CHAPTER 71

Financial Risk Assessment of PPP Infrastructure Projects

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ABSTRACT

Public Private Partnerships (PPPs) are vital for meeting the infrastructure demands of developing nations like India, but their multi-stage nature brings financial risks that can deter government involvement and risk consortium bankruptcy. This study prioritizes financial risks across various project phases to aid in better decision-making. The research objectives include identifying critical financial risks, analyzing their impact using the Analytical Hierarchical Process (AHP), and determining the project phase requiring the most attention. A comprehensive literature review, supplemented by expert insights through a structured questionnaire survey, forms the basis of the study. The findings reveal that the execution phase is the most financially vulnerable, with construction cost overruns, delays, and market liquidity crises identified as the highest-priority risks. Further, a case study is also presented to show the application of AHP in choosing from the different models of PPP. These results emphasize the importance of targeted risk management during the execution phase to minimize uncertainties and improve project outcomes.

Keywords: Financial risk; PPP projects; Analytical hierarchical process; Construction phase; Risk prioritization.

1.0 Introduction

PPP projects have become a key solution for addressing infrastructure deficits in India, which hosts one of the largest PPP programs with over 2000 projects in various stages of execution (Department of Economic Affairs, 2020). The evolution of PPP models such as Build-Operate-Transfer (BOT), Design-Build-Finance-Operate-Transfer (DBFOT), and the Hybrid Annuity Model (HAM) showcases India's adaptability in infrastructure development (Asian Development Bank, 2020).

However, despite their benefits, PPP projects face financial risks making effective risk management essential for their long-term success (Shiwakoti & Dey, 2022). Over the years, financial risk assessment in PPP projects has been widely studied in India and globally.

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In the Indian context, early models such as the Net Present Value at Risk (NPV@Risk) introduced by Ye & Tiong (2000) combined the weighted average cost of capital (WACC) with expected NPV to manage financial uncertainties. Singh and Kalindi (2006) explored the annuity model to manage traffic revenue risks in PPP road projects, providing insights into risk allocation. Building on this, Bagui & Ghosh (2012) enhanced the NPV@Risk model by incorporating Monte Carlo simulations, enabling a more comprehensive assessment of NPV under various discount rate strategies. Deshpande & Rokade (2017) identified key financial risks in Indian highway projects, highlighting construction cost, interest rates, and inflation as primary risk parameters. Kagne & Vyas (2020) further identified six financial risk parameters influencing NPV in BOT road projects, with the discount rate being the most critical.

More recently, Gilbile & Vyas (2021) applied the Net Present Worth (NPW)-at-risk method combined with Monte Carlo simulations to assess financial risks in HAM projects, providing valuable insights into risk exposure. Globally, financial risk assessment in PPPs has evolved through diverse methodologies. Nguyen *et al.* (2010) employed Interpretative Structural Modeling (ISM) to identify and prioritize seventeen key risks, including financial closure delays and cost overruns. Makovšek (2013) compared PPPs with traditionally financed projects, revealing that while PPPs incurred 24% higher costs, they experienced fewer overruns due to improved risk management practices. Alasad *et al.* (2014) applied the Analytical Network Process (ANP) to prioritize demand risk factors in infrastructure projects, while Han *et al.* (2017) utilized Monte Carlo simulations to assess financial risks in toll highway infrastructure projects, identifying revenue and cost uncertainties as the most significant risks. While various methodologies have been employed to quantify and evaluate financial risks, they primarily focus on individual risk factors or overall project risks without considering their phase-specific impact. They often lacked the ability to systematically prioritize financial risks across different phases of PPP projects, making it challenging for decision-makers to effectively allocate resources and implement targeted risk mitigation strategies.

