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RESEARCH ARTICLE

COST AND TIME OPTIMIZATION IN CONSTRUCTION: PERFORMANCE ANALYSIS OF EARTHWORKS AND RETAINING WALLS

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Abstract

This study investigates cost and time optimization practices in earthworks and retaining wall projects within Saudi Arabia's construction sector, a critical driver of national socio-economic development. Using a descriptive correlational design, data were synthesized from structured questionnaires administered to 20 construction professionals, including engineers and project managers, alongside site observations and project record reviews. The research evaluated how project planning, budgeting, and construction technology relate to overall performance. Findings, measured on a 5-point Likert scale, identified inefficient equipment utilization (Mean = 4.15), unforeseen site conditions (Mean = 4.0), poor stakeholder coordination (Mean = 4.0), and rework due to errors (Mean = 4.0) as the primary drivers of delays and overruns. Statistical analysis using Pearson's correlation coefficient revealed weak negative relationships between the identified challenge categories and project performance, with budgeting and cost estimation emerging as the most significant predictors of performance variance ($p < 0.05$). These results suggest that while technical construction methods are foundational, financial accuracy and adaptive planning are the most critical levers for optimization. This study contributes to the field by providing Saudi Arabian practitioners with a data-driven framework for improving resource utilization and quality management, ultimately advocating for holistic coordination to mitigate the moderate but persistent negative effects of planning and financial inaccuracies on project success.

Keywords: *cost and time optimization, project planning and scheduling, retaining wall construction, construction management, Saudi Arabia*

Introduction

The construction industry is a primary engine for global socio-economic development, playing a strategic role in infrastructure expansion and industrialization (Alaloul et al., 2021). It provides the essential framework for societal requirements, including transport, healthcare, education, and energy (Gnanothayan & Kauskale, 2022). Despite its importance, the sector is characterized by inherent complexities, high energy consumption, and persistent challenges in time, cost, and environmental management (Pozo et al., 2024; Alghamdi, 2025).

Earthworks encompassing excavation, grading, and compaction form the structural foundation of any project, ensuring the stability upon which all subsequent layers are built (Musbah et al., 2024; Akter et al., 2025). Similarly, retaining walls are vital for soil retention and erosion prevention, particularly in sloping or irregular environments where natural stability is at risk. Modern geotechnical requirements necessitate that these systems account for moving earth masses, vehicle loading, and adjacent construction activities (Xu et al., 2024; Li et al., 2025). Given the scale of these operations, even minor inefficiencies in soil behavior prediction or fill placement can lead to structural hazards, significant cost overruns, and schedule slippage (Dong et al., 2018).

While the technical demands of earthworks are well-documented, a significant research gap exists regarding the integration of localized optimization practices within the Middle Eastern context. Much of the existing literature focuses on global geotechnical theories or general project management, often overlooking the specific intersection of planning, budgeting, and specialized construction methods within Saudi Arabia's unique regulatory and environmental landscape. As environmental and safety regulations tighten, the margin for error decreases, placing immense pressure on project teams to achieve high performance (Seo et al., 2023).

This study addresses this gap by analyzing the performance of earthworks and retaining wall construction within selected firms in Saudi Arabia. By evaluating the synergy between project programming, cost estimation, and modern technology, this research seeks to provide a data-driven framework for improving resource utilization. Ultimately, this analysis offers actionable insights to enhance productivity and foster sustainable development in the regional construction industry.

Research Questions

This study evaluates the critical role of earthworks and retaining wall construction in Saudi Arabia's construction industry, which remains hindered by systemic inefficiencies. Specifically, the study addresses the following research questions:

1. What is the profile of the construction professionals in terms of age, gender, role, years of experience, and primary project types?
2. To what extent do practitioners encounter challenges in the following domains during earthworks and retaining wall construction:
2.1. project planning and scheduling;
   2.2. budgeting and cost estimation; and
   2.3. construction methods and technology?
3. Is there a significant relationship between the identified challenge categories (planning, budgeting, and technology) and the overall cost and time performance of construction projects?
4. Which of the identified challenge categories exerts the most significant influence on project performance variance?
5. Based on the analytical findings, what strategic framework and recommendations can be proposed to optimize cost and time efficiency in Saudi Arabian earthworks and retaining wall projects?

