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The Anatomy of Geotechnical Risk Factors in Transportation Infrastructure Projects

Amadi Alolote

School of the Built Environment University of Salford, UK

Abstract: Ground conditions constitute a key risk factor that can ultimately determine the successful performance of construction contracts, with the literature reporting statistics of projects which have significantly exceeded their initial budget due to geotechnical uncertainties. The study explores the nature of geotechnical risk factors in transportation infrastructure projects, which potentially lead to cost overruns. The study provides a kaleidoscopic view of the various routes to managing risks due to the ground, at the preconstruction phases of highway projects, and how a lack thereof, can culminate to determine the trend of high-cost overruns in highway projects. The study findings reveal arguments and widely contested issues in geotechnical practice, which to various degrees, can have a significant financial impact on project completion cost in highway projects. The findings uncover various error traps and gaps in practice such as the lack of deterministic costing methods that better reflect heterogeneous ground conditions; insufficiency of preliminary geotechnical exploration; poor geotechnical risk containment in contracts as well as non-deployment of multi-dimensional geotechnically bespoke contractor selection algorithm. The study submits that these gaps in practice constitute the various trajectories through which geotechnical risk can trigger inefficiency and wastage of financial resources, leading to cost overruns in transportation infrastructure projects.

Keywords: Cost overruns, Geotechnical risk, Highway projects

1. Introduction

Ground conditions have been repeatedly asserted to account for a significant percentage of the technical risk posed to highway development, due to its complex interfaces with the design and construction of transportation projects. Several publications (Peacock, and Whyte, 1992; Alhalaby and Whyte, 1994; Whitman, 2000; Clayton, 2001; Venmans, 2006) have identified ground conditions, and the relatively high level of uncertainty associated with it, as one of the most fundamental technical explanation of cost overruns in highway projects. Engineering and re-engineering issues related to ground conditions have being consistently discussed in the technical press, as the cause of significant overruns in highway projects located in different parts of the world, with enormous economic implications (NEDO, 1983, 1988; NAO, 1994; ICE, 2001; Alavi and Tavares, 2009; DETR, 2014).

In 1990, an analysis of 67 highways contracts in the UK, revealed average cost overrun value of 28%, 17 of which showed 44% cost increases due to earthworks and unforeseen ground conditions (ICE,1991). The National Audit Office (1994) also reported 210 cases of premature failures, worth about £260 million, due to inadequate ground investigations. The National Audit Office (2001) further revealed that 70% of public sector projects experienced delays, with 73% over budget, in the face of dwindling investment in ground investigations. The New Civil Engineer (2011), reported an audit of geotechnical failures, in the Netherlands, estimated as costing between 5% and 13% of annual expenditure (€70bn/£61b).

Significant cost overruns of up to £516 million were revealed by, the Department of the Environment, Transport and the Regions (DETR, 2014), in the seven largest road projects executed, due to unforeseen ground conditions, accounting for a 63% increase above budgeted funds. Of the seven projects, the M60 Manchester ring road incurred the highest cost overrun of £184 million, due to unforeseen ground conditions amounting from delays of 35 to 46 weeks and claims worth £30 million. Five of the schemes included within the DETR analysis were also revealed to be between one to five years behind schedule. The Hallandsås Tunnel Project, Sweden, designed for the construction of two 8.6 km long railway tunnels at an initial budgeted cost of £440 million in 1992, escalated to £840 million in 2008, due to the unforeseen ground and water conditions (Creedy, 2006). The project was abandoned at 3 km (30%) completion in 1995, resumed in 1996, discontinued in 1997, and resumed in 2004, after seven years. Work progress in as at 2009, was measured to at 59% completion, with completion in 2015, as reported in the technical press (IRJ, 2015). Also, the critical factor cited as responsible for the controversial £900m cost overrun reported in the Big Dig, United States Boston Artery project, were technical issues due to unforeseen ground conditions compounded by high water table two to three meters below the surface which was discovered during construction (Creedy, 2006).

