individuals from diverse professional backgrounds.

C. Statistical Analysis

Analysis was performed in Microsoft Excel.

Relative Importance Index(RII)

The analysis phase of this research employs the RII method to quantitatively evaluate and prioritize risk factors identified in PPP infrastructure highway projects. The RII method provides a methodical way to determine each risk factor's relevance based on ratings given by secondary survey respondents.

The RII is a numerical technique that enables the comparison of the perceived importance of various factors. In the context of this study, the RII is calculated for each risk factor, providing a quantitative measure of its relative importance based on the ratings given by respondents. The formula for RII is as follows:

$$RII = \frac{Mean\ Score\ of\ a\ Risk\ Factor}{Highest\ Possible\ Mean\ Score}$$

Where,

Mean Score of a Risk Factor = Weightage of each risk factor.

*Highest Possible Mean Score = Number of respondents * Highest Score.*

This calculation results in a value between 0 and 1, where a higher RII indicates a higher perceived importance of the risk factor.

Cronbach's alpha

The second analysis phase of this research employs the Cronbach's alpha method to quantitatively evaluate and prioritize risk factors identified in PPP infrastructure highway projects. Applying the Cronbach's alpha method to the Top 20 factors found by the RII method provides a methodical way to determine the relative importance of each risk factor based on ratings given by respondents in the secondary survey.

Using Cronbach's alpha in research analysis provides a reliable measure of internal consistency for survey items. It ensures that the items in study consistently measure the same underlying construct. High Cronbach's alpha values indicate greater reliability, boosting confidence in the validity of your data and enhancing the overall robustness of your research findings.

$$a = \frac{K}{K-1}[1 - \frac{\sum S^2 y}{S^2 x}]$$

Where,

K = Numbers of Factor.

$\sum S^2 y$ = total variance of the items.

$S^2 x$ = variance in the overall score.

α = Cronbach's alpha.

This calculation results in a value higher than 0.7, where a higher RII indicates a higher perceived importance of the risk factor.

Probability Importance Index(PII)

The PII is an additional method employed in risk analysis, complementing the RII and Cronbach's alpha approaches. While RII focuses on respondents' perceptions and Cronbach's alpha assesses internal consistency, PII introduces a quantitative dimension by considering the possibility of occurrence and possible consequences connected to any risk factor.

The computation of PII values for each risk factor, stakeholders can gain insights into the quantitative significance of different factors influencing PPP highway projects. Prioritizing risk factors based on PII values allows for strategic decision-making and targeted mitigation efforts. The formula for RII is as follows:

$$PII = Probability\ of\ Occurence * Potential\ Impact$$

$$PII\ range = PII\ max - PII\ min$$

$$\text{PII normalize} = \frac{PII - PII\ min}{PII\ range}$$

Where,

PII = individual Probability Importance Index for a specific risk factor.

PII min = minimum PII value in the dataset.

PII max = maximum PII value in the dataset.

PII range = range of PII values, calculated as PII max − PII min.

PII normalize = normalized PII value within the standardized range (0 to 1).

This calculation results in a value between 0 and 1, where a higher PII indicates a higher perceived importance of the risk factor.

