

Original Research

**CLIMATE-INDUCED PROJECT SCOPE CREEP AND COST OVERRUNS IN
LONG-HORIZON INFRASTRUCTURE PROJECTS: THE MEDIATING
ROLE OF ADAPTIVE RISK RE-ASSESSMENT**

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Abstract

Despite the many years of reform attempts, long term infrastructure projects have continued to show systematic problems with scope deviations, cost overruns, and delay. This study proposes a mediation model where adaptive risk reassessment is identified as the mediator through which climate disruptions affect project performance negatively. Building on megaprojects theory, contingency theory, and research on risk management effectiveness, the research posits that climate disruptions are not directly related to project outcomes; rather, the impact of climate disruptions is largely mediated by the number and effectiveness of risk review cycles carried out by the project team after each disruption event. Three hypotheses are generated from the model and framed in a way that allows for testing using survey or project archives data. The findings provide actionable insights for project managers and policymakers dealing with climate change risks in infrastructure development. Serbia is increasing its investment in infrastructure projects as part of the country's alignment with European Union policies, there is an urgent need for understanding the relationship between climate change and project performance with climate risk situation. The theoretical contribution of this study fills a significant void in the literature in treating climate change and contingencies.

Keywords: climate-induced disruptions, infrastructure projects, cost overruns, scope creep, adaptive risk re-assessment.

INTRODUCTION

Infrastructure projects consistently fail to deliver on time and within budget. Flyvbjerg et al. [1] surveyed 258 transport projects across 20 countries and found that nine out of ten experienced cost overruns, with rail projects averaging 44.7% above budget. A more recent study of 662 energy infrastructure projects across 83 countries, drawing on nearly nine decades of data, found that more than three-fifths exceeded their initial budgets, and that schedule overruns on renewable energy portfolios averaged between 15% and 25% [2]. These are not isolated failures. They point to something structural, a pattern that has persisted through decades of reform and institutional learning.

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Scholarship has historically blamed cost overruns on optimism bias, strategic misrepresentation, and poor risk estimation [1,3]. Ika and Pinto [4] pushed back on the assumption that success and failure can be read off a single Iron Triangle of time, cost, and scope, arguing instead for contextually sensitive evaluations. Both lines of inquiry, however, treat the project's external environment as broadly stable. What has changed is that long-horizon projects, those taking four to twelve years to execute, now routinely encounter floods, heat episodes, and storms that simply were not in scope when the budget was set.

The IPCC Sixth Assessment Report [5] confirmed that even at 1.1°C of warming, extreme weather events affecting infrastructure are already more frequent and severe than historical baselines. Leal Filho *et al.* [6] reviewed infrastructure case studies across five continents and found that roads buckle in heat waves, bridges are undermined by flooding, and coastal assets are compromised by storm surge well ahead of their engineering design thresholds. At the macroeconomic level, the OECD [7] estimated that climate-induced failures are widening an already enormous global infrastructure investment gap.

Project management literature has been slow to respond. Most studies treat weather as one item in a checklist of risk factors rather than as a dynamic, escalating threat that compounds over a project's lifecycle [8]. This matters in practice: a project manager overseeing a dam in the Western Balkans or a highway in South Asia needs more than a generic risk register. They need a framework for translating a climate shock into a revised risk posture, a corrected scope baseline, and a defensible cost re-estimate.

This paper proposes a mediation model to address that gap. The relationship between climate-induced disruptions and project performance failure is not direct or inevitable. It passes through a mechanism: the quality and frequency of adaptive risk re-assessment during execution. Teams that treat risk re-assessment as an iterative, ongoing process rather than a one-time exercise at project initiation are better placed to absorb shocks before they cascade into overruns [9,10].

The paper makes three contributions. It brings climate science and project management literature into dialogue to theorize a clear causal chain from climate disruption to project failure. It builds a conceptual framework that researchers can take to survey or archival data. And it draws implications for practitioners and policy makers, with specific reference to Serbia's EU-alignment infrastructure agenda, where large transport and energy projects are now being planned and executed against a backdrop of rising climate volatility [11].

MATERIALS AND METHODS

Research design and approach

This paper is a conceptual study. It does not draw on primary survey data, field observations, or archival project records. Instead, it builds a theoretical model from systematic synthesis of published literature across three research domains. This design is appropriate when the goal is to identify and theorize a relationship that has not

previously been examined, and to produce testable hypotheses for future empirical work [31]. Conceptual research of this kind contributes by clarifying constructs, specifying causal pathways, and providing a framework that empirical researchers can then take to data [32]. The paper is a theory building exercise rather than a theory testing one.

The limitation this entails is clear: the three hypotheses developed here remain unconfirmed until a survey-based or archival study tests them against real project data. The justification for proceeding at the conceptual level is that no existing study has brought together climate disruption, adaptive risk management behavior, and project performance outcomes in a single integrated framework. The theoretical groundwork is a necessary first step before any data collection can be meaningfully designed.