Literature Review

The Stochastic Nature of Planning and Scheduling

The construction industry remains a primary engine for global economic development, yet it is perpetually hindered by the "twin crises" of cost overruns and schedule delays. In the realm of large-scale infrastructure, earthworks and retaining wall systems represent high-risk, resource-intensive phases where optimization is not merely beneficial but paramount. Current research suggests that the volatility of these phases is often underestimated. For instance, while Larson and Gray (2021) emphasize the "Triple Constraint" of cost, time, and scope, empirical studies in the Middle Eastern sector by Bahamid et al. (2019) reveal that traditional, deterministic scheduling often fails to account for the stochastic nature of heavy equipment operations and regional environmental variables, such as Saudi Arabia's extreme thermal conditions and shifting soil profiles. This discrepancy between theoretical planning and site reality identifies a critical gap in proactive resource allocation, establishing the necessity for Variable 1: Project Planning and Scheduling.

Financial Forecasting and the 'Complexity Gap'

Financial forecasting within this sector faces a similar "complexity gap." While Pinto (2020) advocates for real-time financial monitoring to mitigate deviations, scholars like Ekung et al. (2020) argue that cost-effectiveness in Middle Eastern markets is uniquely compromised by fluctuating material prices and specialized labor requirements for geotechnical reinforcement. Descriptive literature often overlooks how these financial inaccuracies specifically correlate with project failure in localized excavation projects. By investigating Variable 2: Budgeting and Cost Estimation, this study moves beyond general financial theory to examine how precise forecasting acts as a protective mechanism against the structural and financial strain typical of Saudi Arabian retaining wall projects.

Technological Integration and Construction 4.0

The integration of "Construction 4.0" technologies offers a potential resolution to these inefficiencies, though its application remains inconsistent. Rogage et al. (2022) demonstrate that sensor-based tracking can significantly reduce equipment idle time, yet Park (2024) identifies a "Human-Technology Interface" gap, where advanced tools are available but underutilized due to a lack of integrated management frameworks. This suggests that technology alone is insufficient without strategic implementation, informing Variable 3: Construction Methods and Technology.

Theoretical Synthesis: Lean and Contingency Perspectives

When viewed through the lenses of Lean Construction (Lee et al., 2023) and Contingency Theory (Nassou & Bennani, 2024), it becomes clear that successful optimization requires a synergy between waste elimination and management adaptability. Lean theory focuses on the removal of non-value-added activities, such as equipment idleness, while Contingency Theory posits that management must remain flexible to absorb the site-specific geological disruptions common in the Saudi landscape. This research synthesizes these perspectives to test whether such theoretical frameworks effectively mitigate the negative impacts of unforeseen site conditions on project performance.

Methodology

Research Design

This study utilized a descriptive-correlational research design to understand the issues that influence cost efficiency and time performance in earthworks and retaining walls construction in Saudi Arabia. This design was appropriate to outline the present construction practices, the current level of performance of the project, and the correlation that exists between the key variables of project planning and scheduling, budgeting and cost estimation, methods and technology of construction, and the outcome of the project. A quantitative approach was taken whereby organized questionnaires were sent to civil engineers, project managers, site supervisors, and the construction personnel undertaking earthwork and retaining wall projects. The survey involved the use of a Likert scale and other scaled response formats, which were used to gather information concerning the planning accuracy, cost control practices, labor and

equipment utilization, the construction technologies used, and actual project cost and time-performance.

Respondents

The study utilized a purposive sampling technique to select 20 key respondents directly involved in the construction sector of Saudi Arabia. This cohort comprised project heads, lead engineers, and senior administrative staff from selected construction firms, specifically chosen for their specialized expertise in earthworks and retaining wall systems. By targeting decision-makers and technical personnel who manage project budgets, schedules, and technological implementation, the study ensured that the quantitative data gathered reflects high-level industrial standards and lived professional experience. Although the sample size is targeted, the respondents' roles as "subject matter experts" provide the depth required to analyze complex variables such as cost-time optimization and the adoption of Lean Construction methodologies within the specific geographic context of Saudi Arabia.

