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FROM "OPTIMISTIC" PROJECTS TO A SURGE OF VARIATIONS: ETHICAL EXPLANATIONS OF TECHNICAL AND COST DEVIATIONS IN ROAD CONSTRUCTION

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Abstract

Managing road infrastructure projects involves a complex interaction of technical, contractual, and organizational processes. While technical and financial deviations are often attributed to unforeseen circumstances or insufficient documentation, practice shows that a significant portion of problems arises from unethical decisions made at various project stages. This paper aims to analyse the impact of engineering ethics on technical reliability, cost stability, and project execution efficiency, using examples from regional practice. Typical patterns leading to deviations have been identified, including underestimation of quantities during design, shortening or neglecting investigative works, selective presentation of financial data when approving variations, shifting responsibility between designers, contractors and engineers, and decision-making under institutional or time pressures. Based on these findings, a framework is proposed to enhance ethical decision-making in infrastructure projects, including early-warning mechanisms, clearer responsibility definitions, more transparent change management, and consistent technical-contractual documentation.

Keywords: engineering ethics, road construction, project management, technical deviations, cost deviations

1 Introduction

Managing road infrastructure projects involves a complex interplay of technical, contractual, organizational, and stakeholder-related factors. Despite established standards and planning tools, significant technical and cost deviations remain common. In major infrastructure projects, cost and technical deviations (conventionally attributed to unforeseen geological conditions, adverse weather, incomplete documentation, or emergent regulatory requirements) are pervasive and persistent, with systematic overruns reported across geographies and delivery models. While technical and external factors contribute to project outcomes, extensive research shows that structural cognitive biases play a central role in shaping initial estimates and decision-making in infrastructure projects. This is particularly related to optimism bias, which leads planners to underestimate costs and risks while overestimating benefits [1].

The engineering and project management community has established structured retrospective analyses showing that projections for major infrastructure frequently followed a pattern of underestimated costs, with measured overruns not attributable solely to technical errors. For example, research on public works cost forecasting [2] found that systematic cost underestimation could not be fully explained by random error and appeared better accounted for by intentional misrepresentation and planning biases. This insight aligns with broader observation in behavioural science that decision-makers often rely on "inside views" of

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projects anchored in optimistic best-case scenarios, rather than "outside views" based on historical performance data. The persistence of cost and technical deviations highlights an often-overlooked aspect of infrastructure delivery: engineering ethics and professional responsibility, including obligations to public safety, transparency, competence, and honesty. Although ethical standards are well established, their influence on routine decisions (such as cost estimation, investigative scope, and variation approval) remains limited, allowing technically compliant yet ethically questionable practices to produce avoidable deviations. This paper reconceptualizes technical and cost deviations in road construction as ethically informed outcomes of interacting professional norms, cognitive biases, and organizational pressures, and proposes a structured framework that bridges technical project appraisal with normative professional standards beyond purely managerial or econometric explanations.

2 Ethical framework applied to road infrastructure projects

Ethical considerations of road-project delivery, focusing on points where technical decisions, commercial choices, and accountability intersect, can be understood through three complementary pillars, which together help identify common ethical risks and guide preventive actions within routine project processes.

Professional duties and codified ethics: professional engineering codes operationalize ethical principles by requiring protection of public welfare, competent practice, and truthful, transparent reporting, as explicitly stated in widely adopted standards such as those of ASCE and NSPE [3, 4]. Embedding these duties in routine project documentation (through declared assumptions, investigation limits, and signed professional accountability) creates auditable normative anchors for technically ambiguous decisions. Beyond formal compliance, engineering ethics is exercised through everyday technical judgment under uncertainty and institutional pressure, where early design and scope decisions in road projects can have lasting implications for safety, cost, and public trust [5].

