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Review Article

The Impact of Early Identification of the Unknown Project Risks on Project Success: A Case Study of the First Implementation of Wick Drains and PHC Piles in Saudi Arabia

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Abstract

Unknown project risks play a critical role in the successful execution of projects. These risks may originate from internal or external sources and can present opportunities, threats, or neutral outcomes. The objective of this paper is to examine unknown project risks that may affect project outcomes. It discusses the challenges associated with identifying unknown risks and highlights the role of project managers and risk management teams in managing these risks and their potential impacts as well as in transforming unknown risks into known and manageable risks through structured risk identification, investigations and continuous monitoring. Effective identification and management of unknown risks enhance project decision-making, reduce uncertainties, and increase the likelihood of project success. This paper also presents a case study on the implementation of new technologies in Saudi Aramco. The study examines the challenges encountered during implementation and demonstrates how thorough investigations and clarification of identified uncertainties, known and unknown risks contributed to the successful implementation and adoption of these technologies within the company.

Keywords: Unknown Risks, Project Risk Management, Risk Identification, Risk Assessment, Risk Mitigation.

1. INTRODUCTION

Starting a new project can be challenging because project conditions continually evolve. Even when a project appears to be under control, new risks may emerge that require additional attention, timely action, and decision-making. A lack of familiarity with these emerging risks often makes them difficult to identify and manage. Consequently, they may be overlooked until their impacts become significant and detrimental to the project.

By following the Project Risk Management Process described in the Project Management Body of Knowledge [PMBOK® Guide] [1], project teams can better anticipate risks and uncertainties, thereby minimizing their negative impacts and increasing the probability of project success.

This study examines unknown project risks and their impact on project success. These risks may be classified as threats, opportunities, or neutral events. Successfully identifying and managing unknown risks depends on the competence of the risk management team, the effectiveness of the risk management process, and strong leadership capable of addressing project risks proactively. Risk identification should encompass all major risk categories, including financial, managerial, technical, legal, regulatory, internal, and external risks.

2. Known Risk versus Unknown Risk

Project risks can be classified as either known or unknown. Known risks are generally easier to identify because they are associated with previous experience, familiar technologies, established environments, and recognized regulations or standards. In contrast, unknown risks remain hidden until they are discovered and assessed. For this reason, they may also be referred to as hidden risks.

Unknown or hidden risks are more difficult to recognize and evaluate, yet they can have a significant impact on project success. These risks are often associated with new technologies, unfamiliar environments, innovative construction methods, or newly introduced regulations and standards. Because they are difficult to predict, unknown risks require additional analysis, expert judgment, specialist involvement, and continuous monitoring, particularly when they are indirectly related to the project.

Focusing only on known risks while overlooking unknown risks can result in significant project threats and may ultimately lead to project failure. Likewise, inaccurate risk assessments can adversely affect project quality, cost, schedule, and safety performance, while also reducing team morale, motivation, and collaboration.

Therefore, a comprehensive risk management strategy should be developed to address both known and unknown risks. The strategy should include appropriate methodologies for identifying, evaluating, and monitoring all relevant risks, whether internal or external and whether directly or indirectly related to the project. It should also document each risk's root causes, early warning indicators, and mitigation measures to support successful project execution.

3. Risk Identification and Management

Risk identification should be based on accurate and reliable information related to the project's objectives, assumptions, and constraints. It should evaluate the potential impact of risks on the project schedule, budget, and resources while addressing both known and unknown risks that may affect the project during its execution and throughout its life cycle.

Effective risk identification can be achieved through the collection and analysis of project data, active involvement of project stakeholders and subject matter experts, consideration of future developments, and assessment of project resources, including resources shared with other projects. The project manager plays a critical role in guiding the team, monitoring project performance, tracking progress, and ensuring that risks are managed effectively and efficiently.

The project team should focus on identifying potential sources of risk, such as design deficiencies, inadequate verification and validation processes, unrealistic project assumptions, resource limitations, and other issues that may affect project performance. Continuous verification, validation, and monitoring are essential for identifying emerging risks and ensuring that appropriate mitigation measures are implemented in a timely manner.

4. Required Skills for Effective Risk Management

Effective communication and strong technical knowledge form the foundation of successful risk management. Clear communication ensures that accurate information is shared among project team members, enabling everyone to remain informed, engaged, and aligned with the project's objectives. Risk-related information and project decisions should be communicated in a timely, accurate, complete, and easily understood manner to all relevant stakeholders.

