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The Impact of Change Orders on Cost and Schedule Performance of Highway and Bridge Construction Projects: Empirical Evidence from Egypt's National Road Network.

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Abstract

Change orders remain one of the most persistent sources of cost and schedule growth in highway and bridge construction, yet empirical, project-level evidence from national road agencies in the Middle East and North Africa (MENA) region remains scarce. This study quantifies the impact of change orders on the cost and duration performance of 50 major highway, bridge, and urban-axis projects implemented under Egypt's national roads and bridges program. Project-level records were compiled and analyzed using descriptive statistics, Pearson correlation, independent-samples t-tests, and simple linear regression. The results show that change orders increased contract costs by a mean of 24.48% (SD = 6.65%; weighted mean = 23.83% across a portfolio value of EGP 381.0 billion) and extended implementation duration by a mean of 17.54% (SD = 4.23%; weighted mean = 16.97%). Cost growth and schedule growth were positively and significantly correlated ($r = 0.566$, $p < .001$), and did not differ significantly between completed and ongoing projects ($p > .05$), indicating that change-order impacts are established early in project delivery and persist through completion. Scope-change and lane-widening orders were the most frequent trigger (36% of cases) and, together with service-facility additions, produced the largest average cost impact. These findings are substantially larger than change-order growth rates reported for mature-market highway programs (approximately 5-7%), pointing to weaker front-end planning and design maturity as key drivers. The study contributes an empirical benchmark for change-order risk in large-scale Egyptian infrastructure and offers actionable recommendations for contingency budgeting, front-end planning, and change-order governance for road authorities operating in similarly fast-track infrastructure programs.

Keywords: change orders; variation orders; cost overrun; schedule overrun; highway construction; infrastructure megaprojects; Egypt

1. Introduction

Highway and bridge infrastructure is a strategic driver of economic development, and since 2014 Egypt has pursued one of the most extensive national road-expansion programs in its modern history, adding thousands of kilometers of new and upgraded roads, ring roads, and river-crossing axes under the General Authority for

Roads, Bridges and Land Transport (GARBLT). As in most large public infrastructure programs, however, the gap between planned and as-built project cost and duration is substantial, and change orders — formally authorized modifications to contract scope, cost, or schedule — are widely recognized as among the most influential drivers of that gap (Anastasopoulos, Labi, Bhargava, Bordat, & Mannering, 2010; Shrestha & Maharjan, 2018).

Change orders are, to some extent, unavoidable in construction: design documents are rarely complete, site conditions are only fully revealed once excavation begins, and owners' operational needs evolve over a project's multi-year delivery horizon (Ezeldin & El Sarag, 2018; Khalifa & Mahamid, 2019). However, when change orders become frequent or large relative to the original contract, they erode budget certainty, extend the public's exposure to construction disruption, and increase the likelihood of contractual disputes and claims (Assaf & Al-Hejji, 2006; Serag, Oloufa, Malone, & Radwan, 2010). Quantifying the magnitude of this impact — and identifying which categories of change are most costly — is therefore essential for evidence-based contingency planning and change-order governance.

Most existing empirical studies of change-order impact draw on data from North American state departments of transportation (e.g., Texas, Indiana, Kentucky, Florida), and most Egyptian studies of variation orders rely on perception-based questionnaire surveys of causes rather than analysis of actual project cost and schedule records (Albasyouni & Ashraf, 2022; Balbaa, El-Nawawy, El-Dash, & Badawy, 2019). There is consequently a gap in the literature regarding the measured, project-level magnitude of change-order impact on large national highway and bridge programs in the MENA region.

This study addresses that gap using an original dataset of 50 major Egyptian highway, bridge, and urban-axis projects, each with recorded pre- and post-change-order cost, recorded pre- and post-change-order implementation duration, project status, and a narrative description of the change order(s) issued. The specific objectives of the study are to: (1) quantify the magnitude of cost and schedule growth attributable to change orders across the sampled portfolio; (2) test the statistical relationship between cost growth and schedule growth; (3) examine whether the impact of change orders differs between completed and in-progress projects; and (4) classify the underlying causes of change orders and compare their relative cost impact.