Behavioural drivers and organizational pressures: Engineering estimates in infrastructure projects are prone to cognitive biases, including optimism bias and the planning fallacy, which systematically underestimate costs, durations, and risks, often reinforced by incentive structures favouring project approval over forecast accuracy. Strategic misrepresentation, deliberate understatement of costs or risks, accounts for much of the persistent underestimation in public works beyond random error [6]. Ethical lapses are typically systemic rather than individual, with "normalization of deviance" describing how repeated small departures from professional standards become institutionalized [7, 8]. In road projects, incremental compromises in investigations, design checks, or variation handling can accumulate significant technical and contractual risks, sustained by organizational culture and informal reward mechanisms.

Contractual context and integrative implications: Ethical decision-making in road projects is strongly influenced by contractual and procedural contexts, where standard contracts like FIDIC [9] can be undermined by ambiguity or informal practices if transparency is weak. Ethics should be viewed as procedural controls that complement technical standards, shaping what is disclosed, justified, and formally accepted. Practically, this requires explicit disclosure of assumptions and investigation limits, routine benchmarking against historical data, and formal ethical accountability at key decision points.

3 Mechanisms leading to technical and cost deviations

Technical and cost deviations in road infrastructure projects commonly arise from recurring decision-making patterns that reflect both cognitive and institutional pressures and carry significant ethical implications.

3.1 Underestimation during design phase

Underestimation of quantities and costs at the design stage is a recurring source of technical changes and cost deviations in road infrastructure projects. Studies link incomplete design data, insufficient quantity take-offs, and inadequate treatment of geotechnical uncertainty with later cost overruns and variations [10]. Beyond technical shortcomings, underestimation is driven by optimism bias, strategic misrepresentation, and institutional pressure to align estimates with budgetary or political expectations, resulting in formally acceptable but insufficiently robust designs.
Experience in road projects in the region [17] indicates that underestimation follows recurrent and recognizable patterns. These include deliberate reduction of cost estimates during conceptual or preliminary design to satisfy feasibility thresholds or budget ceilings, often followed by cost increases of 1.5-2 times or more during implementation. Additional practices (such as lowering unit rates, selectively excluding structural elements, or applying value engineering focused on short-term financial constraints rather than technical adequacy) further erode design robustness and lead to construction variations and elevated long-term operational risk. Political and institutional pressures, including the need to advance projects within election cycles, frequently exacerbate these tendencies and result in accelerated deterioration and extensive corrective works.

3.2 Reduction or neglect of investigative works

Reduction or neglect of investigative works, particularly geological, geotechnical, hydrological, and environmental studies, is a major contributor to technical uncertainty and subsequent cost and scope deviations in road projects. Despite recognition that ground conditions are critical risk factors, investigations are often curtailed due to budgetary constraints, tight schedules, or assumptions that uncertainties can be managed during construction, yet empirical evidence consistently links inadequate investigation to claims, variations, and overruns [11, 12]. Beyond technical consequences, curtailing investigations raises ethical concerns, as it reflects a conscious trade-off between short-term objectives and long-term reliability, effectively displacing risk to later stages with amplified cost, delay, and contractual exposure. Regional project experience consistently identifies inadequate site investigations as an early driver of technical errors and disproportionate cost escalation [17]. Typical deficiencies include omitted or limited geotechnical field investigations, insufficient surveys of tunnel portals or retaining structures, reliance on generalized topographic data from satellite imagery or drones, and inadequate assessment of surrounding infrastructure such as pipelines, energy, or hydrotechnical facilities. These reductions often lead to inaccurate ground models, levelling errors, and inappropriate structural solutions, with resulting cost increases frequently exceeding 50-100%, or more in complex cases. Additionally, deferred geotechnical missions in certain countries or phased investigations, where preliminary investigations (mission G21 - supporting design) are incomplete and contractor-led missions (missions G31 - implementation and G32 - monitoring) later reveal missing or inaccurate data, can trigger extensive redesign and exceptionally high additional costs for foundation replacements, retaining structures, or tunnel support systems. Beyond technical consequences, these omissions represent ethically consequential decisions, as they knowingly transfer foreseeable risks to subsequent project stages, magnifying cost, schedule, and operational exposure.