Furthermore, although the AHP has proven effective in multi-criteria decision-making, limited research has applied it to prioritize financial risks in PPP infrastructure projects, particularly in the Indian context. With India's growing reliance on PPPs to meet its infrastructure demands, there is a pressing need for a phase-wise financial risk prioritization framework that offers a clear and structured approach to identifying, assessing, and ranking financial risks. This study addresses this gap by employing AHP to systematically prioritize financial risks across the phases of PPP projects. By doing so, it provides a comprehensive and structured framework that enhances decision-making, helps stakeholders allocate resources more effectively, and improves overall risk management practices in PPP infrastructure projects. The study also demonstrates the application of AHP in a case study, comparing different PPP models to evaluate financial risk exposure. The scope of this research encompasses a comprehensive literature review (see Figure), a structured questionnaire survey, and AHP-based analysis to derive risk prioritization. The study specifically focuses on PPP infrastructure

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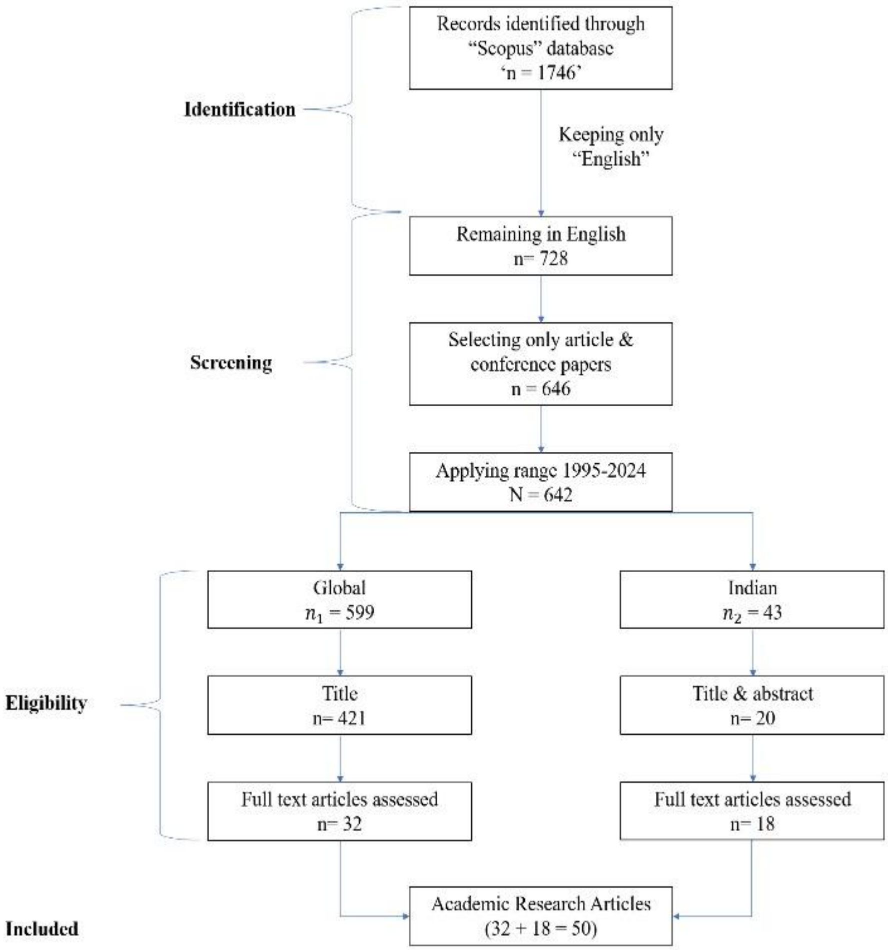
projects in India and uses expert judgment for pairwise comparisons, which may introduce some level of subjective bias. Nonetheless, by capturing expert insights, the study ensures that the financial risks identified reflect practical industry experiences, adding depth and reliability to the analysis.

Figure 1: Approach Followed for Literature Survey



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The organization of the paper is as follows: Section 2 presents the Literature Survey (Indian and Global Scenarios), Section 3 covers the Research Methodology, Section 4 provides the Research Analysis (Results and Interpretation), Section 5 details the Case Example, Section 6 concludes with Future Recommendations, followed by Annexures and References.

