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Assessing Concession Period Risks of Public-Private Partnership Infrastructure Projects Using *FACULTY*

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Abstract

The concession period is critical to Public–Private Partnership (PPP) infrastructure project success because it defines how long private investors operate to recoup costs and earn returns. This study investigates risk factors affecting the concession period in Vietnam's PPP infrastructure projects and introduces a novel evaluation method called *FACULTY* (**F**uzzy **A**HP integrating **C**onsequences, **U**ncertainty, and **L**ikelihood **T**echnolog**y**). The research objective is to identify which risks most significantly influence concession duration and to demonstrate an improved risk assessment approach. FACULTY combines fuzzy AHP with a traditional consequence-likelihood analysis to capture uncertainty in expert judgments. By surveying 90 PPP experts and analyzing 27 risk factors across five risk categories: construction, revenue, macroeconomic, political, and legal risks, this study identified the ten most critical concession period risks for PPP infrastructure projects. These include land acquisition, access, and compensation issues; construction cost overruns; schedule delays; design deficiencies; geological and site conditions risks; force majeure; traffic demand risk; environmental risks; population growth; and concession price risk. These findings indicate that land acquisition and construction-related risks dominate, reflecting persistent challenges in Vietnam's infrastructure delivery. This study provides a comprehensive framework for understanding and addressing risks that influence the concession period, offering valuable insights for policymakers and practitioners aiming to optimize PPP project outcomes.

Keywords: Concession Period; PPP Infrastructure; Risk Assessment; Fuzzy AHP; Vietnam.

1. Introduction

Public-Private Partnership (PPP) projects play a crucial role in addressing infrastructure needs, particularly in developing countries like Vietnam [1]. A central determinant of these projects' success is the length of the concession period, which governs the duration of private investors' operational rights to recoup their investments and generate profits. It grants private entities the right to operate and collect revenue for a specified time. A longer concession increases private- sector incentives but also exposes them to additional risks, whereas a shorter term may undermine project viability [2]. Various risk factors, such as project costs, timelines, and revenue generation, influence the length of the concession period. Understanding and mitigating these risks is essential to ensure the financial sustainability and operational efficiency of PPP projects. Risks in PPP projects are often multidimensional, encompassing construction, financial, legal, political, and environmental domains. For example, risks such as land acquisition delays, cost overruns, inflation volatility, and demand fluctuations frequently lead to prolonged concession periods. Despite the growing body

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of research on PPP risk management, the literature has not explicitly focused on the factors that influence concession periods in infrastructure projects. In other words, this reveals a research gap in explicitly prioritizing which risks most threaten the timely completion of PPP concessions. This study addresses that gap by systematically assessing and ranking the concession-period risk factors in Vietnam's PPP infrastructure projects using a new integrated approach.

To accomplish this, this study developed a hybrid analytical method termed FACULTY (**F**uzzy **A**HP integrating **C**onsequences, **U**ncertainty, and **L**ikelihood **T**echnolog**y**) to assess 27 concession-period risk factors in Vietnam's PPP infrastructure projects. The FACULTY framework combines two techniques: a traditional Consequence–Likelihood risk analysis and a spherical fuzzy AHP (SFAHP) multi-criteria evaluation. First, the Consequence–Likelihood methodology is applied to compute each factor's local risk score; subsequently, SFAHP is employed to determine the relative weights of five risk categories and thereby derive global risk scores. Notably, SFAHP sets enable experts to express uncertainty through independent degrees of membership, non-membership, and hesitation. By integrating these techniques, FACULTY captures both the magnitude of each risk (through CL scoring) and the uncertainty of each risk category (through SFAHP weighting), resulting in a robust prioritization of risks under uncertainty.

This study applied the FACULTY method to 27 concession-period risk factors identified from literature and industry input. It also surveyed 90 PPP experts to evaluate each factor. As a result, the outcome was a ranked list of the ten most critical risks prolonging the concession period in Vietnam. The analysis revealed that risks related to land acquisition and construction costs are among the most critical, reflecting systemic challenges in Vietnam's infrastructure development landscape. Other significant risks include inflation volatility, interest rate fluctuations, and demand uncertainties, all of which introduce complexities into financial planning and project execution. This research contributes to the body of knowledge by offering a structured framework for understanding the concession period risks in PPP projects. The novel FACULTY approach not only fills a gap in concession period risk assessment but also demonstrates improved handling of expert uncertainty compared to previous methods. By highlighting the top ten critical risks and proposing targeted mitigation strategies, the study provides valuable guidance for policymakers, project managers, and investors seeking to optimize concession periods and enhance the success of PPP initiatives in Vietnam.

The rest of the paper is organized as follows: Section 2 reviews relevant literature on PPP risks; Section 3 details the methodology, including data collection, CL technique, and the SFAHP weighting process; Section 4 presents results of critical risks; Section 5 discusses implications and mitigation measures; and Section 6 concludes.

2. Literature Review

Because the concession period balances risk transfer, financial viability, and value for money, understanding how risks evolve—especially through construction into operations—is essential. The construction phase involves the highest uncertainty. Across developing contexts, land acquisition and compensation consistently emerge as the most critical bottlenecks; in Vietnam and similar settings, divided responsibilities between Provincial People's Committees (site clearance) and authorized state entities (contracting) create coordination delays that inflate time and cost [3]. Technical and environmental uncertainties—geological conditions and environmental incidents—further disturb budgets and schedules. Moreover, design deficiencies and inadequate specifications amplify exposure: design changes, equipment failures, material shortages, and skilled labor gaps are recurrent global problems that trigger overruns. Force majeure adds tail risks whose allocation varies across jurisdictions and asset classes, complicating long-term contracts.

The commercial core of PPP viability lies in demand and revenue formation. Traffic demand uncertainty is pivotal in transport PPPs, with forecasts sensitive to competition, evolving travel behavior, and intermodal shifts. User-pays models load demand risk on the private party, whereas availability-payment schemes stabilize cash flows . Beyond volume risk, tariff setting and toll indexation drive revenue volatility, interacting with consumer willingness-to-pay and network geography (location, connectivity) to shape long-run receipts [4]. Operationally, O&M overruns erode margins as assets age; availability and quality requirements, demographic trends, and rising service expectations create performance dependencies that must be actively managed to protect revenue and meet covenants. From a financing perspective, interest-rate movements shift debt service profiles in leveraged structures, with small shocks compounding over decades [5]. Inflation introduces dual pressures: it lifts costs while revenue impacts hinge on indexation and regulatory pass-through. Volatile inflation—common in developing markets—complicates planning and undermines bankability [6]. Broader macro conditions affect demand fundamentals and investor appetite; inflation instability is negatively correlated with private participation, which underscores the need for hedging and scenario-based financial structuring.

Institutionally, tax changes, policy shifts, and government intervention (including expropriation, unilateral tariff actions, or contract rescission) can materially alter PPP economics over multi-decade horizons, even where treaties and constitutional protections exist [7]. Mitigation relies on robust change-in-law clauses, compensation formulas, and credible dispute resolution—but these protections are only as effective as institutional quality and political stability. Corruption cuts across phases—from land clearance to approvals and contract administration—and is widely documented as a high-priority risk in Vietnam, affecting compensation and timeline integrity despite ongoing reforms and oversight efforts.

Based on the comprehensive literature review of risk factors in PPP projects, this research conducted in-depth interviews with four PPP professionals in Vietnam to identify and categorize specific risk factors affecting concession period length. This analysis revealed 27 risk factors, classified into five main categories (see Table 1).

Table 1. Risk categories and risk factors affecting concession period

Code	Categories	Risk factors	References
		Construction and completion risks	
R1		Land acquisition, access, and compensation	[8, 9]
R2		Geological/site condition	[10, 11]
R3		Environmental risks (e.g., regulatory changes, environmental impact issues)	[12, 13]
R4	I	Design or technical specification deficiency	[9, 11]
R5		Construction cost overruns	[14-16]
R6		Schedule delays (construction logistics, equipment failure, materials shortage, shortage of skilled workers, etc.)	[9, 17]
R7		Force majeure (floods, earthquakes, and other natural disasters)	[18-20]
		Revenue and operational risks	
R8		Traffic demand risk	[21, 22]
R9		Concession price risk (toll price)	[23, 24]
R10		Competition risk (alternative services)	[25, 26]
R11		Operating risks (O&M cost overruns, etc.)	[13, 27]
R12	II	Toll levels & adjustments	[28, 29]
R13		Project location and network links risk (traffic congestion)	[2, 30, 31]
R14		Availability and service quality	[32, 33]
R15		Willingness to pay (end-users)	[34-36]
R16		Population growth	[37, 38]
		Macroeconomic risks	
R17		Interest rate fluctuations	[39-41]
R18	III	Inflation volatility	[42, 43]
R19		Foreign exchange exposure	[44-46]
R20		GDP change	[47, 48]
		Political (Host country) risks	
R21		Tax rates & policy changes	[49-51]
R22	IV	Government intervention or expropriation (i.e., a government takeover of a facility without compensation)	[52-54]
R23		Breach or cancellation of a concession	[7, 55]
R24		Tariff change	[6, 56]
		Legal risks	
R25		Inadequate law or law change	[57, 58]
R26	V	Poor functionality of the judicial system (permitting and approval delays, poor transparency)	[59, 60]
R27		Corruption	[61, 62]

3. Research Methodology

To provide a clear overview of the FACULTY approach, Figure 1 illustrates the sequential steps, from risk identification through risk scoring and fuzzy weighting to final prioritization.