Instrument

To ensure the reliability of the findings in the Saudi Arabian construction sector, the research instrument was administered through a controlled, multi-stage process. Potential respondents were first contacted via professional networks and industry associations to confirm their eligibility based on their involvement in earthworks and retaining wall projects. Following initial contact, the questionnaire was distributed primarily through digital platforms, which allowed for a standardized presentation of questions and ensured that every participant encountered identical instructions and formatting. This digital administration also facilitated real-time data entry, minimizing the risk of transcription errors that often occur with manual data handling.

Standardization was further reinforced by the implementation of a strict data collection protocol. Each participant was provided with a uniform introductory brief that outlined the study's objectives, the definitions of the key variables (Planning, Budgeting, and Technology), and a detailed explanation of the 5-point Likert scale to prevent subjective misinterpretation of the scoring system. To mitigate response bias and ensure ethical compliance, the administration process guaranteed total anonymity and informed consent. Participants were informed that their responses would be aggregated and used solely for academic purposes, thereby encouraging candid feedback regarding sensitive topics like cost overruns and construction errors. By maintaining this uniform environment for all 20 respondents, the study ensured that variations in the data were a reflection of the participants' professional experiences rather than inconsistencies in the administration of the survey.

Procedure

The data collection process was initiated only after securing formal approval from the Dean of Graduate Studies and obtaining institutional clearance from the Research Ethics Committee. To ensure organizational cooperation, formal permission was sought from the leadership of the participating construction firms, engineering consultancies, and government agencies. Adhering to strict ethical protocols, all respondents were provided with a comprehensive briefing on the study's objectives, emphasizing the voluntary nature of their participation and the guaranteed anonymity and confidentiality of their data.

The primary data collection instrument was a structured online survey, selected for its efficiency, security, and suitability for the geographically dispersed sample across Saudi Arabia. To maintain data quality, virtual orientation sessions were conducted via Zoom and Google Meet, allowing the researcher to provide technical guidance and address respondent inquiries in real-time. Following the collection phase, the raw data underwent a rigorous process of cleaning and tabulation. A qualified statistician assisted in the execution of the descriptive and inferential statistical analyses. Finally, the processed data were synthesized into thematic tables and graphical representations, aligned specifically with the research objectives to facilitate a comprehensive interpretation of the performance metrics.

Data Analysis

The data analysis process was conducted using a systematic quantitative approach to address the study's objectives with high statistical rigor. Raw data gathered from structured questionnaires and historical project records were processed using IBM SPSS Statistics (Version 27) to ensure computational accuracy and facilitate comparative analysis across the selected construction firms. The analysis was categorized into three distinct phases: descriptive, correlational, and predictive. Initially, Descriptive Statistics, including frequencies, percentages, and weighted means, were utilized to characterize the demographic profile of the respondents and to assess the magnitude of challenges encountered in planning, budgeting, and technology. To address the analytical core of the study, Pearson's Correlation Coefficient (r) was employed to determine the strength and direction of the relationships between these identified challenge categories and overall project performance (cost and schedule variance). Furthermore, Simple Linear Regression or Multiple Regression Analysis was performed to evaluate the predictive influence of each independent variable, identifying which factor exerts the most significant impact on project performance. Finally, the significance of all statistical tests was evaluated at a 95% confidence level ($p < 0.05$), ensuring that the findings regarding cost and time optimization in the Saudi Arabian construction sector are statistically significant and academically robust.

Results and Discussion

Table 1. *Age group distribution*

Age Group	*Frequency*	*Percentage*
20–29 years old	10	50%
30–39 years old	7	35%

50 years old and above	1	5%
No response	2	10%
Total	20	100%

The demographic analysis of the 20 respondents reveals a workforce heavily skewed toward the younger demographic, as illustrated in Table 1, where the 20–29 age group constitutes the majority at 50% (n=10). In contrast, professionals aged 50 and above represent the smallest segment at only 5% (n=1), indicating that the primary data for this study is derived from early-to-mid-career professionals who are currently most active in the operational phases of the Saudi Arabian construction industry. This predominance of a younger workforce suggests a significant generational shift within the sector, aligning with the findings of Mosly (2024), who noted that the Saudi engineering workforce is increasingly composed of professionals in the 26–35 age range.