3.3 Variations as a financial correction mechanism

Variations, or change orders, are ubiquitous in road infrastructure projects and often represent the contractual outcome of earlier design underestimation and incomplete investigations.

While formally justified as responses to unforeseen conditions or regulatory changes, research shows that a significant share of variation costs arises from foreseeable but deferred issues, effectively correcting optimistic initial assumptions [3, 13]. Ethically, variations are legitimate only when addressing genuinely unforeseen circumstances; practices such as selective reporting, claim fragmentation, or strategic sequencing to influence cash flow are questionable and increase project risk. Empirical evidence links frequent variations to prior underestimation, limited investigation, and weak contractual transparency, revealing interconnected technical and ethical failures that drive financial adjustments [14, 15].
Regional examples [17] include multiple incremental variation requests triggered by initial underestimation of quantities or inadequate geotechnical data, selective reporting of variation costs, and fragmentation of claims to bypass scrutiny, all of which amplify project expenditures. Variations are often employed to retroactively adjust budgets affected by low initial estimates, omitted structural elements, underestimated stabilization works, or insufficient allowances for site-specific uncertainties, resulting in cumulative cost increases frequently ranging from 50% to several multiples of original estimates. Even routine design corrections following inadequate surveys or topographic misrepresentation manifest as variation orders, further illustrating the predictable financial consequences of early-stage deficiencies.

3.4 Responsibility shifting and role dilution

Responsibility shifting and role dilution disperse accountability across designers, contractors, supervising engineers, and employers, often without clear assignment of duties or authority. Even when contracts define responsibilities, actors may defer, share, or obscure accountability, allowing technically and ethically questionable decisions to persist [15, 16]. This weakens professional integrity, reduces incentives for rigorous judgment and transparent reporting, and increases the likelihood of underestimated risks, incomplete designs, or reduced investigative work.
Manifestations in the region [17] include the strategic use of designer supervision or consent mechanisms to accumulate additional payments, low-effort design contracts resulting in incomplete field investigations and design verification, and official design review processes that are rushed or inattentive to critical elements such as bills of quantities or geotechnical constraints. Responsibility dilution often interacts with previously described mechanisms, amplifying the cost and technical deviations arising from underestimated quantities, neglected investigations, and fragmented variation orders, producing cumulative and predictable project inefficiencies and increased financial exposure. A further recurring manifestation is the uncritical acceptance of informal instructions or strategic directives from political actors or road authorities (often without formal documentation or technical justification) which effectively displaces professional judgment and accountability while embedding externally driven risks into the project.

4 Ethical interpretation of deviations

Ethical interpretation of deviations requires framing both individual actions and systemic patterns, highlighting how cognitive biases, incentive structures, and organizational norms collectively shape outcomes. Professional ethics codes require engineers to act with honesty, objectivity, and primary regard for public welfare. Non-disclosure of material uncertainties, incomplete reporting of design or investigative limitations, or biased variation assessments constitute ethical lapses even when contractually compliant. Such lapses rarely stem from clear misconduct but from rationalization under schedule, budgetary, or organizational pressures, where technically permissible decisions gradually diverge from ethical intent. Recognizing and resisting this drift is a core professional responsibility [5].