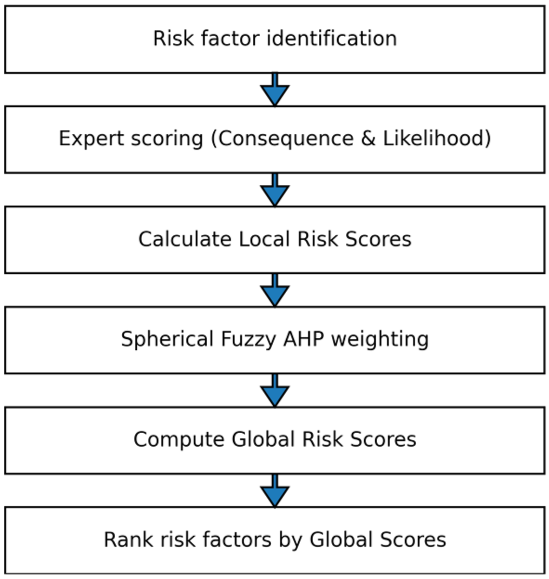

Figure 1. Flowchart of the FACULTY risk assessment methodology

In summary: (1) relevant concession-period risk factors are identified through literature review and expert input; (2) experts evaluate each risk factor's consequence and likelihood using linguistic scales; (3) these are converted to numerical scores and aggregated to compute each factor's local risk score; (4) experts perform spherical fuzzy AHP pairwise comparisons to assign weights to the major risk categories; (5) the local risk scores are multiplied by category weights to obtain global risk scores; and (6) risk factors are ranked by their global scores.

There are many definitions of risk. Some authors describe risk as events with negative and uncertain consequences. Akintoye & MacLeod [63] observed the actual management of infrastructure development projects under the PFI/PPP. They concluded that the general awareness of risks under the PFI/PPP is the capability of non-forecasted factors adversely affecting the project in cost, time, and quality. In other words, risks are inherent in the infrastructure development projects under the PPP form. Such risks arise from uncertainty about future events and can negatively affect service delivery or a project's profit feasibility. Other researchers similarly define project risks as events or factors that, when they occur, negatively impact a project's cost, schedule, quality, or profits. The definition of risk has evolved to the effect of uncertainty on objectives. In this definition, uncertainty is the state, even partial, of deficiency of information related to understanding or knowledge of an event, its consequence, or likelihood. This definition focuses attention on the reason for an investment or a project and what it intends to achieve—its business case —rather than on a project manager's narrow objectives in the delivery phase of completing on time, within budget, and to an acceptable level of quality. The consequences of risk and the effect of uncertainty may be positive as well as negative. In other words, the risk embraces events or circumstances with threats as well as those with opportunities. Moreover, the focus of risk management used to be solely on problems and things that could go wrong. Nowadays, most risk managers acknowledge the 'upside' potential of risk (opportunities) in addition to the downside.

To evaluate a risk, we need to know two dimensions: the impact level and the probability of occurrence [64, 65]. Risk is often expressed in terms of a combination of the consequences of an event and the associated likelihood of occurrence. The likelihood of a risk factor represents the chance that it will occur and potentially cause adverse effects on the project. It may be measured by determining the rate of the numbers which such factor occurs in the total times. The consequence of a risk factor refers to the magnitude of impact on the project's performance when that risk occurs. Approaching the management concept, some risk management studies from roadway projects measured each risk factor by multiplying consequence and occurring probability with an impact rate of such risk factor [66, 67]. This concept appreciates the role of risk management. It emphasizes that risk management is not merely about eliminating threats; it also involves transferring each risk factor to the party best able to manage it at the lowest cost. Using this concept, a combined risk score can be obtained. In short, the local risk score is calculated using the consequence–likelihood (CL) formula [68]:

$$Local\ R_i = \bar{C}_i + \bar{L}_i - (\bar{C}_i \times \bar{L}_i) \tag{1}$$

$$\bar{C}_i = \frac{\sum_{j=1}^{n} c_{ij}}{5n} \tag{2}$$

$$\bar{L}_i = \frac{\sum_{j=1}^{n} l_{ij}}{5n} \tag{3}$$

where, $Local\ R_i$: The local risk score; $\bar{C}_i$: The average risk consequence value; $\bar{L}_i$: The average risk likelihood value; $\sum_{j=1}^{n} c_{ij}$: The summation of consequence scores for risk i across all respondents j, from 1 to n. C_{ij}: The consequence score given by respondent j for risk i; $\sum_{j=1}^{n} l_{ij}$: The summation of likelihood scores for risk i across all respondents j, from 1 to n; l_{ij}: The likelihood score given by respondent j for risk i; n: The total number of expert respondents.

To account for the relative importance of risk categories, we applied an SFAHP procedure. The five main groups (Construction, Revenue, Macroeconomic, Political, Legal) serve as criteria in the hierarchy. Each expert provided pairwise comparisons among these five groups using linguistic terms. These were converted to spherical fuzzy numbers (SFNs) according to established scales. Table 2 illustrates sample linguistic labels and their SFN equivalents to reflect uncertainty.

The SFAHP is separated into several steps: [69]

(i) Construct a hierarchical structure of five main risk groups (Construction and completion, Revenue, Macroeconomic, Political, and Legal).

(ii) Create pairwise comparisons using spherical fuzzy judgment matrices from experts based on language terms in Table 1.

Table 2. Spherical fuzzy scales for pairwise comparisons [70]

Linguistic Term	SFN (ω, ξ, ψ)	Score index
Absolutely high (AHI)	(0.9, 0.1, 0.0)	9
Very high (VHI)	(0.8, 0.2, 0.1)	7
High (HI)	(0.7, 0.3, 0.2)	5
Slightly high (SHI)	(0.6, 0.4, 0.3)	3
Equal (EI)	(0.5, 0.4, 0.4)	1
Slightly low (SLI)	(0.4, 0.6, 0.3)	1/3
Low (LI)	(0.3, 0.7, 0.2)	1/5
Very low (VLI)	(0.2, 0.8, 0.1)	1/7
Absolutely low (ALI)	(0.1, 0.9, 0.0)	1/9

Table 2's score indices (I) are calculated using Equations 4 and 5:

$$I = \sqrt{\left|100 \times \left[\left(\omega_{\tilde{A}_{SF}} - \psi_{\tilde{A}_{SF}}\right)^2 - \left(\xi_{\tilde{A}_{SF}} - \psi_{\tilde{A}_{SF}}\right)^2\right]\right|} \tag{4}$$

for AHI, VHI, HI, SHI, and EI

$$I^{-1} = \frac{1}{\sqrt{\left|100\times\left[\left(\omega_{\tilde{A}_{SF}} - \psi_{\tilde{A}_{SF}}\right)^2 - \left(\xi_{\tilde{A}_{SF}} - \psi_{\tilde{A}_{SF}}\right)^2\right]\right|}} \tag{5}$$

for EI, SLI, LI, VLI, and ALI

where, $\omega_{\tilde{A}_{SF}}$, $\xi_{\tilde{A}_{SF}}$, and $\psi_{\tilde{A}_{SF}}$ represent membership, non-membership, and hesitancy degrees, respectively, of spherical fuzzy set $\tilde{A}_{SF}$.

(iii) Verify the consistency ratio (CR) of each pairwise comparison matrix. (threshold 10%).

(iv) Determine the spherical fuzzy weights of five main groups (Construction, Revenue, Macroeconomic, Political, Legal) and derive the crisp priority weights via defuzzification using Equations 6 and 7:

$$W_w = \left\{\left[1 - \prod_{j=1}^{n}\left(1 - \alpha_{\tilde{A}_{SF_{ij}}}^2\right)^{w_j}\right]^{1/2}, \prod_{j=1}^{n} \beta_{\tilde{A}_{S_{ij}}}^{w_j}, \left[\prod_{j=1}^{n}\left(1 - \alpha_{\tilde{A}_{SF_{ij}}}^2\right)^{w_j} - \prod_{j=1}^{n}\left(1 - \alpha_{\tilde{A}_{SF_{ij}}}^2 - \chi_{\tilde{A}_{SF_{ij}}}^2\right)^{w_j}\right]^{1/2}\right\} \tag{6}$$

$$SF(\widetilde{w}_j^{SF}) = \sqrt{\left|100 \times \left[\left(3\alpha_{\tilde{A}_{SF}} - \frac{\chi_{\tilde{A}_{SF}}}{2}\right)^2 - \left(\frac{\beta_{\tilde{A}_S}}{2} - \chi_{\tilde{A}_{SF}}\right)^2\right]\right|} \tag{7}$$

Using the above category weights, each factor's global risk score was computed as:

$$Global\ \mathrm{R}_i = w_{(i)} \times \mathrm{Local\ R}_i \tag{8}$$

4. Results

The rankings of the 27 concession-period risk factors, derived from respondents and computed using Equations 1 to 3 based on consequence (C) and likelihood (L), are shown in Table 3. All experts had substantial experience (mostly over 5–10 years) with PPP infrastructure projects. Based on the computed C and L scores, we identified 12 critical factors with a high-risk level (*Local R* > 0.8 on a 0–1 scale) and an additional 10 factors with a medium risk level. Figure 2 presents the risk contour diagram for all 27 risk factors.