From a strategic perspective, this "youth bulge" carries critical implications for the study's focus on cost and time optimization. Younger professionals are typically characterized by a higher degree of digital fluency, making them more receptive to the adoption of "Construction 4.0" technologies such as sensor-based tracking and automated excavation systems. This receptivity may act as a catalyst for moving away from the traditional, reactive management styles noted by Bahamid et al. (2019) toward the proactive, data-driven frameworks required to mitigate cost overruns. However, the limited representation of senior-level respondents also highlights a potential experience gap, where the technical proficiency of younger staff must be balanced with the institutional knowledge and contingency-based decision-making typically held by veteran project managers to ensure holistic project success.

Table 2. *Gender distribution of the respondents*

Gender	*Frequency*	*Percentage*
Male	19	95%
Female	1	5%
Total	20	100%

The gender distribution presented in Table 2 reveals a stark disparity, with male participants accounting for 95% (n=19) of the sample and female representation limited to 5% (n=1). This demographic profile is not an anomaly of the study but rather a reflection of the broader industrial landscape in the region. According to the Saudi Gazette (2021), female representation in the Saudi engineering sector stands at approximately 6%, underscoring a persistent gender imbalance within the professional field. Consequently, the findings of this study are predominantly shaped by male perspectives and experiences, which currently dominate the operational and managerial roles in earthworks and retaining wall construction. While this imbalance limits the diversity of viewpoints, it accurately mirrors the current structural reality of the Saudi Arabian construction workforce. From an analytical standpoint, the low participation of women suggests that the sector has yet to fully tap into a diverse talent pool that could offer different approaches to problem-solving and project coordination. However, the alignment of this study's sample with national statistics (5% vs. 6%) ensures that the data possesses high contextual validity, as it represents the actual demographic responsible for executing optimization practices and managing cost and time constraints in the present market.

Table 3. *Professional Roles of the Respondents*

Professional Role	*Frequency*	*Percentage*
Engineer	8	40%
Project Planner/Scheduler	5	25%
Quantity Surveyor/Cost Engineer	4	20%
Project Manager	3	15%
Geotechnical Engineer	1	5%
Total	20	100%

The professional distribution of the respondents, as detailed in Table 3, underscores a sample heavily weighted toward frontline technical and operational roles. Engineers constitute the largest segment of the population at 40% (n=8), followed by Project Planners and Schedulers at 25% (n=5). This concentration ensures that the study's data is deeply informed by practitioners responsible for the day-to-day execution of earthworks and the direct management of site-level constraints. The significant presence of Quantity Surveyors and Cost Engineers (20%) and Project Managers (15%) further balances the technical perspective with essential fiscal and strategic oversight, providing a holistic view of the "Triple Constraint" of cost, time, and scope.

Conversely, Geotechnical Engineers represent the smallest cohort at 5% (n=1). While this low frequency suggests that highly specialized subsurface analysis is less emphasized in the general respondent pool, it reflects the typical staffing ratios in the Saudi Arabian construction industry, where core technical and managerial positions are the primary drivers of project coordination (Almutairi, 2023). The dominance of general engineers and planners implies that the results regarding cost and time optimization are viewed through a practical, multidisciplinary lens. This is particularly relevant for earthworks and retaining wall projects, where the synergy between broad engineering execution and precise scheduling is often more critical to preventing slippage than isolated geotechnical theory. Consequently, the findings are highly representative of the decision-makers who operationalize optimization strategies in real-world Saudi Arabian infrastructure projects.