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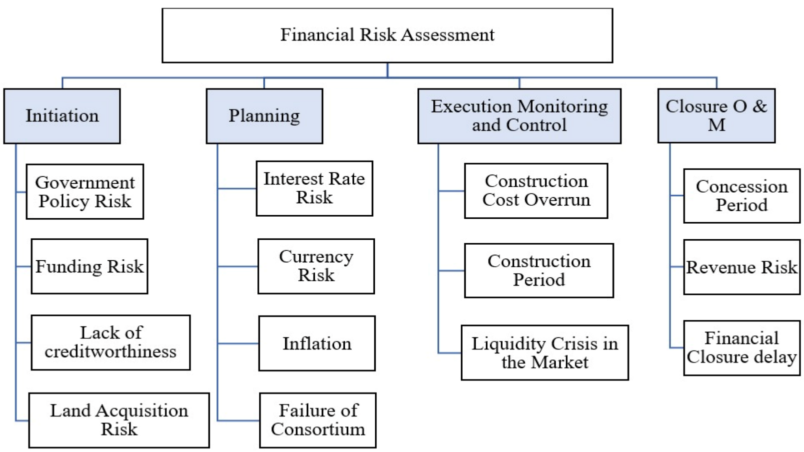
2.0 Research Methodology

AHP is a decision-making tool introduced by Thomas L. Saaty (1980) that provides a structured framework for evaluating complex problems with multiple criteria and alternatives. It integrates both quantitative and qualitative factors by breaking down the objective into hierarchical components, representing the relationships between the goal, criteria, and options. The process involves pairwise comparisons, assigning values from 1 to 9 to indicate relative importance, where 1 denotes equal relevance and 9 indicates high importance (Saaty, 2008). The consistency ratio (CR), which should be below 0.1, ensures reliable assessments. Finally, weighted scores are synthesized to rank the alternatives, with the highest-ranking option being the most preferred.

2.1 Identification of financial risks

A comprehensive literature survey was conducted to identify 14 financial risks associated with PPP projects in the Indian context. These risks were categorized into four phases of the construction life cycle based on the Project Management Institute (PMI) framework. The financial risks associated with PPP projects span across various phases as shown in Figure 2.

Figure 2: Hierarchy for AHP



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2.2 Data collection and questionnaire design

The questionnaires were designed to collect expert opinions and conduct pairwise comparisons for each financial risk. There are two questionnaires prepared which are answered by 40 people. Some of the responses were discarded due to inconsistency in results. The first questionnaire is prepared to determine the priority of different phases, and the second one consists of choosing from three alternative projects.

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3.0 Research Analysis

In this stage a set of pairwise matrix is prepared for comparison from the questionnaire responses. Every element at a higher level is utilized to evaluate the items in the level that is directly below it. A scale is used ranging from 1 to 9 to ascertain the relative relevance of two compared items. This matrix is a square reciprocal matrix (p = [a_{ij}]) of n^{th} order. The importance of any element in the row (sayC_i) with respect to any element in the column (sayC_i) is determined by the element a_{ij}, where a_{ij} is the reciprocal of a_{ji} for non-diagonal element and all the diagonal elements are 1. In this study, the pairwise comparison matrix is prepared with the help of the responses received through a questionnaire. Thereafter, a normalization matrix is constructed to calculate the eigenvector. In AHP, the eigenvector represents the relative weights or priorities of the various criteria or alternatives involved in the decision-making process. They also help in consistency checks, where the principal eigenvalue indicates the reliability of judgments. A Consistency Ratio (CR) is used to ensure the comparisons are valid and consistent. The consistency index (CI) and CR is calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad ...1$$

Where, λ_{max} is principal eigen vector. Now the consistency ratio is given by:

$$CR = \frac{CI}{RI} \qquad ...2$$

Where, RI is the random consistency index which is given as in Table 1.

Table 1: Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

The CR should be either 0 or less than 0.1.

3.1 Prioritization of Financial Risks using AHP

Prioritization is carried out to find out which phase of the project is more prone to financial risk and to rank the various risks prevailing in different phases of the project. Pair-wise construction phase matrix formed from the response and normalized matrix is shown in Table 2 and Table 3 respectively for one respondent.

Table 2: Pairwise Matrix for Construction Phase Comparison for Respondent

	P1	**P2**	**P3**	**P4**
P1	1.000	1.000	0.200	1.000
P2	1.000	1.000	0.333	3.000
P3	5.000	3.000	1.000	3.000
P4	1.000	0.333	0.333	1.000
Sum	8.000	5.333	1.867	8.000

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The different phases are named as follows to simplify: Initiation phase as P1, Planning Phase as P2, Execution, Monitoring and Control phase as P3 and Closure, O & M phase as P4.