From these results, we observe that some risk factors scored high in both consequence and likelihood. For example, land acquisition and compensation (R1), construction cost overruns (R5), and corruption (R27) all rank highly on both dimensions. However, several factors showed the opposite pattern: some had high consequence but low likelihood, and others vice versa. For instance, force majeure (R7) was judged to have a high consequence but very low likelihood, whereas legal framework risk (e.g., inadequate law or law changes, R25) was given a moderate likelihood but a low consequence.

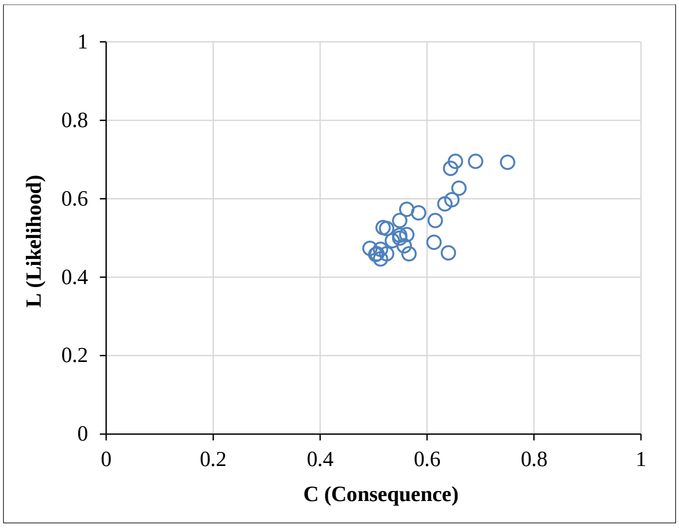

Figure 2. Risk contours diagram

Table 3. Ranking of risk factors affecting concession period

Code	Risk factors	C	L	Local RF	Weight	Global RF	Rank
R1	Land acquisition, access, and compensation	0.7511	0.6933	0.9237	0.2517	0.2325	1
R2	Geological site condition	0.5844	0.5644	0.8190	0.2517	0.2061	5
R3	Environmental risks (e.g., regulatory changes, environmental impact issues)	0.5133	0.4711	0.7426	0.2517	0.1869	8
R4	Design or technical specification deficiency	0.6333	0.5867	0.8484	0.2517	0.2135	4
R5	Construction cost overruns	0.6911	0.6957	0.9060	0.2517	0.2280	2
R6	Schedule delays (construction logistics, equipment failure, materials shortage, shortage of skilled workers, etc.)	0.6444	0.6778	0.8854	0.2517	0.2229	3
R7	Force majeure (floods, earthquakes, and other natural disasters)	0.6400	0.4622	0.8064	0.2517	0.2030	6
R8	Traffic demand risk	0.6156	0.5445	0.8249	0.2324	0.1917	7
R9	Concession price risk (toll price)	0.5489	0.5067	0.7775	0.2324	0.1807	10
R10	Competition risk (alternative services)	0.5044	0.4578	0.7222	0.2324	0.1678	18
R11	Operating risks (O&M cost overrun, etc.)	0.5489	0.5000	0.7744	0.2324	0.1800	11
R12	Toll levels & adjustments	0.5178	0.5267	0.7717	0.2324	0.1793	12
R13	Project location and network links risk (traffic congestion)	0.4933	0.4733	0.7332	0.2324	0.1704	16
R14	Availability and service quality	0.5356	0.4933	0.7647	0.2324	0.1777	13
R15	Willingness to pay (end-users)	0.5067	0.4600	0.7336	0.2324	0.1705	15
R16	Population growth	0.5489	0.5444	0.7945	0.2324	0.1846	9
R17	Interest rate fluctuations	0.6467	0.5978	0.8579	0.1959	0.1681	17
R18	Inflation volatility	0.6600	0.6267	0.8731	0.1959	0.1710	14
R19	Foreign exchange exposure	0.5622	0.5089	0.7850	0.1959	0.1538	19
R20	GDP change	0.5244	0.4600	0.7432	0.1959	0.1456	20
R21	Tax rates & policy changes	0.5578	0.4800	0.7700	0.1794	0.1381	22
R22	Government intervention or expropriation (i.e., a government takeover of a facility without compensation)	0.6133	0.4889	0.8024	0.1794	0.1440	21
R23	Breach or cancellation of a concession	0.5667	0.4600	0.7660	0.1794	0.1374	23
R24	Tariff change	0.5133	0.4467	0.7220	0.1794	0.1295	24
R25	Inadequate law or law change	0.5244	0.5244	0.7738	0.1406	0.1088	27
R26	Poor functionality of the judicial system (permitting and approval delays, poor transparency)	0.5622	0.5733	0.8132	0.1406	0.1143	26
R27	Corruption	0.6533	0.6956	0.8945	0.1406	0.1258	25

Next, we derived the category weight vector $w = [w_1, w_2, w_3, w_4, w_5]$ (for Construction & Completion, Revenue, Macroeconomic, Political, and Legal risk groups, respectively) using Equations 4 and 5 based on expert pairwise comparisons. The experts' fuzzy pairwise judgments were aggregated and defuzzified using Equations 6 and 7. Experts were provided with written guidelines explaining the qualitative ratings and the pairwise comparison scale for SFAHP based on Table 2. We also checked the consistency of each expert's SFAHP judgments and ensured they were within acceptable limits (all were below the 0.1 threshold, indicating good consistency). Finally, combining the category weights with local scores (using Equation 8) yielded each factor's global risk score. All 27 risks were then ranked in descending order of global risk score to prioritize concession-period risks. The ten most critical risk factors (in order) were identified as follows:

- Land acquisition, access, and compensation (R1);
- Construction cost overruns (R5);
- Schedule delays—including construction-logistics constraints, equipment failures, material shortages, and shortages of skilled labor—(R6);
- Design or technical specification deficiencies and changes (R4);
- Geological/site conditions (R2);
- Force majeure (e.g., floods, earthquakes, other natural disasters) (R7);
- Traffic demand risk (R8);
- Environmental risks (e.g., regulatory changes, environmental impact issues) (R3);
- Population growth (R16); and
- Concession price risk (R9).

5. Discussion

Most of the critical concession-period risks are risks related to the construction phase of the PPP infrastructure projects. These significant risks are analyzed as follows.

5.1. Land Acquisition, Access, and Compensation Risk (R1)

Land acquisition, access, and compensation is confirmed as the highest-ranked risk (*Global R* = 0.2325). This risk significantly impacts project schedule, budgets, and stakeholder satisfaction. Failure to secure land for project deployment leads to project delays and cost overruns, with disputes often arising from compensation rates below market value. Additionally, varying compensation rates between regions create inconsistencies, further complicating negotiations and prolonging timelines. Evidence from Vietnam highlights land acquisition as the primary cause of delays in most PPP projects.

The inconsistent legal framework governing land acquisition in Vietnam exacerbates these challenges. Different regions apply varying compensation rates, often misaligned with actual market prices. Overlapping legal jurisdictions and fragmented dispute resolution processes further hinder progress. For example, in Quang Ninh province, land clearance delays accounted for 40-50% of project preparation time in PPP transportation initiatives, discouraging private sector participation. Moreover, the absence of comprehensive resettlement policies and socioeconomic support for displaced populations fuels community resistance, particularly in urban areas with high land values.

The effects of land acquisition delays are far-reaching, causing extended construction schedules, increased costs, and reduced investor confidence. Prolonged negotiations inflate project costs by 20-30%, jeopardizing financial feasibility. Persistent uncertainties deter private investors, limiting their willingness to engage in future PPP projects. These delays disrupt construction schedules, extend concession periods, and diminish profitability, posing significant risks to project success.

To address these issues, Vietnam must adopt a comprehensive approach. Streamlining the legal framework for land acquisition with standardized compensation mechanisms and independent arbitration bodies can minimize delays. Engaging affected communities early in the planning process builds trust and reduces resistance, while transparent compensation policies and livelihood restoration programs enhance social acceptance. Assigning land acquisition responsibilities to the government and creating contingency budgets for unforeseen expenses provide financial stability. Training local authorities in stakeholder management further ensures efficiency and facilitates conflict resolution. By implementing these strategies, Vietnam can mitigate land acquisition risks, improving the efficiency, attractiveness, and overall success of its PPP projects.

5.2. Construction Costs Overruns Risk (R5)

Construction cost overruns, which occur when actual construction costs exceed initial estimates, are a significant risk in PPP transportation projects in Vietnam. Factors such as material shortages, unforeseen site conditions, and inflation frequently disrupt project budgets. For example, in the Mekong Delta, a shortage of construction materials like sand, stone, and gravel has increased input costs. Additionally, the region's soft soil conditions require expensive engineering solutions, often inflating costs three- to four-fold relative to other areas. A striking instance is the Rach Mieu BOT Bridge Project, where the investment surged from VND 599.9 billion to VND 988 billion, compelling the government to raise its budget contribution from 25.8% to 60%.