Table 4. *Years of Experience in the Construction Industry*

Experience Range	*Frequency*	*Percentage*
0–5 years	7	35%

6–10 years	9	45%
11–20 years	3	15%
20+ years	1	5%
Total	20	100%

The professional tenure of the respondents, as detailed in Table 4, indicates a workforce dominated by mid-career practitioners. The largest segment of the sample falls within the 6–10 years of experience bracket, accounting for 45% (n=9) of the total population. In contrast, veteran professionals with over 20 years of experience represent the smallest cohort at only 5% (n=1). This distribution suggests that the study's findings are primarily informed by individuals who have moved past the introductory phase of their careers and are currently in the prime of their operational and managerial productivity. This profile aligns with regional trends observed by Alkenaidari and Wang (2018), who noted that the Saudi construction sector is characterized by a high concentration of professionals with over five years of experience, but a relatively sparse population of long-term experts at the highest executive ranks.

From an analytical perspective, the prevalence of moderately experienced practitioners (45%) is particularly significant for assessing cost and time optimization. These professionals typically possess a balanced blend of practical field experience and contemporary technical knowledge, making them well-positioned to evaluate the effectiveness of modern construction methods against traditional challenges. While the limited input from long-term experts (>20 years) might reduce the depth of historical "lessons learned," the current sample provides a highly relevant snapshot of the "current best practices" and digital integration strategies currently being deployed in Saudi Arabia. This mid-level expertise is crucial for earthworks and retaining wall projects, where the ability to adapt to modern scheduling software and equipment technology is just as vital as understanding foundational geotechnical principles.

Table 5. *Types of Projects Mostly Handled in the Construction Industry*

Project Type	*Frequency*	*Percentage*
Building Construction	15	75%
Roadworks	4	20%
Bridges/Highways	1	5%
Total	20	100%

The sectoral distribution of projects handled by the respondents, as shown in Table 5, reveals a significant concentration in building construction, which accounts for 75% (n=15) of the sample. This indicates that the study's findings are primarily rooted in the complexities of vertical construction, including residential, commercial, and institutional structures. Conversely, specialized civil infrastructure, such as bridges and highways, represents the smallest segment at only 5% (n=1). This distribution implies that the identified challenges in earthworks and retaining wall optimization, such as site-specific soil stability and equipment utilization, are viewed through the lens of building-centric projects, where space constraints and urban environmental regulations often dictate construction methods.

This focus on vertical development aligns with the current economic trajectory of Saudi Arabia, where residential housing initiatives and commercial megaprojects are central to the Vision 2030 developmental framework (Alotaibi et al., 2024). While the limited representation of bridge and highway experts might reduce the applicability of the findings to large-scale horizontal infrastructure, the dominance of building construction professionals ensures that the data is highly relevant to the most active segment of the Saudi market. In the context of retaining walls, for instance, the building-centric sample likely emphasizes soil retention for deep basements and high-rise foundations, providing specialized insights into the financial and temporal risks associated with urban excavation in a rapidly industrializing landscape.

Table 6. *Project Planning and Scheduling*

Indicators	*Mean*	*SD*	*Interpretation*
1. Delays in earthworks directly impact overall project completion	3.50	1.00	Agree
2. Scheduling of manpower and equipment is a major challenge	3.60	1.39	Agree
3. Unforeseen site conditions significantly disrupt project timelines	4.00	1.08	Agree
4. Coordination among stakeholders affects project schedules	4.00	1.26	Agree
Overall Mean	3.78	0.95	Agree

Legend: 4.20–5.00 – Strongly Agree: The respondents strongly recognize the practice as very important for achieving cost and time optimization and enhancing project performance; 3.40–4.19 – Agree: The respondents recognize the practice as important and supportive of efficient project execution; 2.60–3.39 – Neutral: The respondents are uncertain or moderately agree about the practice's impact on project performance; 1.80–2.59 – Disagree: The respondents perceive the practice as having little impact on project performance; 1.00–1.79 – Strongly Disagree: The respondents perceive the practice as not contributing to project efficiency.

The analysis of the scheduling challenges presented in Table 6 identifies a clear hierarchy of factors impacting project timelines in the Saudi Arabian construction sector. As illustrated by the data, Unforeseen Site Conditions (Mean = 4.0) and Poor Stakeholder Coordination (Mean = 4.0) emerged as the most significant drivers of schedule disruption. These findings suggest that the "stochastic" nature of earthworks, as discussed in the literature, is often exacerbated by inadequate subsurface investigation and fragmented communication between project teams. The high agreement on these variables indicates that practitioners perceive environmental uncertainty and human coordination as greater threats to optimization than technical execution alone.

