



Risk Management in Land Development: Strategies for Mitigating Site-Related Uncertainties

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Abstract

Land development projects inherently involve substantial uncertainties that, if inadequately managed, can significantly impact schedules, costs, and compliance with regulatory standards. This paper evaluates strategic approaches to identify, analyze, and mitigate three primary categories of site-related risks: environmental impacts, regulatory compliance challenges, and geotechnical concerns. A thorough overview of qualitative and quantitative risk assessment methodologies—including ISO 31000 standards and Monte Carlo simulation—is presented to analyze and quantify project uncertainties systematically. Additionally, practical insights are illustrated through specific case studies, including the Bridgeport Development and the Harbour View Medical Site, both located in Suffolk, Virginia.

The Bridgeport case study highlights innovative ground stabilization methods, such as surcharging, to address significant geotechnical risks from previous agricultural land uses. Similarly, the Harbour View site study emphasizes proactive mitigation of regulatory and environmental risks through comprehensive geotechnical assessments and adaptive foundation solutions, including shallow and helical piles.

The analysis underlines the importance of early and continuous integration of risk management practices into all stages of the project lifecycle—from initial feasibility and design phases to final construction close-out. Effective collaboration among project stakeholders, specialized consultants, regulatory bodies, and contractors, supported by advanced technological solutions, is vital for successful outcomes. By strategically anticipating and systematically addressing site-related uncertainties, construction managers can substantially improve project performance, ensuring timely completion, budget adherence, and enhanced environmental sustainability.

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1. Introduction

Risk management in land development refers to identifying, assessing, and mitigating potential risks that may arise during the land development process ^[1]. Some key aspects of risk management in land development include:

a) Identifying, assessing, and allocating risks

This entails evaluating all potential risks that could affect the land development project. Environmental concerns, cost overruns, construction delays, market fluctuations, and regulatory changes are common risks. Each identified risk must be analyzed regarding its likelihood of occurrence and potential impact ^[2]. This approach enables the ranking of risks from highest to lowest priority. Risks should be assigned to the party (developer, contractors, local government, etc.) that is best equipped to manage them. For instance, construction risks may be assigned to contractors.

b) Mitigation planning, monitoring, and review

Methods for reducing the impact and likelihood of significant risks must be established. This can involve contingency planning, insurance policies, engaging experienced contractors, and more. The risk management plan requires periodic review to address any new risks or changes to existing ones as the project moves through various stages. Risk management activities must be thoroughly documented for future reference, compliance, and communication of risk allocation to relevant stakeholders.

The aim is to anticipate potential problems, establish accountability, and implement measures that minimize threats to the successful and timely completion of the land development project.

c) Importance of strategic risk assessment for construction managers

Conducting a strategic risk assessment early helps identify risks before the project starts. This leads to improved planning and risk mitigation.

d) Manage risk exposure and reduce uncertainty

Evaluating risks helps quantify exposure, enabling the construction manager to determine effective risk management strategies and allocate resources accordingly. A comprehensive risk assessment minimizes uncertainty regarding potential issues and their effects, providing clarity to stakeholders. Numerous projects necessitate identifying and managing health, safety, and environmental risks for compliance. Risk assessment facilitates this process.

e) Contingency planning and optimizing

Contingency planning involves analyzing possible future events and developing strategies to address them. Assessing risks facilitates planning for contingencies related to time, cost, and resources necessary to manage risk events should they arise. Risk assessment aids in optimizing contingency budgets and preventing both over- and under-provisioning based on realistic risk exposures ^[3]. Risk data allows construction managers to make informed go/no-go decisions and choose the most suitable project delivery methods and risk allocation strategies. This assessment establishes a baseline to track changes in risk levels over time and implement corrective actions if necessary. A proactive approach to risk management, grounded in assessment, typically results in fewer surprises, reduced claims, and enhanced project performance.

f) Key site-related uncertainties in land development

- Environmental impact - Risks related to existing soil, groundwater, or air contamination; disturbances to habitats or sensitive environments; erosion and sedimentation; and effects on water resources.
- Regulatory compliance - Risks arising from complex and evolving zoning codes and land use laws, lengthy approval and permitting processes, and unexpected regulatory changes or compliance issues.
- Geotechnical risks - Hazards associated with unstable soil conditions, compressible or collapsible soils, high groundwater levels, slope failures, seismic risks, and implications for foundation design and structural integrity ^[4].