Key drivers of cost overruns include the reliance on transporting materials from distant locations due to local shortages, fluctuating prices of essential inputs such as sand and steel, and delays caused by supply chain disruptions. In addition, inadequate planning contributes significantly, as many projects fail to account for contingencies, inflation, or changes in material costs. Compounding this issue are frequent changes in project scope or technical specifications, often resulting from incomplete feasibility studies or shifting stakeholder demands. These factors collectively amplify financial pressures on PPP projects.

The impact of cost overruns on PPP projects is severe and multifaceted. The financial strain on both investors and governments necessitates renegotiation of funding arrangements, potentially deterring private sector participation in future projects. Delays in securing additional funds and materials disrupt project schedules, thus eroding public trust and investor confidence. In some cases, to manage escalating costs, the project scope or quality may be compromised, undermining the infrastructure's intended benefits and value to society.

Mitigating cost overruns requires a comprehensive strategy. Accurate cost estimation during the planning phase, incorporating contingencies and addressing site-specific challenges, is essential. Strengthening supply chain management by fostering local production and securing long-term contracts for materials can stabilize costs. Employing innovative technologies such as prefabrication and geotechnical improvements can reduce the impact of challenging site conditions. Additionally, incorporating contractual mechanisms for shared risks and real-time project monitoring systems helps maintain financial discipline and accountability. By addressing these issues, Vietnam can enhance the financial sustainability and efficiency of its PPP projects, ensuring better outcomes for both investors and the public.

The identification of land acquisition delays and construction overruns as top risks is consistent with prior observations in Vietnam's PPP experience – for example, Likhitruangsilp et al. [71] found land acquisition and slow approvals to be the most critical perceived risks in Vietnamese PPP projects. Similarly, Osei-Kyei & Chan [72] found delay in land acquisition and cost overruns to be among the top five risks in Hong Kong.

5.3. Schedule Delays Risk (R6)

Schedule delays occur when construction periods exceed planned schedules, resulting in financial and operational challenges. If construction costs completion is delayed, the private concessionaire may require a longer operating period to compensate for higher expenses and lost time. Contributing factors include logistical problems, equipment failures, material shortages, site accidents, and a lack of skilled labor. For example, the BOT Binh Trieu 2 bridge and road project, begun in 2001, is still incomplete, with only three-fifths of its components finished due to capital shortages, design changes, and space constraints. Similarly, the BOT National Highway 13 upgrading project and PPP Cau Gie-Ninh Binh project faced delays caused by investor disputes, contractor bankruptcies, and poor construction quality.

Material and equipment shortages further exacerbate time delays. Many Vietnamese construction companies cannot manage large-scale PPP projects and rely heavily on rented equipment. For instance, Bridge Company No. 14 often rents 12-15 cranes monthly, causing disruptions when rentals are unavailable. Capital shortages and investor disputes further have further prolonged timelines—for example, in the BOT National Highway 13 project, investor substitutions led to work stoppages. Material shortages during peak construction periods and a lack of skilled labor also contribute to inefficiencies and delays, compounding the challenges faced by PPP projects.

The impacts of time delays are significant and multidimensional. They escalate project costs through increased labor costs, material price inflation, and equipment rentals. Persistent delays reduce investor confidence, deterring future participation in PPP projects. Delayed project delivery also undermines public trust, especially for critical infrastructure projects like highways and bridges. In efforts to recover lost time, accelerated schedules often compromise construction quality, as observed in the BOT National Highway 13 project. Taken together, these delays undermine overall PPP effectiveness.

Mitigating time delays requires a comprehensive approach. Enhancing contractor selection by evaluating technical and financial capacity ensures project readiness, while risk allocation in contracts incentivizes timely completion. Strengthening financial management through improved capital allocation and contingency funds minimizes disruptions caused by resource shortages. Optimizing resource planning, including securing long-term material agreements and investing in labor training, reduces inefficiencies. Proactive project management, using advanced scheduling tools and effective stakeholder coordination, facilitates timely interventions. Addressing design and site challenges through thorough feasibility studies and proper site preparation minimizes mid-project changes. By adopting these strategies, Vietnam can enhance the reliability and efficiency of its PPP projects, ensuring timely delivery and sustained public confidence.

5.4. Design or Technical Specification Deficiencies and Changes Risk (R4)

Design or technical specification deficiencies and changes rank as the fourth most critical risk for PPP projects in Vietnam. This risk occurs when project designs or technical specifications are incomplete, unclear, or frequently revised, resulting in errors in cost estimates, modifications to project scope, and waste during construction. A notable example is the Cau Gie-Ninh Binh Highway Project, where repeated changes in objectives and technical specifications—from an expressway to an upgraded road and then to a new highway—caused extensive delays. The project also underwent a shift from a BOT model to bond financing, requiring ownership changes and further complicating execution.

The root causes of this risk include poorly defined objectives and incomplete feasibility studies, which often lead to unclear or deficient technical specifications. Without thorough geological surveys, environmental assessments, and stakeholder consultations, projects are prone to design changes during execution. Furthermore, frequent scope changes driven by evolving needs or external pressures disrupt timelines and inflate costs. Weak contractual frameworks that fail to define roles and responsibilities create ambiguities, leading to disputes and delays. Additionally, the involvement of inexperienced consultants or contractors results in design errors and costly adjustments during construction.

The impact of these deficiencies is significant. Frequent design revisions inflate costs through additional consultancy fees, material waste, and construction delays, as seen in the Cau Gie-Ninh Binh project. These disruptions extend concession periods, affecting both investors and end-users. Ambiguities in design specifications also lead to disputes among stakeholders, complicating project implementation and straining public-private relationships. Moreover, such uncertainty diminishes investor confidence, deterring future private sector participation in PPP projects.

Mitigating design-related risks requires comprehensive planning, robust contractual frameworks, and proactive project management. Detailed feasibility studies and stakeholder engagement during the planning phase will ensure well-defined objectives and technical specifications. Contracts should include precise design requirements and assign design-related risks appropriately. Engage qualified consultants and enhance technical capacity through training programs to minimize errors. Regular third-party reviews and real-time monitoring improve oversight, while adaptive contract models and scenario planning accommodate necessary changes without significant disruptions. By adopting these strategies, Vietnam can enhance project efficiency, reduce disruptions, and build stakeholder confidence in PPP initiatives.

5.5. Geological and Site Conditions Risk (R2)

Geological and site condition risks are particularly critical in Vietnam due to the limited technical capacity of design consulting companies and the inaccuracies in topographical and geological investigations. These deficiencies result in inappropriate designs and construction plans that fail to align with real-world conditions, leading to technical errors and significant economic losses. For example, the Bai Chay PPP Bridge Project encountered unexpected geological conditions when sites initially presumed to be rock were revealed to be soil. This discrepancy necessitated adjustments to the design, including modifications to the slope and additional reinforcements, increasing the project cost by approximately VND 32 billion—a 110% increase from the initial estimate.

Unpredictable geological conditions, insufficient planning, and environmental factors significantly complicate project execution in Vietnam. Weak soils, waterlogging, and poor site accessibility are prevalent in regions such as the Mekong Delta, where extensive foundation reinforcements and specialized techniques are often required. These challenges inflate project costs, delay timelines, and reduce the profitability of PPP projects. Furthermore, incomplete feasibility studies and insufficient site assessments exacerbate these risks, as unexpected site conditions necessitate costly mid-project interventions.

To mitigate these challenges, a combination of strategies is essential. Conducting comprehensive geological surveys and utilizing advanced technologies like ground-penetrating radar improve site assessments and reduce uncertainties. Adaptive project designs, such as modular structures and flexible engineering solutions, accommodate varying conditions. Risk-sharing mechanisms, such as insurance coverage and contractual provisions, help ensure an equitable burden distribution between public and private stakeholders. Additionally, enhanced project management practices, including engaging geotechnical experts and real-time monitoring, can mitigate risks during construction. By adopting these measures, Vietnam can address geological and site condition risks effectively, ensuring the resilience and success of its PPP projects.

5.6. Force Majeure Risk (R7)

Force majeure refers to extreme, unforeseeable events beyond the control of any party (e.g., floods, earthquakes, typhoons, pandemics) that can interrupt project execution. In PPP transportation, force majeure events typically include natural disasters (e.g., major floods, storms, landslides) and other calamities. Such events are generally defined in concession contracts as grounds for relief and possible extension. Vietnam is one of the world's most climate-vulnerable countries: typhoons, floods, and landslides frequently threaten a high proportion of the country's population and economic assets. For example, Typhoon Damrey caused severe flooding in central Vietnam with an estimated US$1 billion in damages [73]. Internationally, PPP road projects are similarly affected: a case study of Indonesia's Trans-Sumatra toll road found that heavy rains and flooding on swampy land caused serious construction delays, requiring costly rescheduling and cost recalculations [74]. Those delays were further compounded by another force majeure event –the COVID-19 pandemic– in that same project. These findings underscore that force majeure risks could cause tremendous losses if not managed proactively.