Literature sources and search strategy

The review underpinning the model was conducted through systematic searches of Web of Science, Scopus, and Google Scholar. Three keyword clusters guided the search: (a) infrastructure project cost overruns, scope creep, and schedule delay; (b) climate change, extreme weather events, and infrastructure vulnerability; and (c) project risk management, adaptive risk assessment, and project success. Searches were restricted to peer-reviewed journal articles, conference proceedings, and authoritative institutional reports published between 2003 and 2025. This lower bound was relaxed only for foundational theoretical contributions with direct relevance to the model.

Sources were screened first by title and abstract for relevance to at least one keyword cluster, then by full text for theoretical or empirical content directly applicable to the proposed constructs. The final pool of 30 sources spans project management theory [1,4,9,10,18,19], climate and infrastructure research [5–8,24,27], and cost overrun and delay literature [2,3,12–17,22,25]. Institutional reports from the OECD [7], EBRD [21], and European Parliament [11] were included given their direct policy relevance to the Serbian infrastructure context examined in the discussion.

Theoretical foundations

Three theoretical traditions inform the model. The first is the megaproject management literature. Flyvbjerg *et al.* [1] established that cost overruns and scope deviation are systemic and statistically predictable rather than accidental, and subsequent work [2,3,12] has documented their distribution and root causes across industries and geographies. This tradition defines the dependent variable and justifies why infrastructure project failure is a phenomenon worth modelling.

The second tradition is contingency theory as applied to project management [4,19]. Contingency theory holds that the relationship between environmental uncertainty and organizational performance is not fixed. It is shaped by how the organization responds to that uncertainty. Applied to this paper, that means a climate shock does not automatically produce a cost overrun. This depends on the standard of

management's reaction, that is, if the project team conducts a systematic review of risk after the occurrence or views it as a standalone case.

The third tradition is risk management effectiveness research [9,18,20]. Zwikael and Ahn [9] provided the empirical foundation for treating risk management quality as a mechanism that stands between project risk exposure and project outcomes. Their multinational survey evidence showed that it is the quality of risk management practice, not merely the level of risk, that predicts project success. Baron and Kenny [31] provided the conceptual vocabulary for formalizing this mechanism as a mediator: a variable that transmits the effect of an independent variable to a dependent variable rather than simply moderating the size of that effect. That distinction is central to the theoretical contribution of this paper.

Together these three traditions lead to the same conclusion. Climate disruptions create project risk. But it is the adaptive risk management response not the disruption itself that primarily determines whether that risk materializes as project failure.

CONCEPTUAL FRAMEWORK AND HYPOTHESES

The structural context in which all three components operate is that of long-horizon infrastructure projects. Miller and Lessard [34] define these as large-scale engineering undertakings distinguished by irreversible capital commitments, multi-year execution timescales of typically four to twelve years, and sustained exposure to institutional and environmental uncertainty that accumulates throughout the delivery period. It is precisely this extended execution window that transforms episodic climate events into compounding threats to project performance, making the mediation mechanism theorized here both necessary and practically urgent.

The frequency and severity of climate-induced disruptions during project execution. Frequency is the count of distinct climate events, floods, heat episodes above engineering thresholds, and severe storms, at the project site during execution. Severity is the magnitude of each event relative to historical weather baselines [5,6]. Both dimensions are expected to independently increase the probability of scope deviation and cost overrun [15,16].

The adaptive risk re-assessment: how often it happens and how well. Hillson [35] defines risk management in projects as a structured and iterative process of identifying, analyzing, and responding to threats and opportunities throughout the project lifecycle, with the critical qualification that this process must be revisited dynamically as conditions evolve rather than treated as a one-time exercise at project initiation. Chapman and Ward [36] reinforce this view in the context of complex, uncertain environments, arguing that continuous re-appraisal of the risk picture what they term iterative risk assessment is a prerequisite for effective management under conditions of high environmental variability. Adaptive risk re-assessment, as operationalized in this paper, combines both formulations: it is the frequency and quality of post-disruption risk review cycles conducted by the project team. Protocol quality covers whether risk registers are updated after each disruption, whether

residual risk is re-priced, whether scope baselines are formally revised, and whether contingency allocations are adjusted dynamically. This construct builds directly on Zwikaël and Ahn [9] and Chang *et al.* [20].

The project performance deviation, measured along three dimensions. Scope creep, defined by the Project Management Institute [37] as the uncontrolled expansion of project scope without corresponding adjustments to time, cost, and resources, is operationalized here as the scope deviation index the percentage of scope items added or modified after the approved baseline. Cost overrun, characterized by Flyvbjerg *et al.* [1] as a systemic and statistically predictable pattern in megaprojects in which final outturn costs consistently and substantially exceed the estimates on which project approval was based, and further quantified by Merrow [38] as a persistent structural feature of large industrial projects with average cost growth exceeding 25 percent against sanction estimates is measured as the percentage difference between final outturn cost and approved budget. Schedule delay, the ratio of actual to planned project duration, completes the Iron Triangle [1,4]. These three dimensions are operationalized in a way that allows the mediator to exert influence on each sub-dimension separately.