IV. Data Analysis and Discussion

General Information

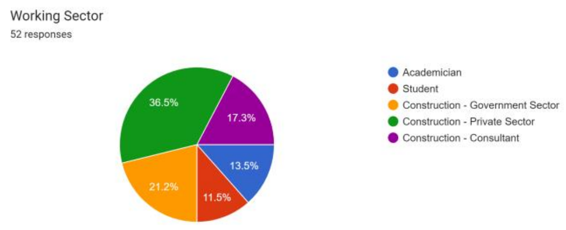

Fig. 1. Working Sector of Respondent

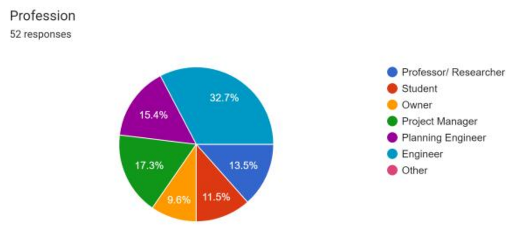

Fig. 2. Profession of Respondent

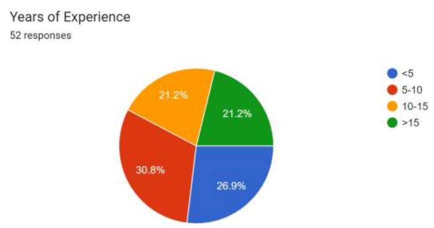

Fig. 3. Years of Experience of Respondent

A. Implementation of Relative Importance Index (RII) Analysis: Prioritizing Categories and Risk Factors

The implementation of the RII analysis serves as a critical step in quantifying and prioritizing risk factors. Focusing on the RII values for 6 categories, and 77 specific risk factors. The RII values, ranging from 0 to 1, offer a uniform measure to evaluate the relative weights of every category and risk factor.

Based on RII analysis Top 3 category shown in Table(II) which is critical for success of PPP Highway Project is identified and Top 20 Risk Factors shown in Table(III) which is critical for success of PPP Highway Project is identified. So stakeholders can develop focused mitigation strategies for that category and factor effectively.

TABLE I. RII RANK FOR CATEGORY OF RISK FACTOR

Sr. No.	Category	RII	Rank
1	Land Acquisition Risk - C1	0.736	1
2	Operational Risk - C2	0.728	2
3	Construction Risk - C3	0.725	4
4	Financial Risk - C4	0.728	3

5	Political & Regulatory Risk - C5	0.725	5
6	Other Risk - C6	0.736	6

TABLE II. TOP 3 CATEGORY

Sr.No.	Category	RII	Rank
1	Land Acquisition Risk - C1	0.736	1
2	Operational Risk - C2	0.728	2
3	Financial Risk - C4	0.728	3

TABLE III. TOP 20 RISK FACTOR

Sr.No.	Cate.	Factor	RII
1	C1	Public / political interference for changing the scope/ alignment - F1	0.765
2	C1	Extra land acquisition due to additional approaches/underpasses - F2	0.750
3	C1	Very high land cost - F3	0.754
4	C2	Inadequate quality and safety of service - F4	0.758
5	C2	Frequent accidents and traffic clearance - F5	0.750
6	C2	Lack of supporting infrastructure - F6	0.750
7	C3	Cost overruns - F7	0.762
8	C3	Disputes and Claims (Lack of comprehensive dispute resolution) - F8	0.762
9	C4	Changes in taxes, tariffs, foreign exchange & Interest rate fluctuations - F9	0.762
10	C4	Supply risk (poor market performance) - F10	0.754
11	C5	Poor political decision-making & government decision error - F11	0.750
12	C5	Sanction for competing facility by Government under political pressure - F12	0.758
13	C5	Changes in law / legislation / trade regime (project specific and industry specific) - F13	0.731
14	C6	Poor communications among stakeholders - F14	0.777
15	C6	Force majeure events (war, strike/ blockade/ public agitation etc.) - F15	0.746
16	C6	Differences in working methods and know-how between partners - F16	0.773
17	C6	Higher maintenance cost/frequent maintenance - F17	0.742
18	C6	Environmental impact liability (air, noise and ecology) - F18	0.750
19	C6	Damages due to non-political force majeures (fire/earthquake/flood etc.) - F19	0.762
20	C6	Technology failure - F20	0.750

B. Implementation of Cronbach's Alpha Analysis

The Cronbach's alpha method to prioritize categories and risk factors involves assessing the internal consistency of the survey items related to each factor.

Identified the top 20 risk factors based on the Relative Importance Index (RII) analysis in Table (3). Calculating the internal consistency for each risk factor that has been identified using the Cronbach's alpha formula. Higher values indicate greater internal consistency and reliability.

Prioritize risk factors based on their Cronbach's alpha values. Factors with higher internal consistency are more reliable, suggesting a stronger measurement of the underlying construct.

Based on Cronbach's analysis overall internal consistency result shown in Table(6) which is critical for success of PPP Highway Project is identified. So stakeholders can develop focused mitigation strategies for that 20 factor effectively.