This report examines strategies that construction managers can apply to manage key site-related risks through case studies. It aims to answer questions about how risk assessment frameworks are implemented, what uncertainties need mitigation, and what lessons can be learned from successful risk management practices in land development projects.

2. Risk assessment framework in land development**a) Overview of risk assessment methodologies****1) Qualitative vs. Quantitative risk assessment**

In construction projects, risk assessment methodologies are broadly classified into qualitative and quantitative approaches. Each has distinct applications depending on the project's complexity, available data, and decision-making requirements.

Qualitative Risk Assessment focuses on descriptive and subjective evaluations of risks based on expert judgment, historical data, and experience ^[5]. It is typically used when precise numerical data is unavailable or impractical. Key features include relying on expert opinion, checklists, and risk matrices to categorize risks based on likelihood and impact. Tools include risk registers, SWOT analysis, and the Delphi method. Qualitative assessment provides a quick, cost-effective overview but lacks precise quantification. It is helpful in early project stages.

Quantitative Risk Assessment uses numerical techniques and statistical models to estimate risk probability and impact, making it more objective and data-driven ^[5]. Key features include using numerical data, probability distributions, and simulations to assess monetary, time, or performance risks. The tools employed are the Monte Carlo simulation, sensitivity analysis, fault tree analysis, and failure mode and effects analysis. Quantitative assessment provides measurable risk estimates and facilitates better decision-making with probabilistic insights. However, it requires high-quality data and computational resources.

Choosing between the two depends on project characteristics. Qualitative assessment is ideal for early-stage risk identification or small projects with insufficient data. In contrast, quantitative assessment is preferred for large-scale, high-budget projects where precise risk measurement is needed. Hybrid approaches combining both methods can provide a balanced risk evaluation.

2) Common frameworks (e.g., ISO 31000, PMBOK, Monte Carlo Simulation)

- ISO 31000: Provides a systematic process for identifying, analyzing, evaluating, and treating risks. Helps prioritize treatment strategies. The ISO 31000 standard for risk management is based on well-established principles of organizational management and process control. At its core, ISO 31000 follows a "plan, organize, direct, control" approach for establishing risk procedures and governance ^[6].

This process-oriented methodology views risk as a manageable factor that can be defined, measured, and addressed through standard management practices. If the prescribed steps are followed diligently, an organization's risk management system will continuously refine and optimize over time ^[6].

- PMBOK (Project Management Body of Knowledge): A risk management plan outlines identification, qualitative and quantitative assessment, response planning, and monitoring/controlling processes.
- Monte Carlo Simulation: A quantitative technique that models risk variables as probability distributions to forecast project outcomes under uncertainty.

According to Isa and Shukri ^[7], the Monte Carlo simulation (MCS) is a sampling technique used to create model results that rely on variables or parameters defined as probability distributions. It randomly selects input values to build the model, where the variables have a known range of possible values but an uncertain specific value at a given time. MCS incorporates the inherent variability of outcomes from various potential scenarios, similar to the uncertainty associated with these evaluations ^[7].

Generally, an MCS involves several steps, such as defining statistical distributions for input parameters, simulating the models, and analyzing the results. In recent times, MCS has become widely used for solving many problems due to its relatively low computational requirements compared to the complexity of issues that can be addressed ^[7].

Given enough sampling iterations, an MCS analysis can statistically produce an output realization distribution that accurately represents all possible outcomes. However, the accuracy depends on how completely all input parameters' distributions are characterized. Often, insufficient data is available to define the input probability distributions precisely. Additionally, the number of iterations needed for an exact output distribution is typically large, limiting the use of MCS for early-stage project planning where multiple options may be considered. MCS is a commonly used method for incorporating parameter uncertainty into quantitative risk assessment. It allows an analyst to evaluate uncertainty in an expert's estimates by defining it as a probability distribution rather than a single expected value ^[7].

b) It is important to integrate risk assessment early in the project lifecycle.

