Development of a Risk Analysis Model for Schedule Delays in Infrastructure Construction Projects in Puerto Rico

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ABSTRACT

This paper presents a risk analysis model for schedule delays in infrastructure construction projects in Puerto Rico. The model was developed through five phases aligned with the PMBOK risk management framework: risk identification, risk classification, risk analysis, risk prioritization, and risk response planning. Fourteen delay risk factors were identified through literature review, project data, and expert consultation with construction professionals with 11 to more than 34 years of experience. The risks were classified into six categories and scored using occurrence frequency and delay duration. Permit and government approval delays and imported material delivery delays were the highest priority risks. Advance material procurement and early permit submission were rated as the most effective mitigation strategies.

INTRODUCTION

Infrastructure construction projects are essential to rehabilitate and maintain transportation infrastructure, utility services, and public buildings. Despite scheduling systems, construction projects continue to experience delays due to design changes, delayed submittal reviews, procurement delays, material delivery delays, coordination problems, labor productivity limitations, and government regulatory approval processes.

Construction projects in Puerto Rico face unique challenges: multiple stakeholders increasing coordination complexity, dependence on imported equipment and materials creating supply chain vulnerability, additional federal procurement regulations, and geographical exposure to heavy rainfall and hurricanes.

Objective: Develop a risk analysis model for schedule delays in infrastructure construction projects in Puerto Rico that provides a structured methodology to identify, classify, analyze, prioritize, and develop response strategies.

METHODOLOGY

The model was based on the PMBOK risk management process, developed through five phases:

Phase 1 – Risk Identification: Potential risk factors identified through literature review, project data, and expert consultation via a structured questionnaire distributed to 20 construction professionals.

Phase 2 – Risk Classification: Risk factors classified into six categories: Environmental, Supply Chain/Procurement, Labor/Workforce, Design/Technical, Regulatory/Administrative, and Stakeholder/Contractual.

Phase 3 – Risk Analysis: Each factor scored on a 1–5 scale for occurrence frequency and delay duration. Composite risk score = Frequency × Duration.

Phase 4 – Risk Prioritization: High priority ≥ 15.00; Moderate 10.00–14.99; Low < 10.00.

Phase 5 – Risk Response Planning: Response strategies developed using avoidance, reduction, transfer, or contingency planning. Experts rated 11 mitigation measures for effectiveness.

LITERATURE REVIEW

Construction schedule delays derive from interrelated root causes affecting project quality, cost, and duration. Key findings from the literature include:

Delay Interdependence: A systematic review confirmed that interdependence between delay factors significantly amplifies overall schedule impact, with contractor workload and experience as the most critical factors (Purushothaman et al., 2026).

Weather Risk: Distinguishing foreseeable from unforeseeable weather events is critical for excusable delay determinations, as recognized by AIA and USACE standards (Nguyen et al., 2010).

Supply Chain Disruptions: The most significant supply chain risk factors include inventory management, procurement timing, delivery reliability, and supplier proximity—critical for import-dependent jurisdictions like Puerto Rico (Okika et al., 2025).

Root Cause Analysis: Inadequate bidding and deficient communication were identified as the two root causes from which 16 critical delays derive, with 23 delay mitigation actions linked to root causes (Arantes & Ferreira, 2024).

RESULTS

Table 1: Risk Factor Register

ID	Risk Factor
RF-01	Heavy rainfall or flooding
RF-02	Hurricane or tropical storm
RF-03	Earthquake or ground movement
RF-04	Materials arriving late from outside PR
RF-05	Materials arriving late from local suppliers
RF-06	Shortage of skilled workers
RF-07	Subcontractor not performing as expected
RF-08	Design drawings had errors or were incomplete
RF-09	Unexpected site conditions
RF-10	Permits/gov. approvals took longer than expected
RF-11	Gov. inspections caused work stoppages
RF-12	Owner requested changes during construction
RF-13	Disputes or disagreements between parties
RF-14	Funding was delayed or ran out