As noted from the different popularly cited statistics and case histories, ground conditions constitute a major risk factor that can ultimately determine the successful performance of a contract. The study thus explores the nature of geotechnical risk factors at the pre-contract phase of highway projects, leading to cost overruns at the post-contract phase. As Sower (1993:238) asserts: "Ground-related problems often originate in an earlier phase than the phase in which they occur…out of 500 failures evaluated, 58% originated in design and manifested in construction". The study thus provides a kaleidoscopic view of the various routes to managing risks due to the ground, at the preconstruction phases of highway projects, and how a lack thereof, can culminate to determine the trend of high-cost overruns in highway projects.

2. Conceptual Framework

Love et al. (2012) suggests the unintentional triggering of 'Latent Pathogens,' which lay dormant in the complex interactive processes of infrastructure projects, counterfactually trigger cost overruns. Pathogens, as defined by the authors, represent "*the latent conditions that lay dormant within a system until an error comes to light"* (Love *et al.,* 2012:3). Such pathogens may thus be considered part and parcel of the everyday functioning in an organization, because they have been in existence over a considerable period. However, such practices negate or significantly deviate from best practice, setting off an addictive chain of concomitant errors which creates significant 'error traps' leading to cost overruns. Morris (1990:154) was of the view that inadequate technical preparation at the front-end of projects often characterized publicly funded projects and accounted for budget overruns in infrastructure projects, stating: "*… Appraisal … is very often is devoid of meaning when the emphasis is only on the form of the project proposal rather than on its content.* While, Johansson (2015) was of the view that managing multidimensional uncertainties within a limited time, and cost constraints often trigger cost overruns in infrastructure projects.

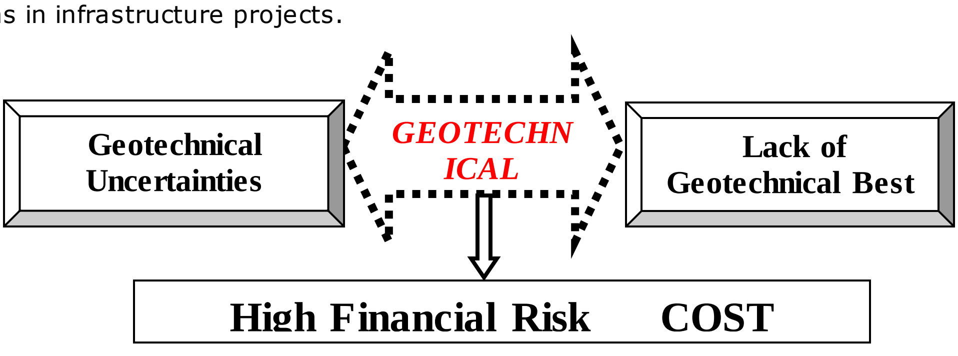

Figure 1: Conceptual Approach to the Study

Following the conceptual framework in Figure 1, the study examines the dictates of geotechnical best practice in the distinct project phases, as a basis to synthesize a theoretical framework for assessing financial risk due to geotechnical uncertainties in highway projects.

3. Method of Study

The study reviews the relevant literature related to cost overruns in highway projects, triggered due to mismanaged geotechnical risks, with a view to deducing shortcomings which can portend error traps in the practices of highway organizations. The study explicitly illuminates geotechnical best practices at the: conceptual costing phase; design preparation phase; as well as at the contractual phase during bidding, tender documentation, and contractor selection. The study deduces gaps in knowledge, suspected as prevailing in the professional practices of highway agencies, by critically analyzing current arguments and divergence between industry practices, as a basis of synthesizing a theoretical perspective for evaluating financial risk triggered by geotechnical uncertainties. Due to the practice-based nature of the research, related articles from the technical press evident in publications by international professional bodies, recognized standards of best practice, research institutes and highway agencies are used to support the bulk of scholarly literature.

4. Geotechnical Error Traps in Project Phases

4.1 Geotechnical Error Traps at the Conceptual Estimate Phase

A conceptual estimate is an estimate prepared at the phase of highway development, whereby only a general idea exists about what the project will entail (Lowe *et al.,* 2006). Various terminologies have been used to label this estimate in a project. Typically, such terms as '*early stage estimates', 'initial estimates', 'top-down estimates', 'preliminary estimates'* and '*investment estimates*' are used in the literature to label this point of initial arbitrariness in project details and definition (Chou, 2005: Tan and Wakmasha, 2010; Asmar *et al.,* 2011). Despite these different terminologies, the initial point of estimation, for any project is the planning stage, during which a business case is identified, and investment decision-to-build must be made.