The remainder of the paper is organized as follows. Section 2 reviews the literature on the causes and impacts of change orders in highway and infrastructure construction. Section 3 describes the dataset and analytical methods. Section 4 presents the descriptive and inferential results. Section 5 discusses the findings in relation to prior literature and practical implications. Section 6 concludes with recommendations for practice and policy, and Section 7 outlines the study's limitations and directions for future research.

2. Literature Review

2.1 Definition and Nature of Change Orders

A change order is a formally authorized addition, omission, or modification to the scope, cost, or time of a construction contract, issued after contract award (Ezeldin & El Sarag, 2018). Change orders are typically classified by origin as owner-related, consultant/design-related, contractor-related, or externally driven (e.g., site conditions, regulatory changes) and by effect, distinguishing cost-neutral scope substitutions from orders that increase contract price or extend the contract period (Khalifa & Mahamid, 2019).

2.2 Causes of Change Orders

Across MENA-region studies, the most frequently cited causes of variation orders are owner-initiated scope enhancements, design errors and omissions, and poor pre-contract planning. Ezeldin and El Sarag (2018) found that client instructions for additional work, contractors exploiting ambiguous contract clauses, and continuous changes to the project schedule were the three leading causes of variation orders in the Egyptian construction industry. Similarly, Albasyouni and Ashraf (2022), surveying small and medium-sized Egyptian contracting firms, identified poor communication, design omissions, owner financial constraints, client-requested additional work, and contractors' profit-seeking behavior as the top-ranked causes. Balbaa et al. (2019) applied a risk-based ranking to variation orders in Egyptian residential projects and found that changes in economic conditions, poor

inter-party coordination, subcontractor performance, delayed owner decision-making, and contractor financial difficulty carried the highest risk weighting. Outside Egypt, Khalifa and Mahamid (2019) reported comparable findings for Saudi Arabian public projects, reinforcing that owner-driven scope changes and design deficiencies are a regional, not purely local, phenomenon. In the broader international literature, Assaf and Al-Hejji (2006) and Hanna, Camlic, Peterson, and Nordheim (2002) similarly identify design changes and incomplete pre-construction planning as leading causes of schedule and cost growth.

2.3 Impact of Change Orders on Cost Performance

Empirical, project-register-based studies from U.S. state transportation agencies provide the most robust quantitative benchmarks available. Anastasopoulos et al. (2010), analyzing 1,939 Indiana Department of Transportation (INDOT) projects, found that change-order frequency varied systematically by project type, with resurfacing and traffic-maintenance projects experiencing fewer change orders than new-construction or reconstruction projects. Shrestha and Maharjan (2018), analyzing 185 large Texas highway projects (each exceeding $10 million), reported an average change-order-driven cost growth of approximately 5–7%, with a significant positive correlation between change-order growth and both cost growth ($r = 0.57$) and schedule growth ($r = 0.44$). Serag et al. (2010) developed a regression-based model to quantify the cost impact of change orders on U.S. roadwork contracts and confirmed that the number and value of change orders are significant predictors of final project cost. Bordat, McCullouch, Labi, and Sinha (2004), analyzing INDOT contracts, similarly documented systematic cost and time overruns linked to change orders and recommended improved front-end planning as the primary mitigation strategy.

2.4 Impact of Change Orders on Schedule Performance

Change orders affect schedule performance both directly, through added or modified scope of work, and indirectly, through disruption and loss of productivity on unaffected activities (Assaf & Al-Hejji, 2006). Shrestha, Shrestha, Maharjan, and Gransberg (2022), analyzing 3,957 Texas DOT highway projects delivered between 1987 and 2015, found a measurable decline in cost growth over time — attributed to improved planning practices but no comparable improvement in schedule growth, suggesting that schedule performance is comparatively harder to control through planning alone. A separate stream of work on design-build delivery (Shrestha, Choi, & colleagues, cited in comparative highway/DB literature) similarly finds that change orders are associated with schedule growth regardless of project delivery method, though the strength of the relationship varies with contract type and project size.