Force majeure risk is driven by climatic and geologic hazards (e.g., typhoon-prone coasts, seismic zones). In Vietnam, annual monsoons and increasingly erratic weather (exacerbated by climate change) raise the likelihood of project-disrupting floods or storms. Inland projects may face landslides during heavy rains. None of these events can be prevented, and their timing/intensity often defy engineering expectations. The diversity of Vietnam's terrain (mountains, deltas, coastline) means many transport links have high exposure. Similarly, international projects in seismically active or typhoon-prone regions (e.g., Philippines, Japan, India) carry analogous risks.

When a force majeure event strikes, it can halt construction (e.g., washed-out sites, damaged access roads) or operation (e.g., closed highway segments), triggering work stoppages. Project costs jump due to emergency repairs and mobilizing resources anew. Timelines slip by weeks or months, and completion dates must be pushed back. In concession terms, such delays often translate into automatic extensions: for example, many concession agreements allow the concessionaire to collect tolls for a longer period to compensate for lost time. Delayed openings mean deferred revenue, which pressures cash flow and may require renegotiating the concession. Repeated or extreme disasters can shake investor confidence – concessionaires may demand higher risk premiums or government support. In practice, Indonesia's toll road operator had to "recalculate construction costs" and reschedule the entire program after floods and COVID-19 issues [74]. In Vietnam, if a coastal highway is flooded for weeks, the concessionaire will likely seek relief (extended term or compensation) under the force majeure clause.

Mitigation of force majeure risk combines technical, contractual, and financial tools. Design and location choice can reduce exposure (e.g., elevate embankments, build levees, reinforce slopes, use flood-resilient materials). Engineering standards can be heightened (seismic design codes, improved drainage) for disaster resilience. Contractually, strong PPP agreements define clear force majeure clauses: often these clauses grant the concessionaire time extensions or partial relief for major disruptions. For instance, contracts may explicitly allow toll collection to continue beyond the original end-date if delays exceed a threshold. Governments can share risk by offering disaster insurance pools or emergency funds for rapid repair (instead of leaving all loss to the private partner). Financially, the project SPV may purchase natural disaster insurance or secure lines of credit. Coordination with meteorological agencies and establishment of emergency SOPs help teams prepare for events in advance. Overall, combining robust design with well-crafted contract provisions helps limit cost overruns and preserve investor confidence in the face of force majeure.

5.7. Traffic Demand Risk (R8)

This risk arises from unforeseen variations in traffic demand. These variations can lead to improper project design, residual or insufficient capacity, and fluctuations in revenue or profit compared to initial projections. For transportation PPP projects, toll revenue is the primary income source for private investors, making traffic demand critical to financial stability. A prominent example is the Phu My BOT Bridge Project. Low traffic volumes and incomplete connecting infrastructure caused significant financial difficulties, prompting the investor to terminate the concession in 2011 due to unmet financial obligations and unfulfilled government commitments.

The causes of demand risks are multifaceted. Optimistic forecasting or limited data often result in overestimates of traffic volumes, leading to revenue shortfalls. Delays in completing connecting infrastructure, such as belt roads for the Phu My Bridge, reduce the accessibility and attractiveness of PPP facilities. Additionally, inconsistent enforcement of toll policies, competition from untolled alternative routes, and failure to prioritize traffic dispersal strategies further exacerbate demand risks. External factors, including macroeconomic downturns, fuel price hikes, and shifting user preferences, also alter traffic patterns, making demand variations difficult for stakeholders to predict and manage.

The impacts of demand risks on PPP projects are significant. Revenue shortfalls jeopardize the financial sustainability of projects, often resulting in an inability to repay loans or meet operational costs. To recover losses, investors may seek extended concession periods, delaying asset transfers to the government and affecting long-term timelines. These uncertainties diminish investor confidence, deter private sector participation in future projects, and increase the cost of capital. Additionally, unmet revenue projections often lead to disputes between public and private stakeholders, straining partnerships and complicating project implementation.

Mitigating demand risks requires a comprehensive approach. Improved demand forecasting through detailed traffic studies and scenario planning ensures realistic revenue projections. Timely completion of supporting infrastructure, backed by coordinated development plans and penalty clauses for delays, maximizes traffic flow to PPP facilities. Revenue support mechanisms, such as minimum revenue guarantees and dynamic toll pricing, protect investors from extreme fluctuations. Clear contractual commitments, risk-sharing mechanisms, and government incentives during initial operations can stabilize traffic demand and encourage private-sector participation. By adopting these strategies, Vietnam can effectively manage demand risks, ensuring the financial viability and success of its PPP projects.

5.8. Environmental Risks (e.g., Regulatory Changes, Environmental Impact Issues) (R3)

Environmental risk in PPP transport refers to threats arising from environmental impacts and the evolving legal/regulatory framework. This includes pollution (air, water, noise, waste) caused by the project, or incidents that breach environmental standards, as well as changes in environmental laws or enforcement that affect the project. Such risks can arise at any stage, from construction (e.g., site runoff, deforestation) through operation (vehicle emissions, noise) to decommissioning. These risks are significant because modern PPP contracts and lenders often require strict environmental compliance. Indeed, environmental risk has been defined as a risk from violations of environmental regulations or pollution that require increased investment to continue operation or cause project failure. In transport PPPs, environmental risk often encompasses costly mitigation (e.g., pollution controls, wastewater treatment) and potential fines or stoppages if laws are violated.

Rapid industrialization and urbanization have worsened Vietnam's pollution problem, prompting stricter laws. Notably, Vietnam passed a Revised Law on Environmental Protection in 2021, which requires facility owners to apply "best available technology" to control pollution. This means that projects planned under older standards may have to retrofit new controls (for example, dust suppression or noise barriers). Similarly, global trends (e.g., Paris Agreement commitments) are leading many governments to tighten emissions and environmental regulations. Pre-construction, sensitive sites (e.g., wetlands, forests) can also force route changes or lengthy permitting. Environment-related delay factors include public opposition (e.g., protests over habitat loss), requirement for additional impact studies, or new international standards (e.g., carbon taxes, biodiversity offsets).

In Vietnam's context, while detailed transport-specific cases are limited in open literature, examples from other sectors are instructive. For instance, a Chinese waste- to- energy PPP (Qinhuangdao) faced severe environmental retrofit requirements mid-project, illustrating how pollution obligations can drive up costs. In road projects globally, there are many cases of delays or redesigns due to environmental clearances (e.g., rerouting highways around wildlife habitats in India or Europe). Conversely, failure to address such risks can halt projects: international experience shows that non-compliance can trigger stop-work orders. Within Vietnam's PPP program, increasing scrutiny by regulators and communities means that any environmental misstep (say, a toxic spill or unmanaged runoff) could lead authorities to impose penalties or demand corrective construction.

Environmental risks can substantially inflate project costs. Compliance measures (e.g., special drainage, filters, noise walls, green tunnels) add to capital and O&M expenses. If new regulations emerge after financial closure, the concessionaire may need costly upgrades. Delays are common: obtaining environmental permits or completing impact assessments can push back construction start. In extreme cases, operations may be suspended for violations, cutting toll revenue. From the concession perspective, these disruptions can lengthen the period needed to achieve the expected returns. For example, if construction is delayed a year due to an EIA dispute, the concession period might be extended correspondingly (or otherwise renegotiated). Moreover, investor confidence is hurt when environment-induced overruns occur, raising the perceived project risk. Lenders may also impose stricter conditions if they see environmental non-compliance risks.

Effective mitigation starts with planning and design: conducting thorough Environmental Impact Assessments (EIAs) early on to identify potential issues, and then designing the project to avoid or minimize impacts (e.g., elevating roadways above floodplains, preserving vegetation). Adopting cleaner technology (e.g., low-emission asphalt plants) and construction best practices reduces pollution during building. Legal/contractual strategies include specifying clear responsibility for environmental compliance (often borne by the private partner) and defining reliefs if new regulations are enacted. Some contracts build in "price adjustment" clauses or require the government to share costs of unforeseen environmental requirements. Financial measures can include setting aside contingency funds or environmental bonds (held in escrow to pay for remediation if needed). Governments can facilitate compliance by streamlining permitting processes and providing timely information on upcoming regulatory changes. Finally, technical solutions like real-time monitoring of emissions, or modular designs that are easier to upgrade, help projects adapt. These approaches collectively reduce the likelihood of expensive retrofits or shutdowns, and thus stabilize costs and timelines when environmental risks materialize.

5.9. Population Growth (R16)

Population growth risk refers to the uncertainty in future population (and thus traffic demand) within the PPP project's catchment area. In transport projects, higher population generally means more potential users (drivers, passengers) and hence higher traffic volumes; conversely, slow population growth or decline can lead to lower usage than projected. Because concession periods are calibrated to projected revenues, misestimating population trends poses a risk. In other words, the size and growth rate of the population served by the facility directly influences demand and revenue, and thus the optimal concession length [6].