It has been opined that highway projects have historically experienced significant cost overruns, often rooted at the point of the decision-to-build (Cantarelli *et al.,* 2010). To circumvent the occurrence of cost overruns, the estimating methodology used to project budgetary outlay at the conceptual phase, will need to yield estimates that closely approximate final costs (Tan and Wakmasha, 2010). The current practices of highway agencies reveal varied methodologies of approximating conceptual estimates (Chou, 2005; Alavi and Tavares, 2009). Different agencies have used various approaches at the preliminary phase to project budget estimates (Alavi and Tavares, 2009: 10). The literature, however, shows the predominance of methods, conventionally associated with the early stage estimation practices of highway agencies (Chou, 2005). From the analysis of the costing practices of several highway agencies, the author revealed a commonality of conceptual costing practices based on historical cost/mile averages. Also, apparent is the fact that none of the methodologies can be identified as having any form of systematic geotechnical input, as unique characteristics such as potential variability in ground conditions are not accounted for (Romero and Stolz, 2009). With a high element of subjectivity required on the part of estimators in deducing to the level of ground similarity with a past project. As Turouchy *et al.* (2001) expounded, these methods often based on cost-per-mile tables, usually have an adjustment made for project specific incidentals, using informal engineering judgment. Methods based on the estimation of "rough" quantities for all major items, basically apply the generic LWD (length, width, depth) method which involves estimating pavement volume, and then adding costs for other items. The LWD method, however, does not accommodate the possible variability in cross-sectional details along the proposed route, with lump sum contingency allocations used to cover for geotechnical uncertainties. It can thus be discerned that the technique of 'lane mile extrapolation' typically used by most highway agencies, may not necessarily account for the real conditions of the site.

Although, it may be argued that no certainty can be achieved in predicting ground conditions for highway projects, at the conceptual phase, Turouchy *et al*. (2001) however reported that a fair attempt to account for ground conditions was observed in the Tennessee Department of Transport, (TnDOT). The TnDOT undergo a more rigorous process, where cost estimates are developed after carrying out comprehensive desk studies. This is supplemented with the use of aerial photography and topographic sheets, with further preliminary site reconnaissance. This is reproduced in a CAD drawing system scaled plan sheet, where a rough layout of the road is produced, based on which the road center line is drawn to envision the typical section for subsequent detailed measurement to generate quantities for 20 major cost items. Turouchy *et al.* (2001) further reported that most of the DOTs surveyed revealed that the pavement cost, represented the most problematic cost item to estimate and often accounted for the most substantial deviations from detailed design estimate and final cost. This contrast with few states DOTs such as Tennessee that dedicate a relatively large amount of financial and human resources to preliminary engineering and have very low deviations from their initial cost estimates.

Despite this technical shortcoming noted, as the literature continues to report, several highway agencies deploying qualitative methods of conceptual estimating due to the speed and ease of its applicability (Chou, 2010). Romero and Stolz (2009:186) thus assert that this practice, evident within highway agencies, will amount to producing no more than just a guestimate, stating: *"Reliance on historical cost per mile data are not well suited for feasibility studies, because not only do construction costs vary widely because of subsurface, geographic, and other project-specific parameters, but also because such construction costs are not generally available in cost databases… This could result in significant budgetary shortfalls as projects progress through the developmental phases of planning and design to construction".*

4.2 Geotechnical Error Traps at the Detailed Design Estimate Phase

Detailed estimates are prepared at later stages of projects, often before the contractual phase, when all project details and cost data previously not adequately defined at the conceptual stage are available. Turouchy *et al. (*2001) opined that each successive phase of the project life cycle is more influential as the focus narrows on the amount each project will cost with a corresponding reduction in contingency allowance. Schexnayder *et al.* (2003) thus stated that subsequent estimates are made throughout project design as continuing checks on cost expectations, and the confidence intervals decline to where the final definitive estimate is expected to be very close (plus or minus 5 percent) to actual project costs and that the estimates are symmetrically distributed around the actual costs.