Table 3: Normalization Matrix for Construction Phases

	P1	P2	P3	P4	Weights(W)	AW	λ
P1	0.125	0.187	0.107	0.125	0.136	0.580	4.262
P2	0.125	0.187	0.178	0.375	0.216	0.895	4.137
P3	0.625	0.562	0.535	0.375	0.524	2.223	4.238
P4	0.125	0.062	0.178	0.125	0.122	0.505	4.121
						λ_{max}	4.189
						CI	0.063
						CR	0.070

Once the consistency is checked for all the responses. The ranking is done based on the weight obtained as shown in Table 4.

Table 4: Weights and Rank for Construction Phases

	P1	P2	P3	P4
Mean	0.098	0.261	0.282	0.198
Ranking	4	2	1	3

Similar to the pairwise construction phase matrix, a pairwise construction risk matrix is also formed for all the respondents in different phases. Figure 3 and Figure 4 depict the final weights calculated for all the risks and their respective ranks in the form of a pie chart.

Figure 3: Weight and Ranks of Construction Phases

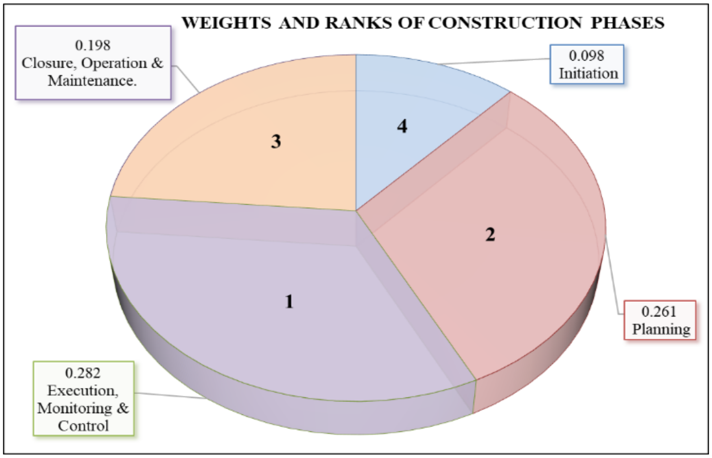

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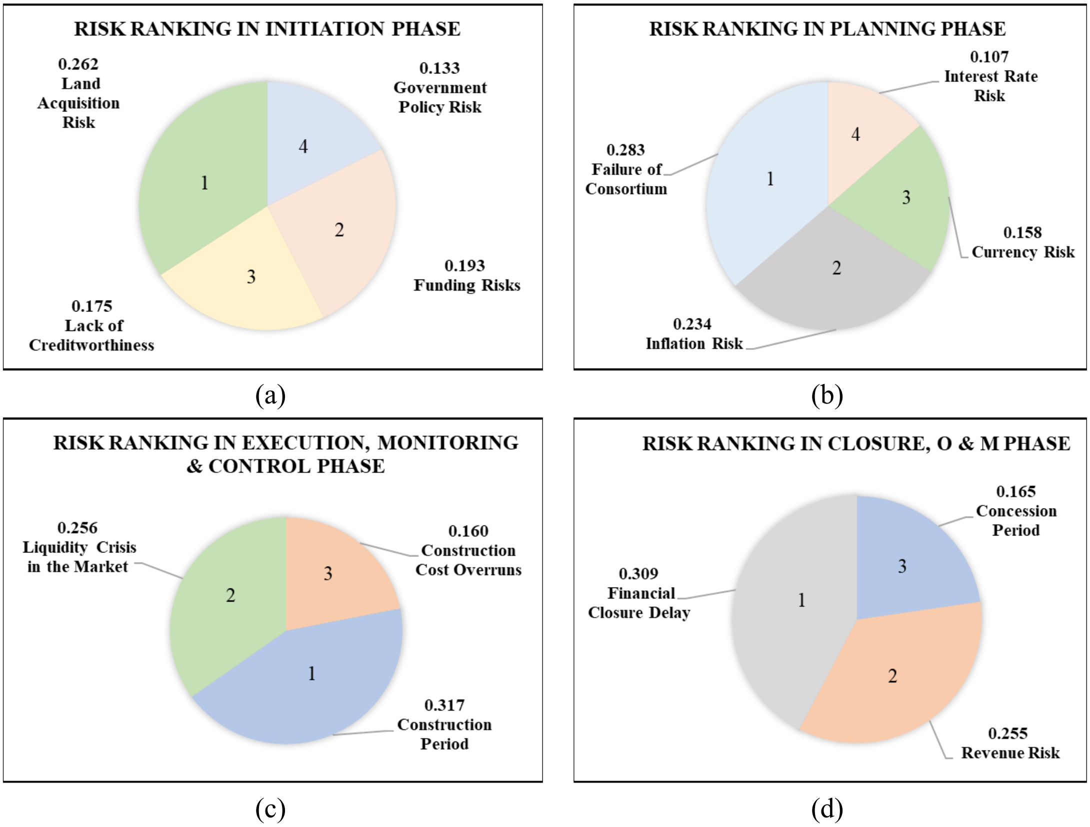
Figure 4: Ranking and Weight of Entire Phase