Early risk assessment allows uncertainties to be proactively addressed through planning and design rather than reactively during construction ^[8]. It prevents cost and schedule overruns. It will enable risks to be adequately planned for and addressed upfront before they affect the project. Identifying risks early gives the project team time to develop risk mitigation strategies. It improves project planning. With risks identified, the project plan can be designed to avoid or minimize risk exposures from the beginning. It facilitates risk-based decision-making. Early risk assessment provides critical information to make informed choices about project scope, resources, methodology, etc. It improves risk communication. Early risk assessment establishes a common understanding of risks among all parties for the entire project. Early risk assessment helps set more accurate project timelines and budgets ^[9]. Understanding potential risks helps create more realistic schedules and cost estimates.

3. Environmental risk management

a) Key environmental risks in land development

Clearing and grading of land removes vegetation that holds soil in place. Rain and wind can erode and transport sediment more easily, polluting nearby waterways. Soil contamination from previous land use can increase remediation costs ^[10].

Surveys and testing help budget remedial measures. Groundwater pollution risks from underground storage tanks or chemical spills require monitoring plans to address liability. Development can overdraw groundwater supplies and alter natural aquifer recharge patterns. Spills or leaks may also contaminate drinking water sources. Improper handling and disposal of hazardous wastes like asbestos, lead paint, and fuels/oils used in construction poses contamination risks to soil and groundwater. Air quality issues during construction due to dust or equipment emissions necessitate controls to minimize complaints and regulatory action ^[11]. Construction activities generate air pollutants from vehicle and equipment exhaust and airborne dust. Noise pollution from construction can also disturb wildlife and nearby communities. The discovery of protected plant or animal species can delay work until impact assessments and permits are obtained. Development often results in habitat fragmentation as natural areas are converted to other land uses. This can negatively impact wildlife populations that rely on intact habitats. Wetlands are especially at risk if not adequately avoided.

Strategies like preliminary site investigations, impact assessments, and environmental management plans are crucial to mitigate environmental risks on land development projects. Poorly planned projects may block scenic views or damage the aesthetic character of an area residents value.

b) Environmental Impact Assessment (EIA) process and regulatory requirements

- Site assessments and remediation techniques - Preliminary assessments identify risks for further investigation and testing. Remediation uses excavation, capping, or bioremediation to treat contaminated soils or groundwater. Excavation refers to digging up and removing contaminated soils and disposing of them properly ^[12]. This is often used for localized areas of significant contamination that cannot be treated. Capping involves installing an impermeable barrier, like a synthetic liner or clay cap, over contaminated soils to prevent exposure and block infiltration ^[13]. This isolates the contamination without complete removal. In bioremediation, microorganisms like bacteria or fungi break down pollutants naturally. Amendments like oxygen, nutrients, or other substrates may be added to stimulate the microbial activity in contaminated soils or groundwater plumes.
- Sustainable construction practices Practices like sediment control plans, dust suppression, green building materials, and energy efficiency help control pollution risks and gain stakeholder support. Sediment control plans help prevent soil erosion and sediment from washing into waterways during construction projects. Things like silt fences and sediment basins trap sediment before it can pollute nearby streams, lakes, etc ^[14]. This controls water pollution risks. Dust suppression, like spraying water on dirt surfaces, helps control airborne dust particles that can be a nuisance and health risk. Suppressing dust from construction sites gains support from nearby residents and businesses. Green building materials, like recycled content products, sustainably harvested wood, etc., signal that a project cares about environmental impacts ^[15]. Choosing greener options builds goodwill with stakeholders concerned about pollution and resource depletion. Implementing energy

efficiency measures, such as better insulation, LED lighting, and solar panels, shows a commitment to reducing emissions and future energy costs. This demonstrates that a project is considering long-term sustainability, not just short-term impacts, and is gaining trust.