Detailed design estimates are typically prepared by breaking down work into the lowest level of detail, (Level-4 Rate Build-up of the WBS) that comprehensively captures all cost components before a contract is awarded and construction commences (DOE, 2011)). Detailed design estimates ideally should cater to all major cost contributors and financial risk factors in the project (GAO, 2009). It is thus a basic underlying assumption that the cost estimate prepared by clients at the detailed design phase is an accurate predictor for future costs of a project, having taken into consideration, the condition of the ground at the proposed site. It is therefore logical that at this point of detailed estimating, that the cost implication of ground related risk in projects, recognized by the institution of Civil Engineers (1991), to be a significant cost driver in transportation projects, has been adequately established. Consequently, it can be deduced that defining the geotechnical properties of the ground, in sufficient detail and accuracy, is of vital importance in the preparation of detailed design estimates, as unanticipated poor sub-grade can undermine the overall financial performance of a highway project.

Accordingly, a site investigation should attempt to foresee and provide against technical and financial difficulties that may arise during construction because of ground and other local conditions (Ashton, 1997). A site investigation as stipulated by best practice should consist of three stages, namely a desk study, a preliminary reconnaissance, and a site exploration. Bell (2007:231) stated that a desk study is undertaken to make an initial assessment of the ground and to identify, if possible, any potential geotechnical problems. The preliminary reconnaissance involves a walk over the site, and its surrounds based on visual inspection. This is because geotechnical uncertainty is always high before a comprehensive site investigation is completed (Ashton and Gidado, 2001). The aim of detailed ground exploration is to determine and thereby understand the nature of the ground conditions on site, and those of its surroundings (Clayton *et al.,* 1996). The ICE (1999) thus emphasized that a desk study and preliminary reconnaissance should not be regarded as an alternative to detailed ground exploration. Clayton *et al. (*1995:38) contradict this stance by opining that: *"The desk study and walk-over survey are the two essential components of ground investigations. Other parts (such as boring, drilling, and testing) may sometimes be omitted, but these parts of site investigation must always be carried out".*

These contradictory stances in the literature may thus imply that the phase of detailed ground investigation may be overlooked, leading to monumental cost-overruns that could have been prevented (Institution of Civil Engineers, 1999). As the literature shows, expenditure on ground investigation is often accorded a low priority (ICE, 1991; Paul *et al.,* 2002; Albatal *et al.,* 2010). Typically, several authors including Clayton, 2001; Paul *et al.,* 2002 and Albatal *et al.,* 2010 have noted that the cost of site investigations as a percentage of the total project cost is small. Typical values of 0.20 to 1.50 percent of the total project cost were revealed by Albatal *et al. (*2010). Clayton (2001) found a direct positive relationship between expenditure on-site investigations and the level of cost overruns experienced in projects. As Cathie (2000:1) asserts: "*Spending money on geotechnical investigations and engineering is like a good insurance policy*."

4.3 Geotechnical Error Traps at the Tendering Phase

The contractual provision made for the allocation of geotechnical risk is the central feature of highway contracts around which hinges the magnitude of risks borne by both parties to a contract (Moleenar *et al.,* 2006). This is because, the tender price forwarded by contractors in bidding for highway contracts, is fundamentally determined by the level of 'knowns' about a project (Moleenar *et al*., 2006). The literature establishes the importance of making fully known, the level and types of risks associated with any project so that inconsistencies in computing tender figures do not arise (DRMB, 2006; Moleenar *et al.,* 2006). As Moleenar *et al*. (2006:31) assert "*The contract is a vehicle for risk allocation ... it defines the roles and responsibilities for risks. Risk allocation in any contract affects cost, time, quality, and the potential for disputes, delays, and claims.* Moleenar *et al.* (2006) further argued that clients are in the best position to assume responsibility for ground-related risks, as indicated in Table 1.