Rapid urbanization, migration patterns, birth and death rates and economic factors all drive population changes. Vietnam's urban centers (e.g., Hanoi, Ho Chi Minh City) have seen substantial population increases, while some rural provinces grow more slowly. Unexpected developments (new industrial zones, housing projects) can attract people and traffic. Conversely, demographic shifts like aging populations or emigration can slow growth. Over the life of a long-term PPP (often 20–30 years), these trends can differ markedly from initial forecasts. This risk is partly exogenous (public sector control is limited), but understanding it is crucial in concession planning. In practice, population-related demand risk has emerged in many PPPs. For example, China's expansion of highways into suburban areas sometimes overestimated population influx, resulting in "underused" toll roads (some became known as "ghost tollways" when factories and commuters did not materialize as planned). Conversely, uncontrolled urban sprawl in Southeast Asia has sometimes caused unexpected congestion on expressways. In Vietnam, transport planners constantly revise forecasts as cities grow: a highway built for a projected population may need additional lanes years later if growth outpaces estimates. (While specific Vietnamese PPP cases are not well-documented publicly, the general pattern holds: the demand for toll roads is highly sensitive to local population dynamics).

If population growth is overestimated, actual traffic—and toll revenue—will be lower than financial models assumed. This shortfall forces longer "break-even" periods, so concessions may need to be extended beyond the original term to allow investors to recover costs. Lower-than-expected users also raise per-user unit costs (maintenance per vehicle). On the other hand, underestimating growth could actually benefit the concessionaire by shortening the payback period (though it may also mean the road gets congested, requiring earlier capacity upgrades or higher maintenance O&M). Both scenarios create uncertainty: a conservative bidder might demand a longer concession if the population growth assumptions are pessimistic, while an optimistic bidder might accept a shorter term but then face financial stress. In any case, inaccurate population/demand forecasts damage investor confidence and complicate tariff-setting. To manage this risk, project sponsors use demographic and economic studies to build robust traffic forecasts under multiple scenarios. Concession contracts can incorporate dynamic adjustments: for example, toll rates or toll escalation formulas may be tied to actual usage or inflation, partly mitigating revenue swings. Demand risk can also be shared with government: in some models, the government guarantees a minimum revenue (paying the concessionaire a fixed subsidy if tolls fall short), or shares excess revenue if traffic exceeds forecasts. Technically, designing infrastructure with reserve capacity allows the project to accommodate unexpected demand without premature overloading. Periodic renegotiation clauses (e.g., mid-term reviews of traffic assumptions) can help rebalance the concession period if significant population shifts occur. Lastly, the financial model can build in conservative buffers (equity ratios or debt covenants) to cushion shortfalls. These measures help ensure that population-driven demand uncertainty does not derail the project's financial viability or lead to continual extensions of the concession.

5.10. Concession Price Risk (R9)

Concession price risk involves uncertainty around setting and adjusting the toll (user fee) levels under a PPP. In toll-road and bridge projects, the toll rate directly determines revenue. This risk arises from regulatory limits, public resistance, competition from alternative routes, and changes in economic conditions (e.g., inflation, currency fluctuations affecting effective toll value). A concessionaire typically relies on agreed-upon toll schedules or escalation formulas to achieve its return; if these are blocked or altered, the project's financial balance is upset.

Common causes include government or regulator-imposed caps on toll increases, delayed tariff approvals, or politically motivated toll freezes. Public backlash can itself force changes: for example, if tolls are perceived as excessively high or unfair (especially on previously free public roads), citizens may protest or refuse to pay. Fuel price changes and inflation also affect toll policy: rising costs may compel toll hikes, but doing so can spark controversy. Competition from untolled alternatives (roads, ferries) can put a practical ceiling on what users will pay. In Vietnam, many BOT toll projects in recent years have become lightning rods for this risk: motorists and local communities mounted organized protests (e.g., blocking booths) when tolls were implemented or raised improperly. For example, Vietnam's "toll booth wars" are a vivid illustration. In 2017–2018 a cascade of protests occurred at multiple BOT booths (e.g. Cai Lay, An Suong, others) because locals felt the tolls were unfairly applied. In one case (Cai Lay), drivers deliberately paid tolls in small coins and banknotes, causing intolerable delays until the operator suspended toll collection. These disputes forced government intervention. A national audit in 2020 subsequently fined 84 BOT projects a total of US$173 million and reduced their concession terms by a combined 300 years. In some of those cases, authorities also ordered toll rate reductions and negotiated extensions of the concession period to compensate the private investors. Internationally, similar issues have arisen (e.g., toll hikes in India and Indonesia have led to boycotts and litigation).

If actual toll rates or revenues fall short of projections (because higher rates were unapproved or contested), the concessionaire earns less than planned. This revenue shortfall delays cost recovery, often necessitating extensions of the concession period so the investor can attain the intended return. Conversely, if tolls are set too low (e.g., due to a cap), the government may avoid further travel demand loss but the private partner's profitability suffers. Either way, renegotiations become likely, which can introduce uncertainty and even project delays. For instance, in Vietnam's Cai Lay case, the concessionaire was allowed to "reduce the fees and extend the collecting period" to resolve a mis-location dispute. Such adjustments directly alter the concession timeline. From an investor standpoint, toll uncertainty can be a red flag: it raises the risk premium demanded by lenders or causes financing difficulties.

Key mitigation lies in sound contract design and public engagement. PPP contracts should clearly define toll-setting rules – for example, linking future toll increases to inflation, GDP growth, or other objective indices – so that revenue forecasts are credible. The contract may allow for periodic toll reviews by an independent regulator. Governments can share demand risk (e.g., by guaranteeing a minimum revenue level), or share upside (capping excess profit beyond a certain toll level). Effective stakeholder consultation before and during implementation can reduce backlash: when communities understand the project benefits and toll justification, resistance may lessen. Technically, offering differentiated tolls (off-peak discounts, electronic toll collection to minimize resistance, or exemptions for local users) can improve acceptance. Financially, building in contingency (like a reserve fund for toll shortfalls) helps. In Vietnam's case, the post-protest settlements involved curbing toll rates and extending concessions–a form of risk-sharing solution. More broadly, transparent toll administration and tying increases to service levels (e.g., only raising tolls if road quality/maintenance is ensured) can also build public support. These policy, technical and financial measures together help stabilize toll-related revenues and thus keep concession periods on track.

6. Conclusion

The concession period is recognized as the most vital decision in the financing of PPP infrastructure projects. It must balance the need for the private partner to recoup its investment against the public interest in affordable, well‐ maintained infrastructure. In recent years, considerable attention has been paid to understanding the risk factors that affect the PPP concession period. Many studies examine PPP risk factors in general, but few focus specifically on concession-period risks. Therefore, this paper identified and prioritized the risks that most impact the concession period in PPP infrastructure projects, using Vietnam as a case study and introducing the novel FACULTY framework. It proved effective in determining where risk management efforts should focus and in capturing experts' uncertainty, thereby enhancing confidence in the risk prioritization. By combining a consequence–likelihood risk matrix with spherical fuzzy AHP, the analysis showed that 27 risk factors influence concession period length. The top ten critical risk factors are land acquisition delays, construction cost overruns, schedule delays, design deficiencies, geological issues, force majeure events, traffic demand shortfalls, environmental risks, population growth, and concession price risk. These top-ranked risks highlight persistent structural challenges in Vietnam's infrastructure delivery, such as protracted land clearance processes and project management issues (e.g., slow approvals or scope changes). Other factors like demand shortfalls and macroeconomic instabilities (e.g., inflation or interest-rate changes) were found to be important but less decisive for concession length than the construction-phase and operational risks. This ranking of risks fills a key gap in the literature by explicitly focusing on concession period determinants in PPP projects. We expect these results to help both researchers and practitioners in estimating appropriate concession periods for PPP projects. While our study focused on infrastructure PPPs in Vietnam, the approach can be adapted to other sectors and regions with appropriate modifications to the risk criteria. By systematically quantifying concession period risks and demonstrating the benefits of proactive risk mitigation, this research contributes to more resilient PPP contract planning and improved value-for-money outcomes in infrastructure development.

7. Declarations

7.1. Data Availability Statement

The data presented in this study are available in the article.

7.2. Acknowledgments

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7.3. Institutional Review Board Statement

Not applicable.

7.4. Informed Consent Statement

Not applicable.

7.5. Declaration of Competing Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

8. References

[1] Dung, N. T. T., & Toan, N. Q. (2025). Public investment disbursement in transport infrastructure construction: current situation and solutions. Archives of Civil Engineering, 71(1), 127–140. doi:10.24425/ace.2025.153325.

[2] Mangano, G., Castelblanco, G., De Marco, A., & Ottaviani, F. M. (2025). Exploring the drivers of concession period in transport public–private partnerships. Built Environment Project and Asset Management, 15(2), 193-210. doi:10.1108/BEPAM-04-2024-0095.

[3] Bagenda, B., & Ndevu, Z. (2024). Principal Risks Associated with Public-Private Partnership Projects in Uganda. Public Works Management and Policy, 29(2), 183–230. doi:10.1177/1087724X231167326.

[4] Rouhani, O. M., Geddes, R. R., Do, W., Gao, H. O., & Beheshtian, A. (2018). Revenue-risk-sharing approaches for public-private partnership provision of highway facilities. Case Studies on Transport Policy, 6(4), 439–448. doi:10.1016/j.cstp.2018.04.003.