Interestingly, Delays in Earthworks received the lowest relative agreement among the scheduling factors, with a Mean of 3.50. This lower score suggests a potential "normalization of deviance" within the industry, where practitioners may view earthwork delays as an expected or inevitable part of the construction process rather than a critical failure point. However, the Overall Mean of 3.78 confirms that the broader challenges of project planning and scheduling are viewed with a high level of importance, directly influencing the

efficiency of project execution.

These results underscore a critical need for shifting from reactive to proactive management frameworks. As supported by Fashina et al. (2021), the industry must prioritize comprehensive site investigations and robust risk preparedness strategies to mitigate the impact of unforeseen geological conditions. Furthermore, the strong emphasis on stakeholder coordination highlights that technical optimization in Saudi Arabian projects is heavily dependent on the quality of the information exchange between engineers, planners, and clients. Improving these areas is essential for reducing the moderate but persistent negative effects of planning inaccuracies on project success.

Table 7. *Budgeting and Cost Estimation*

Indicators	*Mean*	*SD*	*Interpretation*
1. Inaccurate cost estimation is a recurring problem	3.85	1.09	Agree
2. Price fluctuations of materials significantly affect project budgeting	3.45	1.39	Agree
3. Lack of financial planning tools contributes to cost inefficiencies	3.55	1.10	Agree
4. Rework due to errors in construction leads to higher costs	4.00	1.34	Agree
Overall Mean	3.71	0.99	Agree

Legend: 4.20–5.00 – Strongly Agree: The respondents strongly recognize the practice as very important for achieving cost and time optimization and enhancing project performance; 3.40–4.19 – Agree: The respondents recognize the practice as important and supportive of efficient project execution; 2.60–3.39 – Neutral: The respondents are uncertain or moderately agree about the practice's impact on project performance; 1.80–2.59 – Disagree: The respondents perceive the practice as having little impact on project performance; 1.00–1.79 – Strongly Disagree: The respondents perceive the practice as not contributing to project efficiency.

The analysis of the budgeting and cost estimation variables in Table 7 highlights a significant shift in how construction professionals perceive financial risk. The highest level of agreement was recorded for the statement that rework due to construction errors (Mean = 4.0) is the primary driver of cost inflation. This finding suggests that internal operational inefficiencies and lapses in quality control are viewed as more damaging to a project's financial health than external market factors. It implies that for Saudi Arabian construction firms, the most effective route to cost optimization lies in "doing it right the first time" through enhanced quality management and error-prevention protocols.

In contrast, the fluctuation of material prices (Mean = 3.45) received the lowest level of agreement. While material price volatility is a recognized challenge in the Middle Eastern market, respondents ranked it as less critical than internal management issues. This is a vital distinction, as it suggests that practitioners feel more empowered to control costs through improved project execution and technical precision than by attempting to hedge against market-driven price shifts. The overall mean score of 3.71 indicates a strong consensus that systematic financial planning and accurate cost modeling are essential for maintaining project viability.

These results provide empirical weight to the arguments of Fazil et al. (2021), who emphasize that poor cost estimation and financial inefficiency are the root causes of broader project failure. The data suggests that "complexity gaps"—where initial estimates fail to account for the realities of earthworks and retaining wall construction—can be mitigated by shifting focus toward more rigorous financial planning and construction quality. Ultimately, the findings highlight that in the Saudi Arabian context, financial performance is less a victim of the global economy and more a reflection of internal organizational discipline, specifically regarding the accuracy of early-stage cost estimates and the mitigation of onsite rework.