2.5 Research Gap

Taken together, the literature establishes that (a) change orders are pervasive in highway and bridge construction, (b) their causes are dominated by owner-driven scope change and design deficiency, and (c) cost growth and schedule growth attributable to change orders are positively correlated. However, quantitative benchmarks are almost exclusively drawn from North American state DOT project registers, while Egyptian and broader MENA-region evidence is overwhelmingly perception-based (questionnaire surveys of causes) rather than derived from actual project cost and schedule records. This study addresses that gap by analyzing recorded, project-level cost and duration data for 50 major Egyptian highway and bridge projects, providing an empirical benchmark that can be compared directly against the North American literature.

3. Research Methodology

3.1 Data Source and Sample

The dataset comprises 50 major highway, bridge, and urban-axis projects implemented under Egypt's national road and bridge program, compiled from project performance records. The sample spans a diverse range of project types, including inter-city desert highways (e.g., Cairo–Alexandria Desert Road, Cairo–Suez Road), ring roads (Regional Ring Road, Greater Cairo Ring Road, Middle Ring Road), coastal and Red Sea corridor roads (International Coastal Road, Hurghada–Safaga Road), and urban bridge/interchange axes within Greater Cairo and Alexandria (e.g., Rod El Farag Axis, 30 June Axis, Al Mahmoudia Axis). Original contract values in the sample range from EGP 2.5 billion to EGP 40 billion, and original planned durations range from 8 to 40 months,

indicating that the sample captures both medium-scale urban axis upgrades and large-scale national corridor projects. At the time of data collection, 32 of the 50 projects (64%) were recorded as completed, and 18 (36%) were still under execution.

3.2 Variables

For each project, the dataset records: (1) contract cost before change orders and (2) contract cost after change orders, both in billion Egyptian pounds (EGP); (3) the percentage cost increase attributable to change orders; (4) project execution status (completed or ongoing); (5) planned implementation duration before change orders and (6) revised implementation duration after change orders, both in months; and (7) a narrative description of the change order(s) issued for that project (e.g., lane widening, additional flood culverts, route modification). Two derived variables were computed for analysis: the percentage schedule extension, calculated as (duration after − duration before) / duration before × 100, and a six-category classification of change-order cause, derived through content analysis of the narrative change descriptions (described in Section 3.4).

3.3 Analytical Techniques

Data were analyzed using Python (pandas, SciPy). Descriptive statistics (mean, standard deviation, median, minimum, maximum) were computed for cost overrun percentage and schedule extension percentage, both on an unweighted (per-project) and portfolio-value-weighted basis. Pearson's product-moment correlation coefficient was used to test the association between cost overrun percentage and schedule extension percentage. Independent-samples t-tests (Welch's correction for unequal variances) were used to compare mean cost overrun and mean schedule extension between completed and ongoing projects. A simple ordinary least squares (OLS) linear regression was estimated with schedule extension percentage as the dependent variable and cost overrun percentage as the predictor. Statistical significance was evaluated at $\alpha = 0.05$.

3.4 Classification of Change Order Causes

Each project's narrative change-order description was independently coded into one of six mutually exclusive categories based on its dominant technical content: (1) Scope change/widening (e.g., additional lanes, capacity expansion); (2) Drainage / structural addition (e.g., flood culverts, additional bridge structures); (3) Service facility addition (e.g., service stations, emergency facilities); (4) Safety & lighting upgrade (e.g., security checkpoints, modern lighting, barriers); (5) Design/route modification (e.g., realignment due to terrain constraints); and (6) Other/infrastructure (general infrastructure or drainage-network improvements not captured by the preceding categories). This classification enabled comparison of the average cost and schedule impact associated with different types of change-order triggers (Section 4.6).

3.5 Limitations of the Data

The dataset reflects aggregated, project-level before/after values rather than itemized change-order logs; it does not record the number of discrete change orders per project, their individual approval dates, or the identity of the initiating party (owner, consultant, or contractor). The analysis is therefore correlational rather than causal, and findings should be interpreted as describing the association between change-order-driven cost and schedule growth, not as isolating the causal mechanism. These limitations are revisited in Section 7.