[5] Liu, Q., Liao, Z., Guo, Q., Degefu, D. M., Yuan, L., Jiang, S., & Jian, F. (2023). Evaluating the Impact of Macroeconomic Policy Interventions and Recession on a Sewage Treatment PPP Project Using a System Dynamic Model. Advances in Civil Engineering, 2023(1), 2351910. doi:10.1155/2023/2351910.

[6] Alada, H., & Işik, Z. (2022). Political and legal risks in public-private partnership mega transportation projects. Proceedings of the Institution of Civil Engineers: Municipal Engineer, 175(2), 95–106. doi:10.1680/jmuen.21.00017.

[7] Liu, Y., Wang, X., Zhang, J., & Guo, S. (2025). How risk factors lead to the early termination of public–private partnership projects in China: a multi-case study based on social network analysis and interpretive-structure modeling. Engineering, Construction and Architectural Management, 32(2), 824–846. doi:10.1108/ECAM-09-2022-0876.

[8] Babatunde, S. O., Adeniyi, O., & Awodele, O. A. (2017). Investigation into the causes of delay in land acquisition for PPP projects in developing countries. Journal of Engineering, Design and Technology, 15(4), 552–570. doi:10.1108/JEDT-05-2016-0029.

[9] Sharma, K., & Trivedi, M. K. (2023). Statistical Analysis of Delay-Causing Factors in Indian Highway Construction Projects under Hybrid Annuity Model. Transportation Research Record, 2677(10), 572–591. doi:10.1177/03611981231161594.

[10] Ke, Y., Wang, S. Q., Chan, A. P. C., & Lam, P. T. I. (2010). Preferred risk allocation in China's public-private partnership (PPP) projects. International Journal of Project Management, 28(5), 482–492. doi:10.1016/j.ijproman.2009.08.007.

[11] Ullah, F., Thaheem, M. J., Sepasgozar, S. M. E., & Forcada, N. (2018). System Dynamics Model to Determine Concession Period of PPP Infrastructure Projects: Overarching Effects of Critical Success Factors. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 10(4), 4518022. doi:10.1061/(asce)la.1943-4170.0000280.

[12] Castelblanco, G., Guevara, J., Rojas, D., Correa, J., & Verhoest, K. (2023). Environmental Impact Assessment Effectiveness in Public–Private Partnerships: Study on the Colombian Toll Road Program. Journal of Management in Engineering, 39(2), 5023002. doi:10.1061/jmenea.meeng-5015.

[13] Akcay, E. C. (2021). An analytic network process based risk assessment model for PPP hydropower investments. Journal of Civil Engineering and Management, 27(4), 268–277. doi:10.3846/jcem.2021.14650.

[14] Scandizzo, P. L., & Ventura, M. (2010). Sharing risk through concession contracts. European Journal of Operational Research, 207(1), 363–370. doi:10.1016/j.ejor.2010.04.008.

[15] de Marco, A., Mangano, G., & Zou, X. Y. (2012). Factors influencing the equity share of build-operate-transfer projects. Built Environment Project and Asset Management, 2(1), 70–85. doi:10.1108/20441241211235062.

[16] Akomea-Frimpong, I., Jin, X., & Osei-Kyei, R. (2024). Mitigating Financial Risks in Sustainable Public–Private Partnership Infrastructure Projects: A Quantitative Analysis. Systems, 12(7), 239. doi:10.3390/systems12070239.

[17] Yang, J. Bin, Yang, C. C., & Kao, C. K. (2010). Evaluating schedule delay causes for private participating public construction works under the Build-Operate-Transfer model. International Journal of Project Management, 28(6), 569–579. doi:10.1016/j.ijproman.2009.10.005.

[18] Jain, G. (2015). The role of private sector for reducing disaster risk in large scale infrastructure and real estate development: Case of Delhi. International Journal of Disaster Risk Reduction, 14, 238–255. doi:10.1016/j.ijdrr.2014.09.006.

[19] Feng, Y., Guo, X., Wei, B., & Chen, B. (2021). A fuzzy analytic hierarchy process for risk evaluation of urban rail transit PPP projects. Journal of Intelligent and Fuzzy Systems, 41(4), 5117–5128. doi:10.3233/JIFS-189997.

[20] Putri, F. R., Susanti, B., & Toyfur, M. F. (2023). Critical Risk Analysis of Toll Road Public-Private Partnership (PPP) Project Construction Phase. ASEAN Engineering Journal, 13(3), 117–126. doi:10.11113/aej.V13.19462.

[21] Ferrari, C., Puliafito, P. P., & Tei, A. (2013). Performance and quality indexes in the evaluation of the terminal activity: A dynamic approach. Research in Transportation Business and Management, 8, 77–86. doi:10.1016/j.rtbm.2013.06.002.

[22] Jin, H., Liu, S., Li, J., & Liu, C. (2020). Imperfect Information Bargaining Model for Determining Concession Period of PPPs under Revenue Uncertainty. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 12(2), 4520012. doi:10.1061/(asce)la.1943-4170.0000382.

[23] Cruz, O., & Sarmento, J. M. (2021). Renegotiations of Public Private Partnerships in Transportation. Springer International Publishing, Cham, Switzerland. doi:10.1007/978-3-030-61258-0.

[24] Guo, J., Hao, S., & Ren, X. (2016). Concession Period Flexible Adjustment Mechanism Analysis Based on the Condition of Risk in a PPP Project. ICCREM 2016: BIM Application and Offsite Construction - Proceedings of the 2016 International Conference on Construction and Real Estate Management, 822–828. doi:10.1061/9780784480274.100.

[25] Nguyen, N., Almarri, K., & Boussabaine, H. (2021). A risk-adjusted decoupled-net-present-value model to determine the optimal concession period of BOT projects. Built Environment Project and Asset Management, 11(1), 4–21. doi:10.1108/BEPAM-12-2019-0134.

[26] Liu, S., Jin, H., Liu, C., Xie, B., & Mills, A. (2020). Government compensation and costs of non-competition guarantee for PPP rental retirement villages. Engineering, Construction and Architectural Management, 27(1), 128–149. doi:10.1108/ECAM-01-2019-0063.

[27] Geenen, S. (2014). Dispossession, displacement and resistance: Artisanal miners in a gold concession in South-Kivu, Democratic Republic of Congo. Resources Policy, 41(1), 90–99. doi:10.1016/j.resourpol.2013.03.004.

[28] Ameyaw, C., Adjei-Kumi, T., & Owusu-Manu, D. G. (2015). Exploring value for money (VfM) assessment methods of public-private partnership projects in Ghana: A theoretical framework. Journal of Financial Management of Property and Construction, 20(3), 268–285. doi:10.1108/JFMPC-01-2015-0003.

[29] Khanzadi, M., Nasirzadeh, F., & Alipour, M. (2012). Integrating system dynamics and fuzzy logic modeling to determine concession period in BOT projects. Automation in Construction, 22, 368–376. doi:10.1016/j.autcon.2011.09.015.

[30] Albalate, D., & Bel, G. (2009). Regulating concessions of toll motorways: An empirical study on fixed vs. variable term contracts. Transportation Research Part A: Policy and Practice, 43(2), 219–229. doi:10.1016/j.tra.2008.11.008.

[31] Ubbels, B., & Verhoef, E. T. (2008). Auctioning concessions for private roads. Transportation Research Part A: Policy and Practice, 42(1), 155–172. doi:10.1016/j.tra.2007.08.001.

[32] Abdul-Aziz, A.-R. (2001). Unraveling of BOT Scheme: Malaysia's Indah Water Konsortium. Journal of Construction Engineering and Management, 127(6), 457–460. doi:10.1061/(asce)0733-9364(2001)127:6(457).

[33] Debande, O. (2002). Private financing of transport infrastructure: An assessment of the UK experience. Journal of Transport Economics and Policy, 36(3), 355–387.

[34] Roumboutsos, A., & Chiara, N. (2010). A strategic partnering framework analysis methodology for public-private partnerships. Journal of Financial Management of Property and Construction, 15(3), 235–246. doi:10.1108/13664381011087498.

[35] Alasad, R., Motawa, I., Ogunlana, S., & Boateng, P. (2014). Prioritization of Demand Risk Factors in PPP Infrastructure Projects. In *Construction Research Congress 2014* (pp. 1359–1368). doi:10.1061/9780784413517.139.

[36] Ye, X., Shi, S., Chong, H.-Y., Fu, X., Liu, L., & He, Q. (2018). Empirical Analysis of Firms' Willingness to Participate in Infrastructure PPP Projects. Journal of Construction Engineering and Management, 144(1), 4017092. doi:10.1061/(asce)co.1943-7862.0001404.

[37] Caicedo, F., & Diaz, A. (2013). Case analysis of simultaneous concessions of parking meters and underground parking facilities. Transportation Research Part A: Policy and Practice, 49, 358–378. doi:10.1016/j.tra.2013.01.038.

[38] Li, Z., & Wang, H. (2023). Exploring Risk Factors Affecting Sustainable Outcomes of Global Public–Private Partnership (PPP) Projects: A Stakeholder Perspective. Buildings, 13(9), 2140. doi:10.3390/buildings13092140.