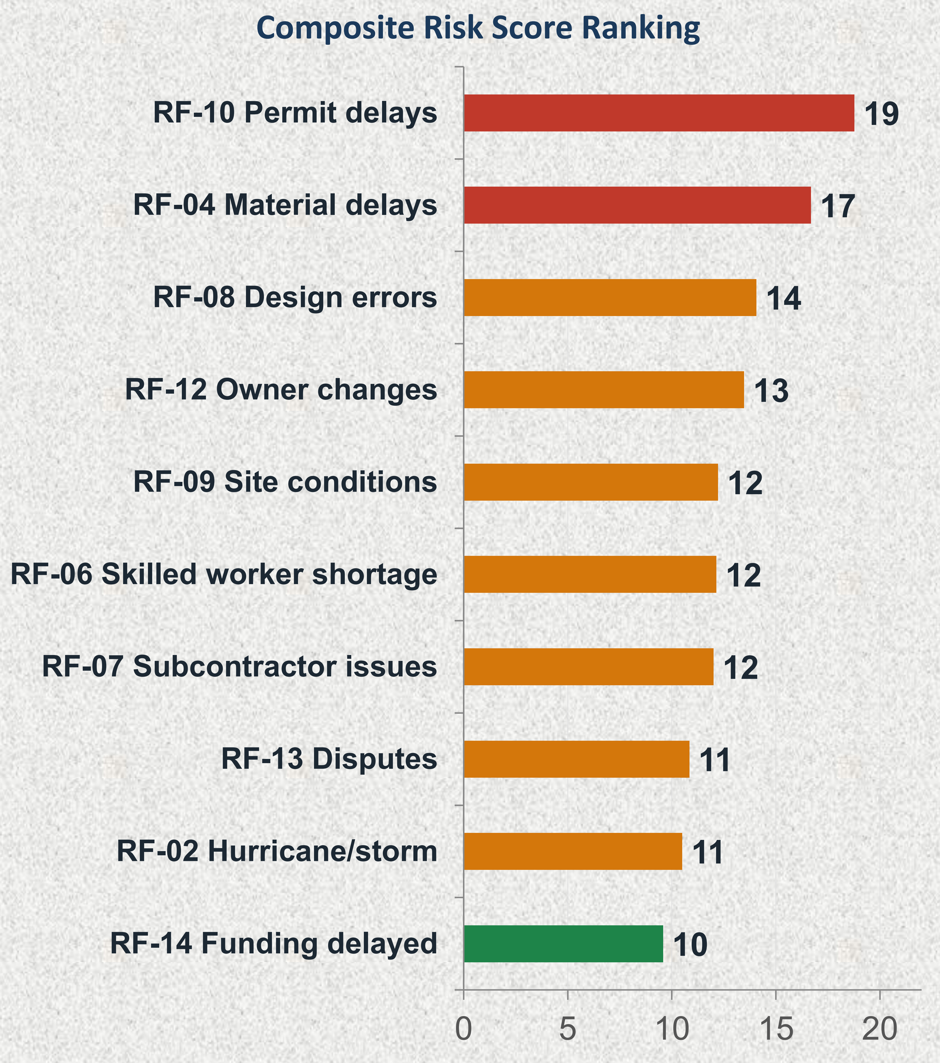

Figure 1: Composite Risk Score Ranking

Table 2: Risk Classification Matrix

Risk Category	Risk Factor IDs
Environmental	RF-01, RF-02, RF-03
Supply Chain / Procurement	RF-04, RF-05
Labor / Workforce	RF-06, RF-07
Design / Technical	RF-08, RF-09
Regulatory / Administrative	RF-10, RF-11
Stakeholder / Contractual	RF-12, RF-13, RF-14

Table 3: Probability-Impact Matrix

ID	Risk Factor	Freq.	Dur.	Pred.	Score
RF-01	Heavy rainfall/flooding	4.00	2.00	3.83	8.00
RF-02	Hurricane/tropical storm	3.00	3.50	4.00	10.50
RF-03	Earthquake	1.50	2.17	1.00	3.26
RF-04	Materials delayed delivery	4.17	4.00	4.00	16.68
RF-05	Materials late from local suppliers	3.17	2.67	3.17	8.46
RF-06	Shortage of skilled workers	3.83	3.17	3.33	12.14
RF-07	Subcontractor issues	4.00	3.00	3.17	12.00
RF-08	Design errors/incomplete drawings	3.67	3.83	3.00	14.06
RF-09	Unexpected site conditions	3.67	3.33	2.17	12.22
RF-10	Permits/gov. approval delays	4.50	4.17	3.67	18.77
RF-11	Gov. inspection stoppages	3.50	2.50	3.00	8.75
RF-12	Owner-requested changes	3.67	3.67	2.17	13.47
RF-13	Disputes between parties	2.83	3.83	3.00	10.84
RF-14	Funding delayed or ran out	2.50	3.83	2.83	9.58

Table 4: Prioritized Risk Ranking

#	ID	Risk Factor	Score	Priority
1	RF-10	Permit and government approval delays	18.77	High
2	RF-04	Imported material delivery delays	16.68	High
3	RF-08	Design errors or incomplete drawings	14.06	Moderate
4	RF-12	Owner-requested changes	13.47	Moderate
5	RF-09	Unexpected site conditions	12.22	Moderate
6	RF-06	Shortage of skilled workers	12.14	Moderate
7	RF-07	Subcontractor performance issues	12.00	Moderate
8	RF-13	Disputes between parties	10.84	Moderate
9	RF-02	Hurricane or tropical storm	10.50	Moderate
10	RF-14	Funding delayed or exhausted	9.58	Low

RESULTS

Table 5: Risk Response Plan: High Priority Risks

ID	Risk Factor	Strategy	Response Actions
RF-10	Permit and government approval delays	Reduction / Avoidance	Early permit submission; permit tracking; agency coordination; schedule buffer.
RF-04	Imported material delivery delays	Reduction / Transfer	Early procurement; backup suppliers; delivery guarantees; local alternatives.

The expert consultation was completed by 20 construction professionals with 11 to more than 34 years of experience. Their roles spanned project engineers, superintendents, administrators, and project managers.

The expert respondents rated 11 common mitigation measures for effectiveness. The two highest measures, ordering materials well ahead of need and submitting permits early, received unanimous maximum ratings. Backup supplier approval, design document review, site walkthroughs and regular schedule updates each received ratings of 4.83, confirming their value for addressing moderate priority risks.

CONCLUSIONS

The Risk Analysis Model for Schedule Delays in Infrastructure Construction Projects in Puerto Rico was developed through five sequential phases aligned with the PMBOK framework. The model identified fourteen risk factors, classified them into six categories, quantified their frequency and duration, prioritized them by composite risk score, and developed targeted response strategies.

The results demonstrated that permit and government approval delays and material delivery delays from outside Puerto Rico represented the two highest priority risk factors. These findings were consistent with the unique challenges of the Puerto Rico construction environment. The highest-rated mitigation measures, advance material procurement and early permit submission, directly addressed these top risks, confirming that proactive planning offered the greatest potential for schedule improvements.

The model should be interpreted as a preliminary decision tool because the expert input was obtained from a limited number of construction professionals. Additional data collection from a broader sample of industry professionals is recommended to validate and refine the model's risk scores and response strategies

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