4. Results

4.1 Portfolio-Level Overview

Across the 50 sampled projects, total contract cost before change orders was EGP 381.0 billion; after change orders, total cost rose to EGP 471.8 billion a portfolio-weighted increase of EGP 90.8 billion, or 23.83%. Total planned implementation duration across the portfolio was 878 months, rising to 1,027 months after change orders, a portfolio-weighted increase of 16.97%. These weighted figures are close to, but slightly below, the unweighted per-project means reported in Sections 4.2 and 4.3, indicating that larger projects experienced marginally smaller percentage impacts than smaller ones.

4.2 Cost Overrun Attributable to Change Orders

The mean cost overrun across the 50 projects was 24.48% (SD = 6.65%; median = 22.54%), with a minimum of 14.58% (Hurghada–Safaga Road Development) and a maximum of 50.0% (Al Mahmoudia Axis, Alexandria). The interquartile range spanned 20.00% to 26.50%, indicating that the majority of projects experienced cost growth clustered around one-fifth to one-quarter of the original contract value, with a smaller number of high-impact outliers. Figure 1 presents the distribution of cost overrun percentages across the sample.

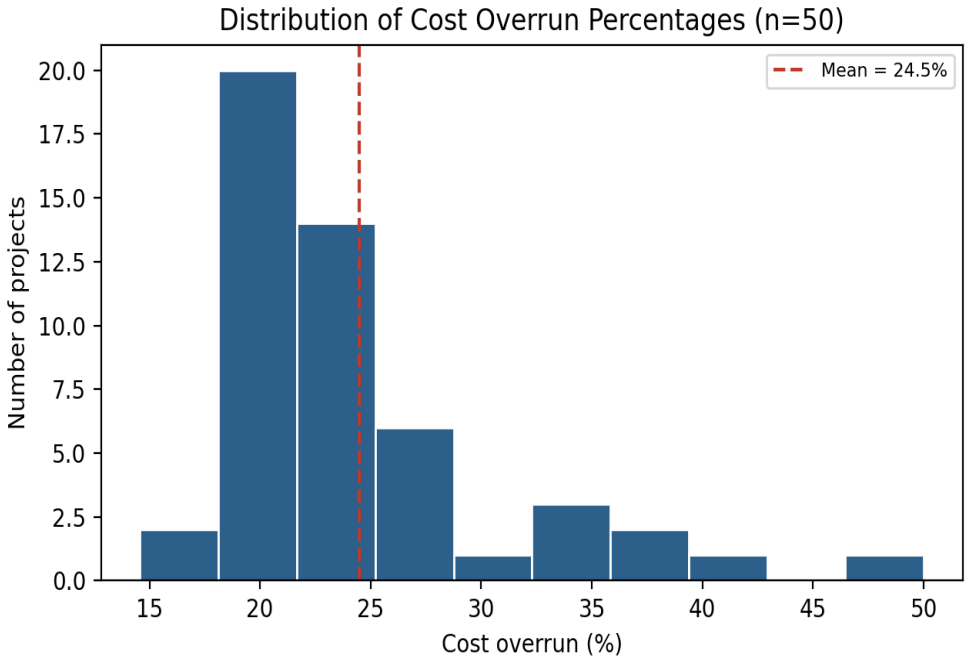

Figure 1. Distribution of cost overrun percentages across the 50 sampled projects (n = 50).

4.3 Schedule Extension Attributable to Change Orders

The mean schedule extension was 17.54% (SD = 4.23%; median = 16.67%), ranging from 11.11% to 28.57% of the originally planned duration. Relative to cost overrun, schedule extension showed a narrower distribution (coefficient of variation of 24.1% versus 27.2% for cost), suggesting that while the magnitude of cost impact varies more widely across change-order types, schedule impact is comparatively more consistent across the portfolio.