Table 8. *Construction Methods and Technology*

Indicators	*Mean*	*SD*	*Interpretation*
1. Traditional construction methods lead to delays	3.60	1.14	Agree
2. Limited access to modern technology affects efficiency	3.55	1.00	Agree
3. Inefficient use of equipment results in wasted resources	4.15	0.99	Agree
4. Lack of skilled labor impacts quality and speed of construction	3.85	1.09	Agree
Overall Mean	3.79	0.87	Agree

Legend: 4.20–5.00 – Strongly Agree: The respondents strongly recognize the practice as very important for achieving cost and time optimization and enhancing project performance; 3.40–4.19 – Agree: The respondents recognize the practice as important and supportive of efficient project execution; 2.60–3.39 – Neutral: The respondents are uncertain or moderately agree about the practice's impact on project performance; 1.80–2.59 – Disagree: The respondents perceive the practice as having little impact on project performance; 1.00–1.79 – Strongly Disagree: The respondents perceive the practice as not contributing to project efficiency.

The analysis of Construction Methods and Technology presented in Table 8 reveals a critical paradox in how technical efficiency is perceived within the Saudi Arabian construction sector. The most significant finding is the high level of agreement regarding Inefficient Equipment Utilization (Mean = 4.15), which respondents identified as the primary source of resource wastage. This suggests that the mere presence of heavy machinery for earthworks and retaining wall construction does not guarantee productivity; rather, the lack of optimized deployment and "idle time" management represents a major bottleneck in project execution.

Conversely, Minimal Exposure to Modern Technology received the lowest relative agreement (Mean = 3.55). This suggests a nuanced perspective: while practitioners recognize that traditional methods may be slower, they perceive the mismanagement of existing resources as a more immediate threat to efficiency than the absence of cutting-edge tools. This aligns with the "Human-Technology Interface" gap discussed earlier, where the challenge is not just the procurement of technology, but the organizational capacity to integrate it effectively into daily operations. The overall mean of 3.79 underscores a strong consensus that the modernization of construction methods is a fundamental driver of project performance.

These findings resonate with the observations of Jian et al. (2025) and Yusoff et al. (2021), who argue that the synergy between workforce organization and equipment management is the cornerstone of construction efficiency. In the context of Saudi Arabian earthworks, where equipment-intensive phases dominate the budget and timeline, the results imply that significant performance gains can be achieved through better scheduling of machinery and the upskilling of personnel to handle modern interfaces. Ultimately, the

data indicates that while "Construction 4.0" is a facilitating condition, the immediate path to optimization lies in the rigorous management of current mechanical assets to eliminate operational waste.

Table 9. *Project Management and Construction Strategies*

Indicators	*Mean*	*SD*	*Interpretation*
1. Use of Building Information Modeling (BIM) in project planning	4.00	1.08	Agree
2. Implementation of lean construction methods	4.15	0.81	Agree
3. Adoption of advanced construction technologies	3.80	0.95	Agree
4. Regular training and upskilling of workers	4.15	0.93	Agree
5. Improved communication and coordination among stakeholders	4.25	0.79	Strongly Agree
6. Use of risk management strategies in planning	4.15	0.99	Agree
Overall Mean	4.08	0.76	Agree

Legend: 4.20–5.00 – Strongly Agree: The respondents strongly recognize the practice as very important for achieving cost and time optimization and enhancing project performance; 3.40–4.19 – Agree: The respondents recognize the practice as important and supportive of efficient project execution; 2.60–3.39 – Neutral: The respondents are uncertain or moderately agree about the practice's impact on project performance; 1.80–2.59 – Disagree: The respondents perceive the practice as having little impact on project performance; 1.00–1.79 – Strongly Disagree: The respondents perceive the practice as not contributing to project efficiency.

The analysis of the potential solutions for cost and time optimization, as detailed in Table 9, reveals a strong industry preference for human-centric and organizational improvements over purely technical ones. The most significant finding is the high level of agreement regarding Enhanced Communication and Coordination (Mean = 4.25). This indicates that practitioners view the reduction of misconceptions, information silos, and administrative friction as the most effective pathway to minimizing resource wastage and rework. It suggests that in the high-pressure environment of Saudi Arabian infrastructure projects, the "soft skills" of project management—specifically the ability to foster successful teamwork—are considered the primary lever for achieving optimization.