Table 1: Risk Allocation Matrix for Highway Projects

Risk	Party recommended to assume risk	Medium of Risk Management
Site access	Owner	Advanced Planning
Methods of construction	Contractor	Specific Contract Clause
Site conditions	Owner	Geotechnical Investigation Reports; Contract Clauses.
Weather/Acts of God	Shared (Owner assumes delay risk; contractor assumes financial risk).	Contract Clause

Source: Moleenar et al., 2006

As Table 1 shows Ground Investigation Reports and the various contractual clauses, serve as risk allocation measures. The inclusion of a 'Ground Investigation Report, and a 'Differing Site Conditions (DSC) clause', implies that, in the event of encountering a subsurface condition different from that which was indicated, the owner bears the additional cost for executing the work under such conditions (O' Toole, 2006). The efficacy of these measures serves to optimally allocate geotechnical risk and therefore avoid costly disputes.

The literature, however, indicates a divergence between industry practices, as some highway agencies try to transfer the risk associated with the ground conditions to contractors in their misguided notion of ensuring certainty of final outturn cost (Chan and Au, 2007). Contractors thus must rely on guesswork to project estimates, which are forwarded in bids, risking potentially undetected ground conditions. Several authors (Tah *et al.,* 1994) thus advocate for the optimal allocation of geotechnical risks in traditionally procured contracts, since this a major factor which is considered by contractors in setting price margins. As Romero and Stolz (2009:8) opine: *"The types of risk allocation measures, or the lack thereof, have a profound influence on a contractor's decision whether to bid for a project and the amount of contingency placed in a bid for risk".*

Where ground investigation reports and DSC clauses are included, the literature evidences a significant reduction in the level of bids received (O' Toole, 2006; Romero and Stolz, 2009; Wong, 2012). This reduction in the level of bids received by clients was attributed to a lessening in the level of risk borne by the contractors relating to ground conditions, and therefore the level of contingency that is included in the bids tendered. Geddes (1985:2) remarking on this stated that: *"Although including ground investigation reports, and as such adding a differing site condition clause to a construction contract, introduces some uncertainty for an owner regarding the ultimate cost of a project. This uncertainty, however, may be offset by lower bids from contractors who will not have to account for unknown conditions by including contingencies in their bids".*

A note of caution is, however, sounded by O' Toole (2006), who raises valid concerns about the accuracy and representativeness of ground investigation reports, suggesting that where incomplete or inaccurate reports are used as a basis of financial and risk assessments by contractors, the client faces significant financial risk due to contractual change events resulting from report inaccuracies. Supporting this view, Wong (2010) identified two common arguments often raised by contractors when faced with the unforeseen ground conditions during the progress of works. Firstly, whether a ground investigation report was included as part of the contract documentation, and secondly whether the report provided, was truly representative of the physical conditions of the site.

If ground investigation report was included as part of the contract and was subsequently found not to be representative of the ground conditions experienced during construction, this can provide sufficient basis for claims and variations to arise in a contract. Thus, case law related to construction projects is rife with cases where the core argument revolves around the issue of non-representative ground investigation reports. For example, the landmark case of *E. H. Morrill Co. versus. The state of California* is both a classic example of one such dispute and the underpinning case law used by contractors wishing to challenge the employer's ground investigation report. The client, in this case, had tried to avoid the liability for unknown or unforeseen site conditions by incorporating '*Disclaimers and Exculpatory Clauses*,' which as the literature shows, do not often hold up to detailed legal scrutiny in the final judgment (O'Toole, 2006). Clients would thus only have to resort to the use of DSC clauses, which would mean paying for those conditions that could not have been revealed in detailed investigations, archetypally expressed in the form of '*Unforeseen Ground Conditions*' or a type-1 DSC (ICE, 1991).