Technical knowledge enables the risk management team to identify project risks at an early stage, anticipate potential unknown risks, assess their potential impacts, and develop appropriate mitigation measures. A thorough understanding of engineering principles, project execution methods, applicable standards, and emerging technologies enhances the team's ability to recognize uncertainties before they develop into significant project issues.

Leadership is another essential competency for successful risk management. Effective leadership promotes collaboration among team members in identifying, assessing, and managing both known and unknown project risks. It establishes a clear vision, encourages accountability, and supports continuous monitoring of project progress and team performance [2]. Strong leadership also fosters a culture of continuous learning, enabling teams to learn from both project successes and failures while improving their ability to identify and respond to emerging risks.

A highly skilled risk management team can transform certain uncertainties into intelligent risks—well-understood risks that, when managed effectively, create opportunities and add value to both the project and the Company.

5. Impact of Unknown Risks on Project Delays and Failures

The main reasons for project delays and failures are inadequate planning and scheduling, as they lead to other issues such as resource shortages, conflicts, ineffective communication, and unproductive risk management. Additional issues include financial difficulties, delays in decision-making, changes in scope, and poor stakeholder coordination, all of which can significantly affect the project, especially during execution [4]. Project managers and teams must concentrate on these causes and investigate potential unknown risks, as these risks are the leading contributors to project delays and failure.

6. Reserves to Manage Risks

Projects typically include two types of reserves: contingency reserves and management reserves. Contingency reserves are allocated to manage known risks with estimated impacts, whereas management reserves are established to address unknown risks with unforeseen impacts.

Management reserves are intended to cover unforeseen events that cannot be accurately predicted during project planning. They are typically estimated at

5% to 10% of the total project budget, depending on the project's complexity and level of uncertainty. For large or mega projects, this allocation can represent a significant amount of capital that may remain unused throughout the project, effectively becoming reserved or "frozen" funds.

7. Example of Project Risks

The following examples illustrate common project scenarios that can be used to identify, assess, and manage project risks.

- **Projects Dependent on Third Parties:** Many projects depend on external organizations, including contractors, vendors, consultants, suppliers, and testing agencies. Potential risks include expired licenses or certifications, non-compliance with government regulations and industry standards, insufficient resources or equipment, and poor contractor performance. These risks can be minimized by regularly reviewing and monitoring documents for validity and expiry, verifying approvals and certifications, confirming personnel qualifications, and ensuring compliance with applicable regulations and standards.
- **Projects Located on Roads with Inadequate Safety Measures:** Projects located in areas where roads lack adequate traffic warning signs and safety instructions are exposed to increased safety risks. Potential risks include traffic accidents, injuries, fatalities, and damage to project assets. These risks can be mitigated by installing appropriate traffic warning signs, implementing traffic management plans, and conducting regular safety inspections and risk assessments throughout the project.
- **Projects Executed in Desert Environments:** Projects executed in harsh desert environments with shifting sand dunes, strong winds, and frequent sandstorms present unique operational challenges. Potential risks include schedule disruptions, reduced productivity, equipment damage, and safety hazards, particularly for personnel working at elevated locations. These risks can be reduced by continuously monitoring weather forecasts, planning work activities around adverse weather conditions, implementing appropriate safety measures, and scheduling indoor activities during severe weather events whenever possible.
- **Projects with Shared Resources:** Organizations often allocate personnel, equipment, and other resources across multiple projects to maximize resource utilization and profitability. However, this approach may introduce risks related to resource shortages, competing priorities, and project delays. These risks can be mitigated by continuously monitoring resource availability, forecasting future resource requirements, maintaining alternative resource options, and implementing effective resource planning and allocation processes.

8. Case Study: First-Time Implementation of Wick Drains and PHC Piles in Ras Al Khair, Saudi Arabia

This case study examines the known and unknown risks associated with the first implementation of two innovative technologies in Saudi Arabia: Prefabricated Vertical Drains [Wick Drains] and Prestressed High-strength Concrete [PHC] Piles. These technologies were introduced for the Steel Plate Manufacturing Project in Ras Al Khair, located on the Arabian Gulf coast [5], [6].

A structured risk management approach was adopted to identify, investigate, validate, and mitigate both known and unknown risks throughout the project. The successful implementation of these technologies demonstrates the importance of risk identification, specialist involvement, pilot testing, and continuous monitoring in reducing project uncertainty.

Both technologies achieved the required technical performance, quality standards, project objectives and schedule, providing valuable experience for their future application in Saudi Arabia.