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3.2 Case study: Financial risk assessment in PPP projects

Three case projects have been assessed to evaluate financial risks in Public-Private Partnership (PPP) projects.

Project A: Hybrid Annuity Model (HAM) – Expressway Project in a Plain Region

Under this model, the government finances part of the project and the contractor finances the remaining part. The payment to the contractor is made in the form of an annuity over the operational phase of the project. This model reduces the financial burden on the contractor upfront but requires careful risk management over the long term. The project involves minimal geographical challenges. This can affect the construction phase as there are no complex terrains or environmental challenges but may increase risks related to land acquisition, local political issues, and the need for more extensive construction for a large-scale expressway. The financing model used is HAM, where the contractor bears a part of the capital expenditure but receives annuity payments from the government.

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The project duration is estimated to be 5 years for construction and 20 years for operation. Land acquisition is mostly free of issues due to the project being in a plain region. The contractor can secure financing with moderate risk, but the long operational phase requires monitoring over time to ensure a steady cash flow.

Project B: Build-Operate-Transfer (BOT) – Expressway Project in a Plain Area

In this model, the contractor builds the infrastructure, operates it for a specified period to recover costs and earn profit, and then transfers the asset back to the government. In this model the contractor is responsible for the initial capital investment and has to manage the operation and maintenance for the entire project lifecycle. Like Project A, this project is located in a plain region. However, the main difference lies in the funding model, as the contractor will bear the full cost of construction and operation for the project period. The project will involve full capital investment by the contractor, which means higher upfront financial exposure. The operation phase is expected to generate revenue from tolls or other sources, making the financial risk more tied to the traffic volume and public acceptance of the toll system. The duration of operation could range from 15 to 30 years, depending on the contractual agreement with the government.

Project C: Design-Build-Operate-Transfer (DBOT) – Expressway Project in a Plain Area

This model is similar to BOT, but with the added element that the contractor also handles the design of the project in addition to construction, operation, and transfer. This allows the contractor to have more control over the project but also increases the financial risk and design responsibility. Given that the contractor handles all aspects, they need to ensure quality control from design through to operation. The inclusion of the design phase adds additional time, costs, and complexity to the project. The contractor will take responsibility for both designing and building the infrastructure. The contractor's financial exposure is higher due to the requirement for greater capital for design, construction, and long-term operation. The operational revenue generation will depend on factors such as toll collection, traffic volume, and management of operation risks. This project will have the longest timeline among the three due to the added design phase (construction: 3 years, operation: 25 years).

The objective was to determine which project carries a higher potential for risk in each specific category. The methodology for assessing financial risks in the three project cases involved similar steps explained in section 3. In the Aggregation of expert opinions, the geometric mean of the risk weights assigned by all respondents was calculated to provide an overall weight for each risk category in each project case. Finally, the Final Risk-Based Ranking of Projects was determined by computing the total financial risk weightage for each project, where a higher risk weightage indicated a less preferred project, meaning projects with greater financial risk exposure were ranked lower in terms of preference. This analysis helps in systematically identifying the project that presents the least financial risk, assisting contractors in making more informed investment decisions. Table 5 and Table 6 show pairwise comparison matrix and normalized matrix for governmental risk.