Different internationally recognized standard forms of contracts and regulations have various adaptations of a DSC clause: The ICE form of engineering contracts; The FIDIC Red and Yellow Books, The American Federal Acquisition Regulations. Even the most recent, newly released version of the Engineers' Joint Contract Documents Committee contracts prepared as a joint document between The American Council of Engineering Companies (ACEC), The National Society of Professional Engineers (NSPE) and The American Society of Civil Engineers Institute (ASCE), contains adaptations of the differing site condition clause. The 7th Edition of the ICE Standard Form of Engineering Contract: Clauses 11 and 12, later replaced by the suite of New Engineering Contract (NEC) forms, focuses on the theme of managing ground risks. The ICE Form of a contract was intended to rationally share the risk on ground conditions between the employer and the contractor, as a basis of fostering adequate management of ground risks in engineering and construction contracts (Wong, 2012). The FIDIC Red Book (1999) focuses on client designed projects, while the FIDIC Yellow Book (1999) focuses on contractor-designed projects. Clause Clause 4.10 -12, of the FIDIC Red Book, centers on three main themes: Information on sub-surface conditions and inspection of the site; Interpretation by the contractor; and physical conditions revealed during contract execution (Wong 2012).

However, some other forms of contracts used in different countries adopt common law position. Typical wordings contained in JCT forms of contract used by the Nigerian Federal Government states: *"…the Contractor shall be deemed to have visited the site and satisfied himself that he has allowed in his price for everything necessary for the completion of the Works."* Similarly, Clause 13(1) of the Hong Kong Government General Conditions of Contract (GCC) for civil engineering or building works states: *"The Contractor shall be deemed to have examined and inspected the Site and its surroundings and to have satisfied himself, before submitting his Tender... as regards the nature of the ground and sub-soil, the form and nature of the Site... the nature of the work and materials necessary for the execution of the Works… and generally to have obtained his information on all matters affecting his Tender and the execution of the Works."*

Others, even within the jurisdiction of the countries which adopt the requirement of differing Site Condition clauses, have resorted to including 'Site Inspection Clauses' stipulating that contractors carry out all requisite inspections. Remarking on this scenario, as a financial gamble by clients, Chan and Au (2007:3) opined that: *"The owner risks tragedy, first, from cost-cutting measures the contractor will take if it hits unforeseen conditions, and then, from fighting contractor claims and picking up the pieces if the contractor abandons the projector goes bankrupt*. Lack of geotechnical risk allocation measures by highway agencies in contract documentation, during bid solicitation, therefore, constitutes significant financial risks in highway projects, which often plays out to trigger cost overruns.

4.4 Geotechnical Error Traps at Contractor Selection Phase

A key underlying feature, implicit in the successful execution of a highway contract, is the efficiency of the contractor. The selection of a contractor has thus been emphasized in the literature (Holt *et al.,* 1995; Crowley and Hancher, 1995), as a risk variable to which utmost consideration should be given during the procurement phase, as it has significant connotation to undermine meeting project performance objectives of cost, quality and time. Holt *et al.* (1995) thus distinguished between the lowest initial bid and the most competitive/viable price for a project under an existing investment climate. This is against the misguided notion of clients often opting to award contracts on a lowest bidder basis, at the risk of incurring huge cost overruns due to contractor's incompetence (Crowley and Hancher, 1995). The need for an informed, unbiased appraisal of contractors' technical capabilities relative to the bid price has thus resulted in the development of multi-parameter quantitative models for contractor selection (Gransberg and Gad, 2014). The authors asserted that comprehensive quantitative approaches to contractor selection require the assignment of relative weighting of critical geotechnical factors, aggregated in deciding on the winning bid. Gransberg and Gad (2014:967) further stated: Gransberg and Gad (2014) further explained that in the United States, during this phase, the inclusion criteria of the project RFQ or RFP is however established based on state laws or published DB procurement guides of the highway agency, and not just on a project-specific basis. The findings of Gransberg and Gad (2014) study revealed the various approaches adopted by US highway agencies, in DB projects. These are shown in Table 2.

As can be discerned from the various methods adopted by highway agencies, geotechnical input is ensured either based on the weightings or extra scores in the technical proposal, Minimal geotechnical requirements relative to other factors may, however, be necessitated under routine construction work in better ground conditions, with higher requirements in more complex projects or adverse difficult ground conditions. Subjectivity in the process of contractor selection is therefore eliminated by the explicitness of the procedure. Lack of a comprehensive qualitative/quantitative mechanism deployed to ensure that geotechnical requirements are incorporated into contractor selection decision, therefore, represents another potential geotechnical error trap at the contractual phase of highway projects, which can trigger catastrophic financial consequences on projects.