- Stakeholder engagement in environmental decision-making - Engaging regulators and the community in risk discussions leads to permit conditions that balance development needs with environmental protection. Early collaboration resolves concerns.

4. Regulatory compliance and legal risks

a) Common regulatory challenges in land development

Developments must conform to zoning designations, which dictate allowable land uses, densities, setbacks, parking requirements, etc. Zoning designations establish clear rules and regulations for different areas, providing predictability for developers and residents. However, they can limit flexibility and innovation if conditions change over time. Rezoning is often required for new developments that do not strictly adhere to the existing zoning. This introduces uncertainty into the development process as rezoning requests may be denied or face community opposition. It can delay projects and increase costs. Developers prefer working within existing zoning to minimize risks. However, zoning may not always align with current market demands or higher/better uses of specific properties over time. Projects require numerous permits from various environmental agencies for site grading, stormwater management, tree removal, infrastructure, etc. Connecting to roads, sewers, water, and other utilities requires agreements and capacity approvals from transportation and utility providers.

Structural, electrical, plumbing, accessibility, fire, and safety codes govern building design and construction ^[16]. Version updates mid-project require re-design. Developments involving protected/heritage structures require approvals for repairs, alterations, or additions. Consultation requirements and public hearings introduce schedule risks from community opposition or requested design changes.

b) Role of regulatory risk assessment in project planning

- Identify applicable regulations from zoning, environmental, building, and other agencies at local, state/provincial, and federal levels.
- Assess the compliance risks and impacts of schedule delays, penalties, conditional approvals, or design changes resulting from non-conformance.
- Evaluate the likelihood and impacts of risk scenarios such as denied permits, unforeseen code issues, or objections from public hearings.
- Understand approval dependencies between different regulatory bodies to avoid delays from sequential processes.
- Estimate compliance timelines and costs to integrate into project schedule and budget for approvals management and contingencies

c) Strategies for ensuring compliance

1) Due diligence and feasibility studies

Due diligence studies are essential to understand existing land use entitlements and development limitations upfront. Thorough title searches verify land ownership and

encumbrances like easements. Reviews of historical zoning and planning approvals confirm that the proposed use conforms. Infrastructure capacity studies from utility providers ensure services are available. Environmental assessments uncover potential contamination issues. Market studies support rezoning applications by demonstrating project viability. Feasibility studies evaluate compliance costs, timelines, and risks to integrate into project budgets and schedules ^[17].

2) Liaising with regulatory bodies and legal consultants

Early pre-application meetings with local planning, building, environmental, and other approval agencies facilitate design iterations for compliance. Engaging land development attorneys experienced in local approval processes navigates complex regulations. Maintaining open communication and being responsive to agency feedback builds relationships. Where possible, negotiating comprehensive development agreements provides regulatory certainty. Legal counsel also assists with permit conditions and public consultation requirements.

3) Implementing compliance monitoring systems

Robust compliance monitoring systems keep projects on track. Checklists and clear responsibility assignments fulfill the conditions of approval. Document control of all submissions, approvals, and inspection records provides a compliance audit trail. Notification procedures for interim inspections avoid penalties. Change order management of design modifications receives approvals. Periodic internal audits verify compliance status before issues escalate. Non-compliances are reported and rectified immediately with regulators.

5. Geotechnical risk mitigation strategies

Geotechnical uncertainties pose significant challenges for land development due to the inherent variations below the ground surface. Common risks include soil instability from collapsible or expansive soils, unpredictable groundwater conditions, and seismic hazards in active fault zones ^[18]. Geotechnical failures can compromise structural integrity, damage infrastructure networks, and threaten public safety without adequately addressing these issues.