4.4 Relationship Between Cost and Schedule Impact

A Pearson correlation analysis found a statistically significant, moderate-to-strong positive association between cost overrun percentage and schedule extension percentage ($r = 0.566$, $p < .001$, $n = 50$), indicating that projects experiencing larger cost growth from change orders also tend to experience proportionally larger schedule extension. A simple linear regression of schedule extension percentage on cost overrun percentage was also significant, $F(1, 48)$, $p < .001$, with cost overrun percentage explaining approximately 32% of the variance in schedule extension ($R^2 = 0.320$; slope = 0.360; intercept = 8.73). This indicates that, on average, each additional 10 percentage points of cost overrun is associated with approximately 3.6 additional percentage points of schedule extension. Figure 2 illustrates this relationship.

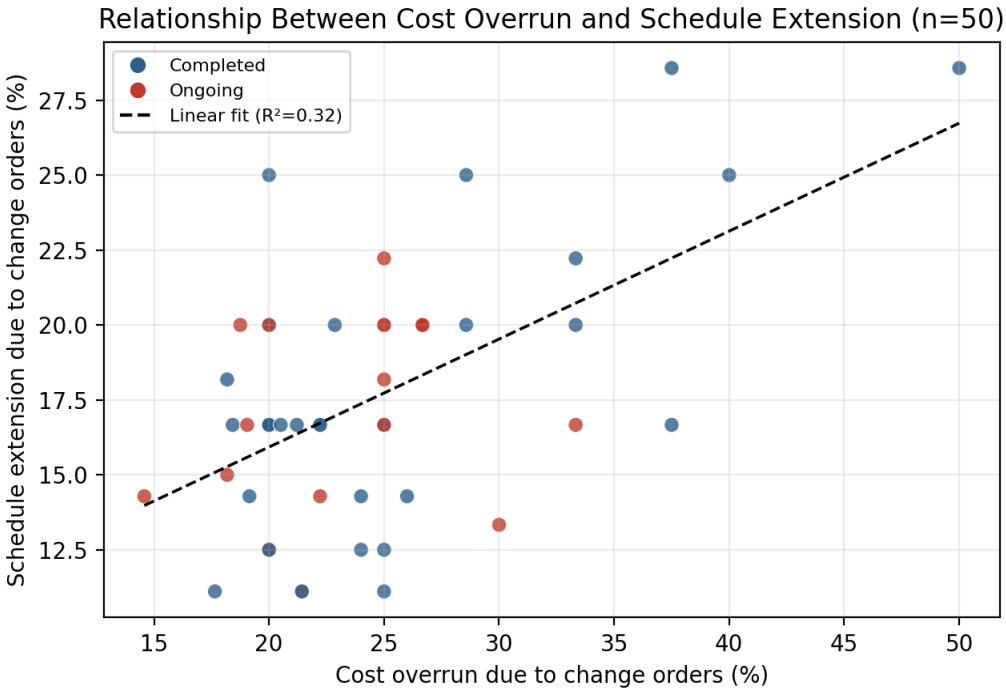

Figure 2. Relationship between change-order-driven cost overrun and schedule extension, by project status (n = 50). The dashed line shows the OLS regression fit ($R^2 = 0.32$).

4.5 Comparison Between Completed and Ongoing Projects

Completed projects (n = 32) showed a mean cost overrun of 25.05% (SD = 7.57%) and a mean schedule extension of 17.69% (SD = 4.74%), compared with 23.48% (SD = 4.61%) and 17.27% (SD = 3.23%), respectively, for ongoing projects (n = 18). Welch's t-tests found no statistically significant difference between the two groups for either cost overrun, t = 0.92, p = .365, or schedule extension, t = 0.37, p = .712. Table 1 summarizes these comparisons.

Metric	Completed (n=32) Mean (SD)	Ongoing (n=18) Mean (SD)	t	p
Cost overrun (%)	25.05 (7.57)	23.48 (4.61)	0.92	.365
Schedule extension (%)	17.69 (4.74)	17.27 (3.23)	0.37	.712

Table 1. Comparison of cost overrun and schedule extension between completed and ongoing projects (Welch's t-test, $\alpha = 0.05$).