Three hypotheses follow from this structure:

H1: Greater frequency and severity of climate-induced disruptions during execution will increase project scope deviation, cost overrun, and schedule delay.

H2: Higher quality and frequency of adaptive risk re-assessment will reduce project scope deviation, cost overrun, and schedule delay.

H3: Adaptive risk re-assessment will mediate the relationship between climate disruptions and project performance failures, accounting for a significant share of the total effect.

RESULTS AND DISCUSSION

The framework draws on three bodies of literature that have, until now, developed in near-complete isolation from each other: megaproject cost overruns [1,2,12], climate impacts on infrastructure [5,6,7,8], and project risk management effectiveness [9,18–20]. Their intersection has become unavoidable. Climate disruptions are intensifying at precisely the moment when global infrastructure investment is accelerating, and the existing tools for managing project risk were not designed with a non-stationary climate in mind.

The standard policy response to climate-related infrastructure failures has been to invest in physical resilience: stronger materials, raised flood defenses, heat-tolerant pavements. These are worthwhile investments, but they are anticipatory and static. They protect against the specific scenarios that engineers modelled at the design stage. They offer little protection against unanticipated event combinations or climate trajectories that exceed design assumptions [8]. Adaptive risk re-assessment works differently. It does not require that every climate scenario be predicted in advance. It requires that the project organization has the reflexes to recalibrate when conditions deviate from assumptions.

This distinction matters in the Serbian context. The EBRD Country Strategy for Serbia 2023–2028 [21] identifies climate resilience as a priority across transport, municipal services, and energy infrastructure. The European Parliament [11] has called on Serbia to adopt a National Energy and Climate Plan and strengthen environmental impact assessment capacity. Neither document, however, addresses what should happen at the project execution level when a climate event disrupts a live construction program. That is the gap this paper fills. Adaptive risk re-assessment is the operationally actionable link between climate shock and project performance outcome. Investing in it through training, process design, and contractual provisions is likely to yield returns in reduced overruns.

Scope creep deserves particular attention. Farooqui *et al.* [13] and Rivera *et al.* [22] both found that scope creep in infrastructure projects is systematically underestimated in risk registers, partly because each individual scope change looks reasonable at the time it is approved. In a climate context, scope creep is harder to resist because it is physically imposed, not stakeholder-driven. A flood that damages completed sub-structure requires remediation that is both necessary and unbudgeted. Adaptive risk re-assessment does not prevent that damage, but it ensures that the cumulative scope impact is formally tracked, its cost implications are estimated, and the project sponsor has accurate information for decisions about continuation, redesign, or delay [9,14].

There is also a temporal dimension worth articulating. Climate disruption and project failure are not simultaneous. Between them lies a sequence of organizational decisions, taken in the days and weeks after an event. Whether to treat the event as an isolated incident or trigger a full risk review. Whether to update the risk register or leave it unchanged until the next scheduled review. Whether to revise the cost-to-complete estimate or hold the existing one. The quality of those decisions determines how much of the shock is absorbed and how much propagates into the final outturn. This is why the mediating effect is expected to be partial rather than total: some direct effect of climate severity on cost overrun will remain, but a meaningful share of variance in project outcomes should be explainable by the quality of the post-event response [18,19].

For empirical validation, a survey-based study of project managers on large infrastructure projects in climate-exposed regions is the most natural starting point. All three constructs, climate disruption experience, adaptive risk re-assessment quality, and project performance deviation, are measurable through project manager self-report and archival cross-validation. Structural equation modelling or path analysis can test the mediation hypotheses [9,16]. Qualitative case studies of projects that experienced major climate events, the 2021 floods in Germany and Belgium [6], or flood-affected dam construction in South Asia [16], could trace the specific decision pathways through which risk re-assessment either absorbed or failed to absorb the shock.

CONCLUSION

In long-horizon infrastructure projects, this study has suggested and theorized a mediation model whereby adaptive risk re-assessment is the link between climate-induced disturbances and project scope deviation, cost overruns, and schedule delays. The model combines three formerly separate bodies of work into a conceptual framework with three testable hypotheses.

The practical lesson is obvious. Though it is important, physical resilience engineering is not enough. The ability of the organization to repeatedly and methodically reevaluate risk following each weather event is what stops shocks from turning into disasters. Standardized post event review procedures, contractual clauses enabling dynamic scope re-baselining, and investment in project manager training all help to develop that capability. It is relatively inexpensive and has not received the policy and research attention that it deserves.

The governance consequence for Serbia and other EU applicant countries with ongoing infrastructure investment projects is plain. Project contracts and monitoring systems must go past risk registers submitted at the start of each project. Dynamic, event triggered risk management systems supported by project managers with the power and ability to change scope baselines in real time should become a requirement for EU infrastructure finance in the Western Balkans.

Future studies ought to concentrate on empirical validation. The most critical next phase is to operationalize the quality of the adaptive risk re-assessment process as a quantifiable metric [33]. A validated tool for this construct would allow survey-based testing of the mediation model across various infrastructure settings and would advance both the project management and climate adaptation fields.

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