Table 2: Geotechnical Approaches in DB Contractor Selection

Highway Agency	Approach
Minnesota DOT	Higher scoring weights Bonus scoring for exceeding minimum requirements;
UDOT	Heavier emphasis on the technical aspects via a 50/50 cost/technical weighting.
Delaware	Submission of a narrative outlining the various geotechnical risks and proposed method of construction
Maine DOT	Superior scores in geotechnical category
Minnesota	5-year warranty for geotechnical failure on a pass/fail basis
Florida	20 points awarded for quality of design and ground Investigations plan and minimization of design changes

Source: Gransberg and Gad (2014)

5. Conclusion

The study has revealed various error traps through which geotechnical risk manifests at the conceptual, detailed design and contractual phases of transportation projects.

These gaps in practice identified can, therefore, serve as a logical theoretical perspective, for assessing financial risk due to ground conditions in highway projects. This implies that poor geotechnical risk containment still currently be ongoing to various degrees on highway organizations, can have a significant financial impact on project completion cost. The dynamics of geotechnical risk aversion can thus have important implications for the accuracy of the project's final outturn cost.

This study has provided clients for road projects (highway agencies), and who therefore constitute the primary target audience, with the necessary theoretical perspective necessary to understand the various trajectory through which geotechnical risk can trigger inefficiency and wastage of financial resources on transportation infrastructure projects.

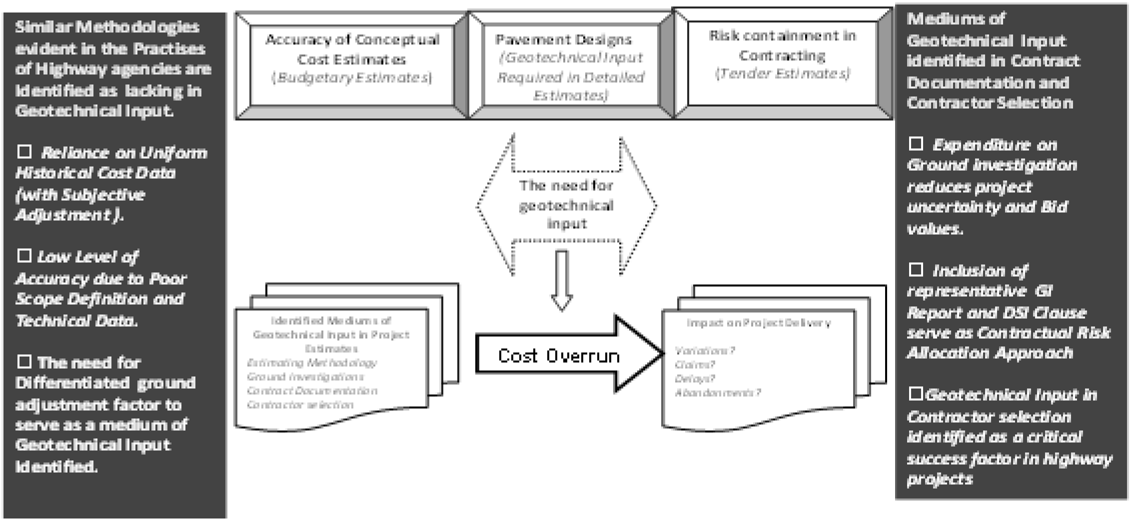

Figure 2: Theoretical Framework for Assessing Financial Risks due to Geotechnical Uncertainties

As Figure 2 illustrates, there are still ongoing divergences in the practices of highway organizations, relating to:

- The methodologies deployed for conceptual cost estimating, to enable the use of more deterministic costing methods that better reflect heterogenous ground conditions;
- The adequacy of ground investigations carried out with calls for sufficient expenditure to be devoted to carrying out more rigorous preliminary exploration.
- Whether there is a need to incorporate Ground Investigation Reports (GIR) and by implication Differing Site Condition (DSC) clauses in engineering contracts, as a mechanism of geotechnical risk containment;
- The incorporation of a comprehensive multi-dimensional algorithm during contractor selection, that incorporates specifically tailored geotechnical factor weightings

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