Project Environment

The project was executed under challenging site conditions characterized by: [1] Extensive areas of sabkha soils. [2] Loose to very loose sandy soils. [3] High soil salinity. [4] High groundwater table. [5] Tight construction schedule

Technologies Introduced

Technologies introduced are [1] Prefabricated Vertical Drains [Wick Drains] to accelerate soil consolidation and improve ground stability. [2] Prestressed High-strength Concrete [PHC] Piles as an alternative deep foundation system to conventional cast-in-place concrete piles.

At the time of implementation, neither technology had previously been constructed in Saudi Arabia, resulting in considerable uncertainty regarding design, construction, testing, and long-term performance.

Initial Risk Assessment

The project team classified project risks into two categories.

a. Known Risks

Known risks were identified based on previous engineering knowledge and experience, and available technical references.

Wick Drains known risks include: [1] Inadequate soil consolidation due to incorrect drain spacing or installation. [2] Reduced drainage efficiency. [3] Damage to wick drains during installation. [4] Delayed soil consolidation. [5] Inaccurate piezometer [PZ] readings.

PHC Piles known risks include: [1] Pile damage during driving due to inappropriate hammer selection or inadequate cushioning. [2] Pile refusal before reaching the required penetration depth. [3] Damage during transportation and handling. [4] Limited availability of pile installation equipment.

b. Unknown Risks

Unknown risks presented the greatest challenge because they could not initially be identified or quantified.

Technical Unknowns risks include: [1] For wick drain: [a] Long-term performance of wick drains. [b] Soil consolidation behavior under local climatic conditions. [2] For PHC: [a] Suitability of PHC piles in sabkha and highly saline soils. [b] Durability of PHC piles against chloride attack. [c] Potential changes to surrounding soil caused by pile driving.

Supply Chain Unknowns risks include: [1] Availability of experienced installation contractors. [2] Manufacturing quality of wick drains and PHC piles. [3] Transportation, storage, and preservation of materials. [4] Availability and reliability of specialized construction equipment. [5] Technical support from international suppliers.

Regulatory Unknowns risks include: [1] Acceptance of the new technologies by local authorities. [2] Compliance with applicable international standards. [3] Meeting inspection requirements. [4] Availability of appropriate testing procedures and equipment.

Construction Unknowns risks include: [1] Contractor experience in implementing the new technologies. [2] Compatibility of construction and testing equipment. [3] Equipment productivity rates. [4] Quality assurance and safety control procedures.

Investigation Strategy

Both technologies were investigated and designed by an international engineering consultant. The feasibility studies confirmed that both technologies were technically suitable and recommended for implementation.

Step 1 – Engineering Research

The engineering team reviewed published case studies, technologies' related standards and technical literature covering successful applications of the technologies in: [1] Southeast Asia. [2] USA. [3] Europe.

Step 2 – Specialist Involvement

Specialists from the following organizations participated throughout the project: [1] Wick drain and PHC pile suppliers. [2] Saudi Aramco specialists from project management and geotechnical consultants. [3] Project partner experts. [4] Design engineering office. [5] Construction contractor and subcontractor specialists.

Step 3 – Additional Site Investigation

Additional geotechnical investigations were performed to reduce uncertainty and improve engineering decisions. The investigation included performing: [2] Additional boreholes. [2] Extra cone Penetration Tests [CPT]. [3] Further laboratory testing. [4] Detailed soil characterization. [5] Groundwater assessment.

The investigations improved the understanding of site conditions and confirmed the most appropriate ground treatment method. Additionally, these investigations created an opportunity. After conducting further tests and analysis, the method for ground treatment was changed from wick drains to dynamic compaction in certain areas within the project site. This change let to cost savings due to reclassifying these areas as non-sabkha and applying dynamic compaction, which is more economical and effective for non-sabkha areas.

Step 4 – Design Verification

Design verification was carried out jointly by the project team, project partner, inspection personnel, and Saudi Aramco consultants. The verification included: [1] Prediction and monitoring for the settlement plate for wick drains and settlement for PHC piles. [2] Capacity assessment and evaluation of installation methods. [3] Soil consolidation analysis and acceptance criteria for the wick drains. [4] Evaluation of dynamic compaction as an alternative to wick drains using updated soil investigation data. [5] Reclassification of certain areas from sabkha to non-sabkha based on the additional geotechnical data. [6] Revision of PHC pile lengths and design assumptions.

Step 5 – Trial Implementation

A pilot installation was performed for the PHC piles. Although no formal pilot was conducted for wick drains, the initial installation was sufficient to validate installation procedures and confirm drain spacing and installation capacity.

PHC Pile Pilot

The pilot program was conducted to: [1] Verify dynamic driving and hydraulic pressing installation methods. [2] Measure driving resistance. [3] Perform dynamic, static, lateral, and tension load tests. [4] Confirm pile integrity.