TABLE IV. CRONBACH'S ALPHA INTERNAL CONSISTENCY

Cronbach's α	Internal Consistency
0.9 and above	Excellent
0.80 - 0.89	Good
0.70 - 0.79	Acceptable
0.60 - 0.69	Questionable
0.50 - 0.59	Poor
below 0.50	Unacceptable

https://www.statisticshowto.com/cronbachs-alpha-spss/

$$a = \frac{K}{K-1}[1 - \frac{\sum S^2 y}{S^2 x}]$$

TABLE V. RESULT OF TOP 20 FACTOR

Variable	Description	Value
K	No of Factor	20
$\sum S^2 y$	Sum of factor varience	27.53
S^2	Variance of total score	356.95
α	Cronbach's alpha	0.97

C. Implementation of Probability Importance Index

PPP infrastructure highway projects, the PII method extends the analysis beyond subjective ratings and internal consistency. For each recognized risk factor, PII entails putting a numerical value on the likelihood of occurrence and potential outcomes. The product of these values yields the PII, a metric that quantifies the importance of a risk factor based on both its likelihood and potential consequences.

TABLE VI. PII RESULT

Category	Factor	Probability of Occurence	Potential Impact	PII	PII min	PII max	PII range	PII normalized
C1	F1	5	3.83	19.15	17.89	19.43	1.54	0.82
C1	F2	5	3.75	18.75	17.89	19.43	1.54	0.56
C1	F3	5	3.77	18.85	17.89	19.43	1.54	0.63
C2	F4	5	3.79	18.95	17.89	19.43	1.54	0.69
C2	F5	5	3.75	18.75	17.89	19.43	1.54	0.56
C2	F6	5	3.75	18.75	17.89	19.43	1.54	0.56
C3	F7	5	3.81	19.05	17.89	19.43	1.54	0.76
C	F8	5	3.81	19.05	17.89	19.43	1.54	0.76

3								
C 4	F9	5	3.81	19.05	17.89	19.43	1.54	0.76
C 4	F1 0	5	3.58	17.89	17.89	19.43	1.54	0.00
C 5	F1 1	5	3.75	18.75	17.89	19.43	1.54	0.56
C 5	F1 2	5	3.79	18.94	17.89	19.43	1.54	0.69
C 5	F1 3	5	3.65	18.27	17.89	19.43	1.54	0.25
C 6	F1 4	5	3.89	19.43	17.89	19.43	1.54	1.00
C 6	F1 5	5	3.73	18.66	17.89	19.43	1.54	0.50
C 6	F1 6	5	3.87	19.33	17.89	19.43	1.54	0.94
C 6	F1 7	5	3.71	18.56	17.89	19.43	1.54	0.44
C 6	F1 8	5	3.75	18.75	17.89	19.43	1.54	0.56
C 6	F1 9	5	3.81	19.04	17.89	19.43	1.54	0.75
C 6	F2 0	5	3.75	18.75	17.89	19.43	1.54	0.56

V. RESULT AND CONCLUSION

Initiatives This research contributes a quantitative perspective to the critical analysis of risk management in PPP infrastructure highway projects. Through rigorous factor validation, primary and secondary surveys, and the application of statistical methods such as RII, Cronbach's alpha, and PII, the study provides valuable insights into the prioritization and reliability of risk factors.

The RII analysis identified the most influential categories and risk factors, guiding stakeholders in focusing their efforts on areas crucial for project success. The exceptional Cronbach's alpha value for the Top 20 factors underscores their internal consistency, reinforcing their reliability for decision-making.

The integration of the PII method adds a probabilistic dimension, allowing for a nuanced understanding of risk factors' perceived importance. The resulting values, expressed in a standardized range, facilitate easy comparison and interpretation, empowering stakeholders with a quantitative tool for strategic risk management.

This research provides a robust framework for risk analysis in PPP highway projects, combining quantitative methodologies to offer actionable insights for both practitioners and policymakers. The prioritized risk factors can inform the development of targeted mitigation strategies, ultimately contributing to the success and sustainability of PPP infrastructure projects.

REFERENCES

[1] Ali Akbari Ahmadabadi, Heravi,"The effect of critical success factors on project success in Public-Private Partnership projects: A case study of highway projects in Iran," Transport Policy Volume 73, January 2019.

[2] Swapnil Garg, Madhukar Dayal,"Road Learnings: Evolution of Public-private Partnerships in the Indian Highway Sector,"Transportation Research Procedia, Volume 48, 2020.