Thorough geotechnical investigations characterize subsurface conditions and inform appropriate risk mitigation strategies ^[19]. Techniques like borehole testing, trial pit excavations, and laboratory soil analysis provide data on soil stratigraphy, shear strength parameters, compressibility, and groundwater levels. The findings from such assessments help determine if problem soils are present, if dewatering will be required, and if the site lies within a liquefaction-prone area. A range of engineering solutions can be employed to manage geotechnical risks. Ground improvement works like vibro-compaction, stone columns, and grouting aim to densify loose soils and improve their load-bearing capacity ^[20]. Foundation designs may also need adaptations such as deep foundations, pile caps, or specially designed shallow foundations to transfer structural loads effectively to competent soil strata. Drainage measures like subsoil and perimeter drains help control groundwater levels beneath structures. Slope stabilization using retaining walls, soil nails, or anchors can prevent landslides on sloping terrain. Proper temporary works design is also crucial during construction to shore excavations and support adjacent properties.

6. Integrating risk management into land development planning

For risk management strategies to be effective, they must be embedded throughout the entire project lifecycle, from planning to construction completion^[21]. A holistic approach coordinates assessment and mitigation activities among various stakeholders. Project teams require cross-disciplinary collaboration between specialists focused on environmental, regulatory, and geotechnical uncertainties. Early engagement with contractors enables risks to be priced appropriately into bids.

Regulatory authorities also play an integral role and must be consulted proactively. For example, permitting processes can be streamlined through ongoing dialogue with approval bodies. This helps flag potential compliance issues upfront before they cause costly delays later.

Technology supports integrated risk management by capturing and sharing substantive data. Geospatial information systems allow spatial risk analysis to be overlaid on property maps^[22]. Building information modeling facilitates design coordination and construction planning around characterized subsurface conditions.

Continuous monitoring further strengthens the process. Assessment does not end at the planning phase but should be revisited periodically or when site or design changes occur. An adaptive approach refines mitigation strategies based on new findings. Similarly, post-development audits identify lessons for future projects. With all parties working collaboratively underpinned by technology, risk management becomes embedded in routine project workflows for land developments.

7. Case Study

In this Article, let us discuss three scenarios in which the owner had to evaluate the risks before occupying the land for development.

a) Bridgeport development in Suffolk, VA

The Bridgeport development project in Suffolk, Virginia, represents a significant mixed-use community halfway completed and has already opened its doors to the public. Upon completion, this vibrant development will encompass over 1,000 residential apartment units and multiple commercial establishments designed to create an attractive, self-contained community. The development has already become a bustling hub, attracting substantial commuter traffic and generating considerable economic returns for its owners.

Before the acquisition, the Bridgeport site posed substantial geotechnical challenges. Historically, the land was utilized for agricultural purposes, specifically for soybean cultivation and hog farming operations. At the core of the property existed a large hog pond, presenting unique ground stability issues and complicating the potential for development. The presence of soft, compressible soils, primarily resulting from organic matter accumulation due to farming practices, heightened concerns regarding site suitability. Consequently,

the anticipated development costs posed considerable financial risks, as extensive ground improvement would be essential before commencing construction activities.

Recognizing these risks, extensive consultations were undertaken with civil and geotechnical engineers and other industry specialists to identify a technically sound yet economically viable ground improvement strategy. Following comprehensive analyses, the experts proposed employing a ground stabilization technique called surcharging. Specifically, this involved constructing temporary surcharge mud piles directly over future building pads. These surcharge piles exerted continuous pressure on the underlying soft soils, consolidating them over a predetermined duration. To optimize structural safety and cost-effectiveness, the surcharge method was complemented by strategically limiting maximum column loads to 400 kips, thus further managing the soil load-bearing demands.

Upon completion of the necessary surcharging period—after ensuring sufficient soil compaction—the surcharge material was effectively repurposed. This approach involved relocating the surcharge select fill to the hog pond and other low-lying areas on-site. Such an innovative approach resolved the geotechnical challenge of unsuitable soils and significantly reduced additional procurement and importation costs associated with fill materials, fostering a sustainable approach to construction practices.

However, despite rigorous pre-construction ground stabilization efforts, isolated areas may occasionally demonstrate pavement distress due to residual pockets of poorly compacted subgrade material. These localized conditions necessitate immediate remedial action, typically involving excavation of the problematic regions (undercutting), followed by backfilling and compaction with dry aggregate stone. This remediation technique restores structural integrity, ensures the pavement's longevity, and maintains user safety.