Step 6 – Comprehensive Testing and Monitoring

A comprehensive Testing and monitoring program was implemented: [1] For wick drain: [a] Settlement plates monitoring. [b] Piezometers to measure water pressure and groundwater levels [2] For PHC Pile: [a] Axial load testing. [b] Static, Dynamic and Lateral load testing. [c] Integrity testing. [d]. Tension testing. [3] Construction quality inspections for both technologies.

Field measurements were continuously obtained and compared with the project acceptance criteria. For wick drains, settlement plate readings were required to achieve settlements within the specified design range of 20–25 cm. For PHC piles, allowable settlement was limited to 25 mm or less, in accordance with Saudi Aramco engineering standards.

Risk Transformation

One of the most significant outcomes of this project was the successful transformation of unknown risks into known and manageable risks through investigation, testing, and continuous monitoring.

Examples include:

Initial Unknown Risk	Investigation	Result
Performance of wick drains and local soil consolidation behavior	Initial installation, piezometer monitoring, and settlement observations	Performance successfully verified
Durability of PHC piles against chloride attack	Factory testing, durability assessment, and application of epoxy protective coating	Confirmed suitable for coastal environments
Equipment and installation productivity	Initial wick drain installation and PHC pile pilot	Productivity validated
Contractor experience	Training, supervision, and specialist involvement	Required competency achieved
Local acceptance of the technologies	Engagement with Saudi Aramco Consulting Services Department	Technology approval obtained
Settlement prediction	Continuous settlement monitoring	Design assumptions successfully verified

Risk Mitigation Measures

The project adopted several mitigation measures, including: [1] Design verification by project partner specialists. [2] Involvement of experienced design consultants and technology specialists. [3] Extensive technical research and engineering investigations. [4] Initial installation of wick drains and a PHC pile pilot program. [5] Active participation of the quality assurance team. [6] Continuous settlement monitoring and performance verification. [7] Effective transfer of technology and engineering knowledge to the project team.

Project Outcome

Both technologies were successfully implemented. Major achievements included: [1] First successful implementation of Wick Drains and PHC Piles in Saudi Arabia. [2] Successful ground improvement using innovative technologies. [3] Achievement of all settlement acceptance criteria. [4] Completion of installation within project objectives. [5] Development of valuable engineering knowledge. [6] Confidence in the successful future implementation of these technologies.

Lessons Learned

This project demonstrated that introducing innovative technologies involves uncertainty, known and unknown project risks. The key lessons learned include: [1] Unknown risks should be investigated. [2] Pilot testing transforms unknown risks into known and manageable risks. [3] Early involvement of technology specialists significantly improves the probability of project success. [4] Continuous monitoring and measurement validate engineering design, assumptions and support decision-making. [5] First-time implementation of new technologies requires additional engineering knowledge, investigation, and technical verification to reduce uncertainty and improve project outcomes.

9. DISCUSSION

The successful implementation of Wick Drains and PHC Piles in Saudi Arabia demonstrates the value of systematic risk management when introducing innovative technologies. Through comprehensive investigations, specialist involvement, pilot testing, design verification, and continuous monitoring, the project team successfully reduced uncertainty and transformed previously unknown risks into known and manageable risks.

The project achieved all technical, quality, and schedule objectives while establishing a strong technical foundation for the future application of these technologies in Saudi Arabia. This case study highlights how proactive identification and management of unknown risks can improve decision-making, enhance project performance, and contribute to long-term organizational knowledge and project success.

10. CONCLUSION

The successful implementation of Wick Drains and PHC Piles in Saudi Arabia demonstrated that innovative technologies can be effectively adopted when project uncertainties are identified, investigated, and managed. Although the project initially involved significant unknown risks due to the absence of previous local experience, a structured approach involving technical investigations, specialist involvement, pilot testing, design verification, and continuous performance monitoring successfully reduced these uncertainties.

The investigation process enabled the project team to transform unknown risks into known and manageable risks before full implementation. This improved the quality of engineering decisions, increased confidence in the selected technologies.

One of the key lessons learned from this project is that the introduction of new technologies represents an opportunity that requires appropriate risk management, technical evaluation, and knowledge development. Early identification of uncertainties, combined with collaboration between project teams, consultants, suppliers, and specialists, provides a practical approach to control risks and improve project outcomes.

The experience gained from this project established valuable technical knowledge and increased confidence in the future application of Wick Drains and PHC Piles in similar challenging environments. This case study highlights the importance of proactively managing unknown risks and demonstrates that effective risk identification and mitigation can significantly contribute to successful project execution.

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