The absence of a significant difference between completed and ongoing projects suggests that change-order impacts are largely established at the point the change order is approved, rather than accumulating disproportionately over the remaining life of the contract; i.e., ongoing projects are not systematically trending toward larger eventual overruns than those already recorded for completed projects of comparable type.

4.6 Change-Order Causes and Their Relative Cost Impact

Content analysis of the 50 change-order descriptions identified scope change/lane widening as the single most frequent trigger, accounting for 18 of 50 projects (36%), followed by drainage/structural additions (9 projects, 18%), service-facility additions (8 projects, 16%), other/general infrastructure improvements (8 projects, 16%), safety and lighting upgrades (4 projects, 8%), and design/route modification (3 projects, 6%). Table 2 reports the mean cost and schedule impact associated with each category.

Change-Order Category	n	% of Sample	Mean Cost Overrun (%)	Mean Schedule Extension (%)
Scope change/widening	18	36.0	25.90	17.73
Drainage / structural addition	9	18.0	22.12	13.81
Service facility addition	8	16.0	26.78	19.07
Other / infrastructure	8	16.0	22.48	18.24
Safety & lighting upgrade	4	8.0	22.04	20.34
Design/route modification	3	6.0	25.50	17.96

Table 2. Frequency and mean impact of change-order categories (n = 50).

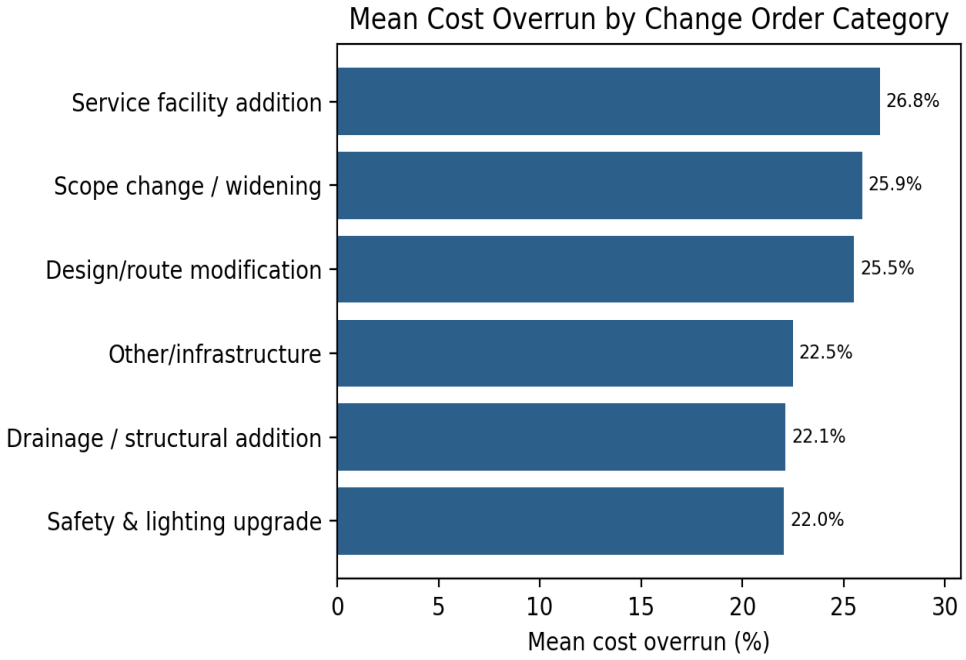

Figure 3. Mean cost overrun by change-order category, ranked from lowest to highest mean impact.

Service-facility additions (e.g., new service stations, emergency-response facilities) and scope-change/widening orders produced the highest average cost impact (26.78% and 25.90%, respectively), while drainage and structural additions and safety/lighting upgrades produced comparatively smaller average cost impacts (22.12% and 22.04%) but, in the case of safety/lighting upgrades, the largest average schedule impact (20.34%).