The supporting visual documentation presented below captures the significant transformation of the Bridgeport site from 2018 to its current status. The sequence illustrates the systematic filling and stabilization of the former hog ponds (highlighted in red circles in Figure 1) utilizing surcharge select fill material—Figure 2 highlights explicitly the ongoing surcharging process post-construction of the 3800 Acqua Apartments. Finally, the most recent visual captures (Figure 3) the completed phases -3800 Acqua Apartments (Phase 1) and Royal Sail Apartments (Phase 2)—along with identified future phases: Alaron Apartments (Phase 3) and Knotts Landing (Phase 4). These figures underscore the extensive planning, meticulous engineering, and successful execution behind this ambitious development project.

Through strategic engineering solutions and adaptive management practices, the Bridgeport development overcame substantial site-specific challenges, creating a thriving, community-oriented development poised for continued success and expansion.

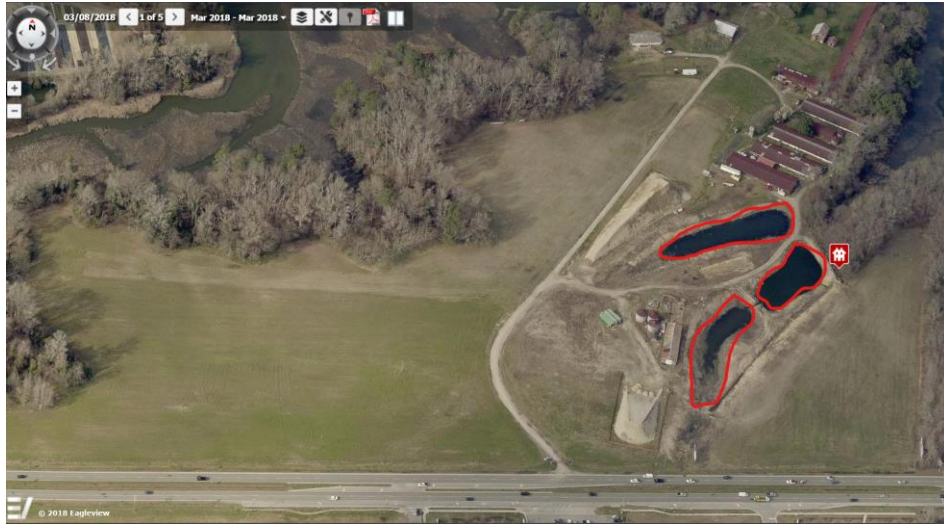


Fig 1: Bridgeport, Suffolk, VA, aerial view from year 2018



Fig 2: Bridgeport, Suffolk, VA, Aerial View from Year 2019



Fig 3: Bridgeport, Suffolk, VA, Aerial View from Year 2024

b) Harbour view medical site Suffolk, VA.

Situated in the heart of Harbour View, one of Suffolk, Virginia's most sought-after commercial districts, this prime development site embodies opportunity and careful strategic planning. When the developer initially considered acquiring this parcel in 2018, it was clear that the potential rewards came hand-in-hand with distinct challenges requiring meticulous consideration.

One primary risk associated with the property was navigating the stringent architectural and usage guidelines imposed by the Harbour View board. Although zoned explicitly for commercial development, the board maintained specific restrictions, limiting certain types of commercial structures. Adhering to these guidelines necessitated additional design reviews, extended approval timelines, and potentially elevated construction costs. Nevertheless, the site's prime location—strategically positioned amidst vibrant commercial activity and extensive visibility—made overcoming these constraints an enticing prospect.

The second significant hurdle involved addressing the site's unique environmental conditions. Initial investigations revealed that beneath the dense, wooded terrain lay moist, problematic soils exacerbated by a natural swale running through the property's center. Such conditions raised immediate concerns regarding foundational stability for future construction. Recognizing the potential implications, the developer promptly undertook proactive measures, obliterating the densely wooded area. Subsequently, the existing swale was filled using carefully selected and compacted fill materials to mitigate soil saturation and improve site stability.