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Table 5: Pairwise Comparison Matrix for Governmental Risk

	A	B	C
A	1.000	0.333	0.200
B	3.000	1.000	0.200
C	5.000	5.000	1.000
Sum	9.000	6.333	1.400

Source: Created by author

Table 6: Normalized Matrix for Governmental Risk

	A	B	C	Weights(W)	AW	λ
A	0.111	0.053	0.143	0.102	0.310	3.033
B	0.333	0.158	0.143	0.211	0.655	3.100
C	0.556	0.789	0.714	0.686	2.254	3.284

Source: Created by author

The weightage of all the risks in Project A, B, and C is shown in Table 7. The results show that Project B has the highest potential for financial risk among the three projects. Similarly, Project A has the least potential of having financial risk. Thus, the contractor should choose Project A which is a hybrid annuity model project. The final decision is ultimately taken by the higher authority which is very experienced and holds expertise. Figure shows the result graphically.

Table 7: Final Ranking of Projects

	Risks	**A**	**B**	**C**
1	Government Policy Risk	0.207	0.256	0.260
2	Funding Risks	0.232	0.191	0.326
3	Lack of Credit Worthiness	0.202	0.282	0.248
4	Land Acquisition Risk	0.272	0.124	0.415
5	Interest Rate Risk	0.125	0.356	0.352
6	Currency Risk	0.171	0.287	0.241
7	Inflation	0.208	0.254	0.240
8	Failure Of Consortium	0.323	0.210	0.193
9	Construction Cost Overruns	0.405	0.480	0.115
10	Construction Period	0.208	0.242	0.283
11	Liquidity Crisis in the Market	0.154	0.299	0.255
12	Concession Period	0.184	0.265	0.297
13	Revenue Risk	0.164	0.380	0.244
14	Financial Closure Delay	0.113	0.340	0.289
	Mean	**0.200**	**0.270**	**0.258**
	Rank	**3**	**1**	**2**
		Lowest Risk	**Highest Risk**	**Medium Risk**

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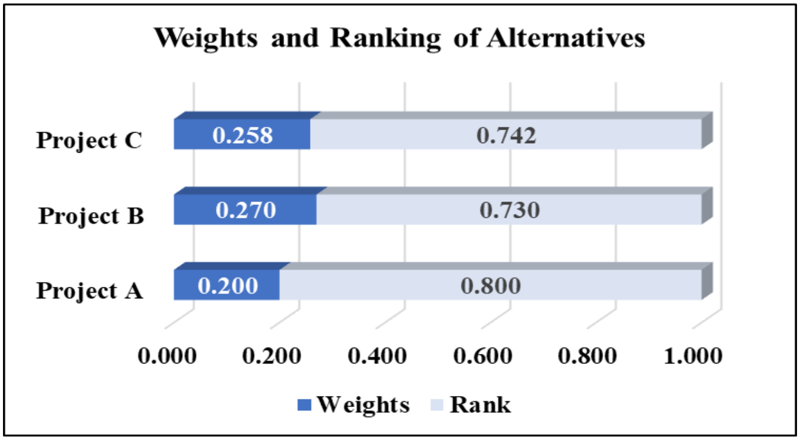
Figure 5: Weights and Rankings of Alternatives/Projects



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4.0 Results and Interpretation

The AHP analysis for financial risk assessment in PPP projects highlights the Execution, Monitoring & Control phase as the most critical, followed by the Planning phase, Closure & O&M phase, and finally, the Initiation phase. The Execution phase ranks highest due to the direct financial impact of cost overruns and liquidity crises, which significantly affect the project's budget and timeline, leading to potential losses and delays. The Planning phase comes next, driven by interest rate fluctuations and currency risks, emphasizing the need for financial forecasting and stable funding, especially for projects involving international financing. The Closure & O&M phase ranks third, mainly due to financial closure delays and revenue risks, which affect the project's long-term financial sustainability. The Initiation phase holds the lowest priority, with government policy risk being the main concern. Although less frequent, policy changes still influence the project's foundation and feasibility.

5.0 Recommendations

To effectively manage financial risks in PPP projects, key strategies include robust liquidity management with financial controls and contingency plans to handle cash flow issues. Hedging strategies and fixed-rate financing can mitigate interest rate risks during the planning phase. Real-time monitoring and cost-tracking systems help prevent construction cost overruns, while early regulatory compliance reduces government policy risks. Lastly, accurate revenue forecasting and flexible financial models ensure timely financial closure and manage revenue risks.

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