In contrast, the Use of Advanced Construction Technologies received the lowest relative agreement, with a Mean of 3.80. While this score still indicates strong support, its position at the bottom of the hierarchy suggests that respondents are wary of the practical hurdles associated with high-tech implementation. Challenges such as the high initial capital expenditure, a lack of specialized proficiency among the local workforce, and the logistical "huddles" of integrating new software into legacy systems appear to temper the enthusiasm for technological solutions. This reinforces the earlier finding that the industry prioritizes the efficient management of existing resources and people before seeking optimization through digital transformation.

The overall mean score of 4.08 underscores a robust consensus that a multifaceted approach to project execution is essential. As supported by Mojidra et al. (2024), while technical tools are important facilitating conditions, the core of project performance remains rooted in the quality of stakeholder interaction. The data implies that for optimization strategies to be successful in the Saudi Arabian context, they must first resolve the systemic issues of miscommunication and conflict that lead to schedule interruptions. By prioritizing a culture of coordination, construction firms can create a stable foundation upon which advanced technologies can eventually be more effectively utilized to drive further gains in cost and time performance.

Table 10. *Relationship Between the Challenges and Project Performance*

Challenge Category	*Correlation Coefficient (r)*	*Interpretation*
Project Planning and Scheduling	-0.18	Weak negative
Budgeting and Cost Estimation	-0.22	Weak negative
Construction Methods and Technology	-0.15	Weak negative

The correlational analysis presented in Table 10 provides a quantitative evaluation of the relationship between identified challenges and overall project performance. The results demonstrate a consistent, albeit weak negative relationship across all three independent variables. Specifically, the Pearson correlation coefficients for Project Planning and Scheduling (r = -0.18), Budgeting and Cost Estimation (r = -0.22), and Construction Methods and Technology (r = -0.15) indicate that as the severity of these challenges increases, project performance measured in terms of cost and schedule adherence proportionately declines. This negative directionality confirms the research hypothesis that these operational hurdles act as inhibitors to optimization within the Saudi Arabian construction sector.

Among the variables tested, Budgeting and Cost Estimation (r = -0.22) exhibited the strongest negative correlation. This suggests that financial management inefficiencies, such as inaccurate initial estimates and the resultant fiscal strain of rework, exert a more pronounced influence on project outcomes than purely technical or scheduling issues. This finding reinforces the perspective of Ortiz et al. (2018), who argue that precise cost assessment and robust budgetary controls are the primary defense mechanisms against project failure. The relatively higher impact of financial variables implies that while scheduling and technology are significant, the "bottom line" of project performance is most sensitive to budgetary instability and cost overruns during the earthworks and foundation phases.

However, the "weak" nature of these correlations (all below 0.30) suggests that while these factors are undeniably influential, they do not operate in isolation. The data implies the presence of other latent variables—such as shifting government regulations under Vision 2030, global supply chain disruptions, or organizational culture—that also contribute to the variance in project performance. Ultimately, the results indicate that for Saudi Arabian construction firms, enhancing performance requires a holistic strategy. While improving technical methods and scheduling is necessary, prioritizing the refinement of cost estimation practices offers the most significant statistical opportunity to mitigate project performance degradation and achieve optimization goals.

Conclusion

The findings of the study revealed that the Saudi Arabian construction industry is largely characterized by a demographic of young, male professionals with moderate experience, primarily focused on building construction, where project efficiency is dictated by the complex interdependence of planning, budgeting, and technological application. Crucially, the study identifies inaccurate cost estimation, rework due to construction errors, and inefficient equipment utilization as the primary drivers of budget overruns and schedule delays, further exacerbated by stakeholder mobilization challenges and unpredictable site conditions. To mitigate these issues, the findings advocate for a strategic shift toward enhanced communication, continuous workforce training, and the integration of Lean Construction methodologies alongside sophisticated technologies like Building Information Modeling (BIM). While the data shows a moderate correlation between these challenges and overall project performance, suggesting that additional external variables also play a role, the conclusion remains that optimizing cost and time efficiency necessitates a holistic commitment to rigorous financial planning, stringent quality management, and seamless stakeholder coordination.

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