[39] Iseki, H., & Houtman, R. (2012). Evaluation of progress in contractual terms: Two case studies of recent DBFO PPP projects in North America. Research in Transportation Economics, 36(1), 73–84. doi:10.1016/j.retrec.2012.03.004.

[40] Ismail, S. (2013). Critical success factors of public private partnership (PPP) implementation in Malaysia. Asia-Pacific Journal of Business Administration, 5(1), 6–19. doi:10.1108/17574321311304503.

[41] Yan, X., Chong, H. Y., Zhou, J., Sheng, Z., & Xu, F. (2020). Fairness preference based decision-making model for concession period in PPP projects. Journal of Industrial and Management Optimization, 16(1), 11–23. doi:10.3934/jimo.2018137.

[42] Rolim, F., Santos, E., & Meira, L. (2014). Competitiveness in the Invitation to Bid for the Concession of the Urban Bus System of the Metropolitan Region of Recife. Procedia-Social and Behavioral Sciences, 160, 160–169. doi:10.1016/j.sbspro.2014.12.127.

[43] Engel, E., Fischer, R., & Galetovic, A. (2020). When and How to Use Public-Private Partnerships in Infrastructure: Lessons From the International Experience. NBER Working Paper Series, 9, 1689–1699.

[44] Alkaf, N., & Karim, A. (2011). Risk allocation in public-private partnership (PPP) project: A review on risk factors. International Journal of Sustainable Construction Engineering & Technology, 2(2), 2180–3242.

[45] Ehrlich, M., & Tiong, R. L. K. (2012). Improving the Assessment of Economic Foreign Exchange Exposure in Public–Private Partnership Infrastructure Projects. Journal of Infrastructure Systems, 18(2), 57–67. doi:10.1061/(asce)is.1943-555x.0000069.

[46] Choi, J. H., & Song, S. (2022). Revisiting the PPP puzzle: Nominal exchange rate rigidity and region of inaction. Journal of International Financial Markets, Institutions and Money, 78, 101540. doi:10.1016/j.intfin.2022.101540.

[47] Yurdakul, H., Kamaşak, R., & Yazar Öztürk, T. (2022). Macroeconomic drivers of Public Private Partnership (PPP) projects in low income and developing countries: A panel data analysis. Borsa Istanbul Review, 22(1), 37–46. doi:10.1016/j.bir.2021.01.002.

[48] Mofokeng, M., Alhassan, A. L., & Zeka, B. (2024). Public–private partnerships and economic growth: a sectoral analysis from developing countries. International Journal of Construction Management, 24(10), 1029–1037. doi:10.1080/15623599.2023.2217374.

[49] Junge, J., & Levinson, D. (2013). Property tax on privatized roads. Research in Transportation Business and Management, 7, 35–42. doi:10.1016/j.rtbm.2013.03.010.

[50] Liu, R., Huang, Y., Zhu, X., Ren, F., & Wang, Y. (2025). Does the improvement of government governance capacity (GGC) mitigate public-private partnership risks (PPP risks)? Evidence from China. Engineering, Construction and Architectural Management, 1–23. doi:10.1108/ECAM-01-2025-0116.

[51] Opawole, A. (2018). Penalty mechanisms for enforcing concessionaire performance in public–private partnership contracts in Nigeria. Journal of Engineering, Design and Technology, 16(1), 161–191. doi:10.1108/JEDT-04-2017-0030.

[52] Hanaoka, S., & Palapus, H. P. (2012). Reasonable concession period for build-operate-transfer road projects in the Philippines. International Journal of Project Management, 30(8), 938–949. doi:10.1016/j.ijproman.2012.02.001.

[53] Lundy, V., & Morin, P. P. (2013). Project leadership influences resistance to change: The case of the Canadian Public Service. Project Management Journal, 44(4), 45–64. doi:10.1002/pmj.21355.

[54] Cantos-Sánchez Pedro, P., Moner-Colonques, R., Sempere-Monerris, J. J., & Álvarez-SanJaime, Ó. (2011). Viability of new road infrastructure with heterogeneous users. Transportation Research Part A: Policy and Practice, 45(5), 435–450. doi:10.1016/j.tra.2011.02.003.

[55] Willoughby, C. (2013). How much can public private partnership really do for urban transport in developing countries? Research in Transportation Economics, 40(1), 34–55. doi:10.1016/j.retrec.2012.06.038.

[56] Ibrahim, A. D., Price, A. D. F., & Dainty, A. R. J. (2006). The analysis and allocation of risks in public private partnerships in infrastructure projects in Nigeria. Journal of Financial Management of Property and Construction, 11(3), 149–164. doi:10.1108/13664380680001086.

[57] Yu, C. Y., & Lam, K. C. (2013). A Decision Support System for the determination of concession period length in transportation project under BOT contract. Automation in Construction, 31, 114–127. doi:10.1016/j.autcon.2012.11.012.

[58] Marques, R. C. (2021). Public interest and early termination of PPP contracts. Can fair and reasonable compensations be determined? Utilities Policy, 73. doi:10.1016/j.jup.2021.101301.

[59] Kumaraswamy, M., & Ling, F. Y. y. (2010). Public private partnerships: Improving governance and performance amidst emerging economic realities. Journal of Financial Management of Property and Construction, 15(3), 281–288. doi:10.1108/jfmpc.2010.37615caa.001.

[60] Hwang, B. G., Zhao, X., & Gay, M. J. S. (2013). Public private partnership projects in Singapore: Factors, critical risks and preferred risk allocation from the perspective of contractors. International Journal of Project Management, 31(3), 424–433. doi:10.1016/j.ijproman.2012.08.003.

[61] Santos, G., Behrendt, H., Maconi, L., Shirvani, T., & Teytelboym, A. (2010). Part I: Externalities and economic policies in road transport. Research in Transportation Economics, 28(1), 2–45. doi:10.1016/j.retrec.2009.11.002.

[62] Ghahari, S. A., Queiroz, C., Labi, S., & McNeil, S. (2024). Corruption Propensity and Mitigation at Different Phases of Infrastructure Development. Public Works Management and Policy, 29(1), 5–44. doi:10.1177/1087724X231162544.

[63] Akintoye, A. S., & MacLeod, M. J. (1997). Risk analysis and management in construction. International Journal of Project Management, 15(1), 31–38. doi:10.1016/S0263-7863(96)00035-X.

[64] Williams, T. M. (1996). The two-dimensionality of project risk. International Journal of Project Management, 14(3), 185–186. doi:10.1016/0263-7863(96)00030-0.

[65] Ke, Y., Wang, S., Chan, A. P. C., & Cheung, E. (2011). Understanding the risks in China's PPP projects: Ranking of their probability and consequence. Engineering, Construction and Architectural Management, 18(5), 481–496. doi:10.1108/09699981111165176.

[66] Pham, P.-A.-H., & Pham, Q.-N. (2024). Study on Solutions for Early Dismantling of Aluminum Formwork Systems in High-Rise Building Construction. Civil Engineering Journal, 10(10), 3225–3239. doi:10.28991/CEJ-2024-010-10-07.

[67] Bing, L., Akintoye, A., Edwards, P. J., & Hardcastle, C. (2005). The allocation of risk in PPP/PFI construction projects in the UK. International Journal of Project Management, 23(1), 25–35. doi:10.1016/j.ijproman.2004.04.006.

[68] Cooper, D., Bosnich, P., Grey, S., Purdy, G., Raymond, G., Walker, P., & Wood, M. (2014). Project Risk Management Guidelines: Managing risk with ISO 31000 and IEC 62198. John Wiley & Sons, New Jersey, United States.

[69] Moslem, S. (2024). A novel parsimonious spherical fuzzy analytic hierarchy process for sustainable urban transport solutions. Engineering Applications of Artificial Intelligence, 128. doi:10.1016/j.engappai.2023.107447.

[70] Nguyen, P. T., Nguyen, Q. L. H. T. T., Huynh, V. D. B., & Nguyen, L. T. (2024). E-learning Quality and the Learners' Choice Using Spherical Fuzzy Analytic Hierarchy Process Decision-making Approach. Vikalpa, 49(2), 143–156. doi:10.1177/02560909241255003.

[71] Likhitruangsilp, V., Do, S. T., & Onishi, M. (2017). A comparative study on the risk perceptions of the public and private sectors in public-private partnership (PPP) transportation projects in Vietnam. Engineering Journal, 21(7), 213-231. doi:10.4186/ej.2017.21.7.213.

[72] Osei-Kyei, R., & Chan, A. P. C. (2017). Risk assessment in public-private partnership infrastructure projects: Empirical comparison between Ghana and Hong Kong. Construction Innovation, 17(2), 204–223. doi:10.1108/CI-08-2016-0043.

[73] Wang, Y., Wang, Y., Wu, X., & Li, J. (2020). Exploring the risk factors of infrastructure PPP projects for sustainable delivery: A social network perspective. Sustainability (Switzerland), 12(10), 4152. doi:10.3390/su12104152.

[74] Nguyen, A., Mollik, A., & Chih, Y.-Y. (2018). Managing Critical Risks Affecting the Financial Viability of Public–Private Partnership Projects: Case Study of Toll Road Projects in Vietnam. Journal of Construction Engineering and Management, 144(12), 5018014. doi:10.1061/(asce)co.1943-7862.0001571.