To ensure long-term structural integrity, the developer commissioned a comprehensive geotechnical study to assess the feasibility of constructing a two-story Class-A medical office building. Results from this detailed analysis confirmed the need for additional ground improvement techniques

beyond standard site grading. The geotechnical engineers advised employing specialized foundation support systems, such as shallow or helical piles, strategically placed beneath critical structural column loads. Though adding initial costs to the project budget, these methods promised substantial long-term benefits by safeguarding the integrity of the future structure and enhancing overall project value.

As of today, the developer continues to actively evaluate the optimal solution between shallow and helical pile systems. Both solutions are renowned for their effectiveness in stabilizing buildings on challenging terrain, providing necessary support without extensive excavation or soil replacement. The final method will be chosen based on cost-benefit analyses, structural requirements, construction timelines, and long-term site performance considerations.

The provided aerial image (Figure 4) vividly illustrates the site's original condition, characterized by dense vegetation and the central swale. This starkly contrasts the recent state captured in Figure 5, post-clearing and leveling activities. The visual transformation underscores the meticulous planning and execution already invested in preparing this premier location for development.

Ultimately, while initial risks associated with regulatory compliance and soil stability were considerable, the developer approached the acquisition as a calculated risk, carefully balancing potential costs against expected returns. This decision has proven prudent: rigorous planning, strategic investments in engineering studies, and early collaboration with the Harbour View board have significantly reduced these risks, paving the way for the project to advance confidently toward successful completion. Today, the Harbour View Medical Site represents prudent risk management and visionary development, enhancing both the aesthetic appeal and economic vitality of Suffolk's thriving Harbour View community.