[3] Shiying, Heap Chong, Xiaosu Ye,"Examining the Interrelationship among Critical Success Factors of Public Private Partnership Infrastructure Projects,"Sustainability 2016, Volume 8, Issue 12, 16 Dec, 2016.

[4] Lakshya Kumar, Apurva Jindal, Nagendra R. Velaga,"Financial risk assessment and modelling of PPP based Indian highway infrastructure projects,"Transport Policy Volume 62, February 2018.

[5] Rakesh Kulshreshtha, Anil Kumar, Dinesh Kumar Likhi,"Critical Success Factors in Implementation of Urban Metro System on PPP: A Case Study of Hyderabad Metro,"Glob J Flex Syst Manag 18, 303–320 (2017).

[6] Effah Ernest Ameyaw, Albert P. C. Chan, Yun Le,"Application of Delphi method in construction engineering and management research: A quantitative perspective,"Journal of Civil Engineering and Management Volume 22, 2016 - Issue 8.

[7] Chuen-Ming, Luh-Maan Chang,"Critical success factors for PPP infrastructure: perspective from Taiwan,"Journal of the Chinese Institute of Engineers Volume 40, 2017 - Issue 5.

[8] Tirth Dineshkumar Patel, Theo C. Haupt, Tejas Bhatt,"Fuzzy probabilistic approach for risk assessment of BOT toll roads in Indian,"Journal of Engineering, Design and Technology, Vol. 18 No. 1, pp. 251-269.

[9] B Flyvbjerg, W Rothengatter - 2003, Megaprojects and Risk- An Anatomy of ambition.

[10] Darrin Grimsey, Mervyn K. Lewis, "Discount debates: Rates, risk, uncertainty and value for money in PPPs," Public Infrastructure Bulletin, Vol. 1, Iss. 3 [2004], Art. 2

[11] Sameh Monir El-Sayegh,"Risk assessment and allocation in the UAE construction industry," Volume 26, Issue 4, May 2008, Pages 431-438.

[12] Robert Osei-Kyei, Albert P.C. Chan,"Review of studies on the Critical Success Factors for Public–Private Partnership (PPP) projects from 1990 to 2013,"International Journal of Project Management, Volume 33, Issue 6, August 2015, Pages 1335-1346.

[13] Patrick Zou, Guomin Zhang, Jiayuan Wang,"Understanding the key risks in construction projects in China,"International Journal of Project Management, Volume 25, Issue 6, August 2007, Pages 601-614.

[14] Meghdad Attarzadeh, David K.H. Chua, Michael Beer, Ernest L.S. Abbott,"Options-based negotiation management of PPP–BOT infrastructure projects,"Construction Management and Economics Volume 35, 2017 - Issue 11-12.

[15] Iman Mirzadeh, Bjorn Birgisson,"Evaluation of Highway Projects under Government Support Mechanisms Based on an Option-Pricing Framework,"Journal of Construction Engineering and Management Volume 142, Issue 4.

[16] Yan Wang, Yujie Wang , Xiuyu Wu, Jiwang Li,"Exploring the Risk Factors of Infrastructure PPP Projects for Sustainable Delivery: A Social Network Perspective,"Sustainability 2020, 12(10), 4152.

[17] Faruk Buyukyoran, Selin Gundes,"Optimized real options-based approach for government guarantees in PPP toll road projects,"Construction Management and Economics Volume 36, 2018 - Issue 4.

[18] Khwaja Mateen Mazher1, Albert P. C. Chan, Hafiz Zahoor, Mohsen Islam KhanErnest Effah Ameyaw,"Fuzzy Integral–Based Risk-Assessment Approach for Public–Private Partnership Infrastructure Projects,"Journal of Construction Engineering and Management Volume 144, Issue 12.

[19] Li Liu , Yubo Guo, Chuan Chen, Igor Martek,"Determining Critical Success Factors for Public–Private Partnership Asset-Backed Securitization: A Structural Equation Modeling Approach,"Buildings 2021, 11(5), 199.

[20] Alireza Valipour, Hadi Sarvari, Jolanta Tamošaitiene,"Risk Assessment in PPP Projects by Applying Different MCDM Methods and Comparative Results Analysis,"Adm. Sci. 2018, 8, 80.