Ethical conduct is shaped by organizational and institutional contexts. The normalization of deviance shows how repeated acceptance of minor departures in investigations, design assumptions, or variation approvals can become institutionalized, creating systemic vulnerabilities [7]. Role dilution and unclear accountability further allow questionable decisions to persist, transforming isolated technical issues into recurring project outcomes [16]. Institutional incentives reinforce these patterns. Contractual arrangements, performance metrics, and reporting systems may unintentionally reward underestimation, limited investigation, or selective variation management when short-term cost or schedule compliance is prioritized over long-term integrity [15]. As a result, deviations emerge not merely as technical failures but as systemic expressions of ethical gaps in project governance. By linking individual actions with systemic structures, it becomes possible to classify deviations into three ethically informed categories:

- Technically unavoidable deviations: Resulting from genuinely unforeseen conditions or inherent uncertainties, despite adherence to professional and ethical standards.
- Foreseeable but ethically avoidable deviations: Arising from insufficient investigation, optimistic assumptions, or technical shortcuts, which could have been mitigated through rigorous professional practice and transparent disclosure.
- Ethically induced deviations: Stemming directly from actions where ethical lapses - such as misrepresentation, selective reporting, or deliberate responsibility shifting - contribute materially to project divergence from expected outcomes.

This classification emphasizes that, while technical and financial outcomes are measurable, the ethical dimension explains why some deviations are predictable and preventable, rather than purely stochastic.

Table 1 Proposed framework for ethical decision-making and deviation mitigation

Framework component	Objective	Key measures/tools	Ethical/technical rationale
Early-warning mechanisms	Identify high-risk decisions and conditions before deviations occur	Risk-informed design reviews, probabilistic analysis, outside-view benchmarking, integrated risk registers	Reduces foreseeable deviations; counteracts optimism bias and strategic misrepresentation
Clarity of responsibility	Prevent role dilution and responsibility shifting	Responsibility matrices, independent verification, ethical signoffs	Strengthens accountability; ensures decisions are traceable to competent professionals
Transparent change management	Ensure variations reflect genuine needs rather than corrective financial mechanisms	Comprehensive variation reporting, aggregation rules, early contractor involvement	Promotes transparency; prevents selective reporting or manipulation of variations
Consistent documentation and ethical oversight	Embed professional ethics in project governance	Investigation and design records, formal ethical declarations, periodic audits	Makes decisions auditable; aligns with codes of professional conduct; reduces ethically induced deviations

5 Proposed framework for ethical risk reduction

Building on the analysis of technical and cost deviations and their ethical underpinnings, a structured framework is designed to integrate ethical principles into routine decision-making in road infrastructure projects. It consists of four interlinked components (table 1), and by combining them projects can:

- reduce technically avoidable deviations by addressing known risks proactively

- strengthen professional accountability by linking actions to traceable ethical and contractual obligations
- improve systemic resilience by preventing the normalization of deviance and minimizing incentive structures that promote ethically questionable decisions.

In practice, this framework supports a shift from reactive to proactive project governance, where ethical considerations are operationalized as procedural safeguards rather than abstract norms.

6 Conclusion

This paper shows that technical and cost deviations in road infrastructure projects are seldom caused solely by unforeseen conditions, but rather by a combination of design underestimation, limited investigations, variation management practices, and ethical shortcomings embedded in organizational and contractual frameworks. Technical standards alone are insufficient to prevent such deviations without clear accountability, transparency, and ethical oversight. The analysis has several limitations. It is primarily based on regional road infrastructure practice, which may differ from other contexts in regulatory, contractual, and institutional terms. The approach is qualitative and interpretive, drawing on project documentation and observed patterns, which limits quantitative generalization. While the proposed framework is grounded in established engineering ethics and risk management literature, its application requires adaptation to specific organizational and contractual settings.
Despite these constraints, the findings are transferable to contexts with comparable governance, procurement, and professional conditions. Projects characterized by fragmented responsibilities, budget pressures, or limited investigative scope may exhibit similar deviation patterns. The framework's integration of ethical oversight with technical and procedural controls is therefore broadly applicable beyond road construction to other infrastructure sectors influenced by human and organizational factors. The proposed framework operationalizes these insights by integrating early-warning mechanisms, responsibility clarification, transparent change management, and consistent documentation. Implementing this framework can reduce foreseeable deviations, enhance professional accountability, and improve both technical reliability and cost stability.

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