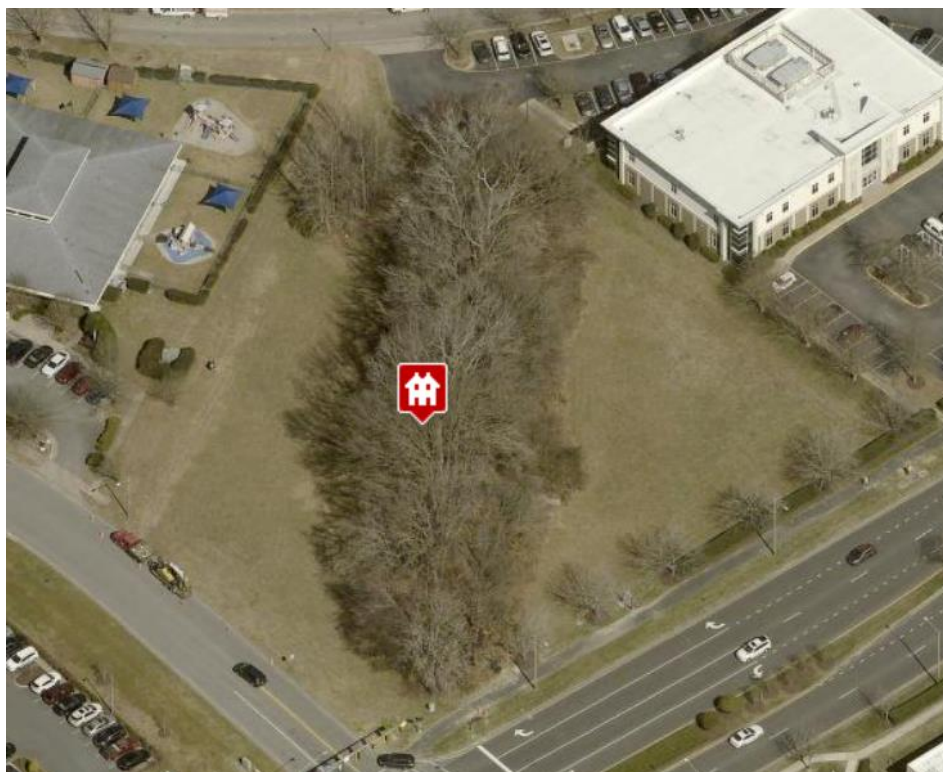


Fig 4: Harbour View Site, Suffolk, VA aerial view, 2018



Fig 5: Harbour View Site, Suffolk, VA aerial view, 2018

8. Conclusion

This paper has systematically explored methodologies for effectively managing critical site-related risks inherent in land development projects. Through detailed examination, it is clear that implementing structured risk assessment frameworks, such as ISO 31000 and PMBOK, complemented by quantitative techniques like Monte Carlo simulation, significantly reduces uncertainties associated with environmental, regulatory, and geotechnical challenges [6, 23, 7]. Utilizing qualitative approaches in early project phases and quantitative methods during detailed planning ensures a balanced and robust risk management strategy [5].

The effectiveness of early risk management was demonstrated in practical case studies of two prominent developments in Suffolk, Virginia—Bridgeport and Harbour View Medical Site. In the Bridgeport project, careful geotechnical analysis led to successfully adopting surcharge techniques to consolidate historically unstable farmland, mitigating substantial ground improvement costs and project delays [19]. Conversely, the Harbour View project illustrated the importance of proactively addressing regulatory compliance issues alongside environmental and geotechnical constraints. Strategic engagements with regulatory entities and advanced engineering solutions like shallow or helical piles addressed challenging ground conditions and facilitated compliance with stringent local development standards.

Furthermore, environmental risks necessitate comprehensive preliminary site investigations, environmental impact assessments, and sustainable construction practices [15]. Geotechnical uncertainties similarly demand thorough subsurface investigations, proactive engineering solutions, and ongoing monitoring to ensure long-term structural stability [4]. Regulatory risks require vigilant due diligence, collaborative dialogue with regulatory authorities, and robust compliance monitoring frameworks [8].

Overall, proactive integration of structured risk management throughout project lifecycles substantially enhances project success rates, minimizes schedule delays, and promotes sustainability. The insights gained underscore the importance of adopting systematic risk assessment frameworks, combined with a proactive, adaptive approach to planning and management.

9. Recommendations

Based on insights from the case studies and the literature reviewed in this paper, the following recommendations are presented to enhance risk management practices in land development:

a) Implement early and continuous risk assessments:

Risk assessments should commence early, during the conceptual or feasibility stages, and continue throughout the project lifecycle. Early identification and assessment of risks facilitate timely and informed decision-making, ultimately minimizing costly and disruptive risk events during construction [8].

b) Enhance interdisciplinary collaboration:

Land development projects should actively foster collaboration among construction managers, geotechnical engineers, environmental experts, and regulatory authorities. Such collaboration improves the depth and comprehensiveness of risk assessments and mitigates issues arising from stakeholder misunderstandings or conflicts [8].

c) Adopt advanced risk modelling techniques:

Projects should increasingly utilize advanced quantitative modeling tools such as Monte Carlo simulations and Geographic Information Systems (GIS). These tools enable construction managers to visualize, quantify, and manage complex risks more accurately, improving decision-making

under uncertainty ^[10].

d) Promote sustainable and technologically driven solutions:

Emphasizing sustainable building practices, including using green construction materials and techniques like soil stabilization, erosion control, and sustainable remediation methods, significantly reduces long-term environmental liabilities and enhances regulatory approval efficiency ^[10].

e) Strengthen regulatory relationships and compliance management:

Active collaboration with regulatory agencies and local stakeholders is crucial. Developers should maintain continuous communication through pre-application meetings, transparent documentation practices, and robust compliance monitoring systems, significantly reducing regulatory risk and minimizing potential delays or additional costs ^[16].

f) Invest in capacity building and professional training:

Regular professional training on risk assessment methodologies, evolving environmental regulations, geotechnical advancements, and technological innovations is recommended. Continuous education enhances the project team's capability to address risks proactively, thus ensuring higher standards of project management performance ^[21].

By adopting these recommendations, construction managers and developers will be better equipped to anticipate, assess, and mitigate critical site-related uncertainties, ensuring successful and sustainable project outcomes.

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