4.7 Notable Cases

The largest percentage cost impact in the sample was recorded for the Al Mahmoudia Axis in Alexandria (EGP 4.0 billion to EGP 6.0 billion, +50%), attributed to lane widening and beautification works. In absolute terms, the largest cost growth was recorded on the Regional Ring Road and the Greater Cairo Ring Road Development, each increasing by EGP 8.0 billion, reflecting the scale of these flagship capacity-expansion projects. The Safaga–Qena Road, whose change order involved route realignment due to mountainous terrain, illustrates a design/route-modification case where the change was driven by geotechnical rather than demand-related factors, a distinction discussed further in Section 5.

5. Discussion

The mean change-order-driven cost overrun observed in this study (24.48%, portfolio-weighted 23.83%) is substantially higher than the 5–7% average change-order growth reported for large Texas highway projects by Shrestha and Maharjan (2018) and the broader Texas DOT portfolio analyzed by Shrestha et al. (2022). This gap is consistent with the causal patterns identified in Egyptian and MENA-region survey literature, which consistently points to owner-driven scope enhancement, design omissions, and weak front-end planning as dominant drivers of variation orders (Ezeldin & El Sarag, 2018; Albasyouni & Ashraf, 2022; Khalifa & Mahamid, 2019). In the present dataset, scope-change/widening orders — essentially discretionary capacity enhancements rather than corrections of design deficiencies — were both the most frequent (36% of cases) and among the most costly categories, suggesting that a considerable share of Egypt's change-order burden reflects evolving strategic or demand-driven decisions made after contract award rather than unforeseen site conditions alone. This pattern is consistent with Bordat et al.'s (2004) conclusion that improved front-end planning, including firmer demand forecasting and capacity decisions before contract award, is the most effective lever for reducing change-order exposure.

The moderate-to-strong positive correlation between cost overrun and schedule extension ($r = 0.566$) closely replicates the correlation coefficient reported by Shrestha and Maharjan (2018) for Texas highway projects ($r = 0.57$), despite the substantial difference in absolute overrun magnitude between the two contexts. This convergence suggests that, while the scale of change-order impact differs across institutional and planning environments, the underlying mechanism linking cost and schedule growth added scope requiring both additional expenditure and additional construction time is a structural feature of highway change-order dynamics rather than a context-specific artifact.

The absence of a statistically significant difference in cost or schedule impact between completed and ongoing projects has a practical implication for portfolio-level risk management: it suggests that the impact of a change order is realized largely at the point of authorization, rather than escalating disproportionately over the remaining project life. For GARBLT and similar road agencies, this implies that early, rigorous scrutiny of proposed change orders before authorization is likely to be more effective at containing overall portfolio risk than attempting to renegotiate or claw back cost growth once construction has proceeded further.

The relatively high cost impact of service-facility additions and the relatively high schedule impact of safety/lighting upgrades both point to a common driver: these categories often require coordination with utilities, third-party service providers, or additional regulatory approval (e.g., fuel station licensing, electrical connections), which can disproportionately extend schedule relative to the direct construction cost involved. This is broadly consistent with Assaf and Al-Hejji's (2006) finding that coordination-related and approval-related delays are among the leading causes of schedule overrun in large construction projects, independent of the direct cost of the underlying scope change.

From a practice standpoint, three implications follow. First, given a mean cost impact approaching one-quarter of original contract value, road agencies operating in comparable fast-track infrastructure programs should consider contingency reserves in the order of 20–25% for major highway and bridge contracts, rather than the lower contingency allowances (typically 5–10%) common in more mature planning environments. Second, because scope-change/widening orders are both the most frequent and among the costliest categories, strengthening demand forecasting and lane-capacity decisions during the design phase — before contract award offers the greatest potential to reduce future change-order exposure. Third, because cost and schedule growth are correlated but not perfectly so ($R^2 = 0.32$), cost-focused contingency planning alone is insufficient; schedule contingency and construction-phase resource planning should be managed as a related but distinct risk, particularly for service-facility and safety-related change categories.

6. Conclusion and Recommendations

This study analyzed change-order-driven cost and schedule performance across 50 major Egyptian highway, bridge, and urban-axis projects. Change orders were found to increase contract cost by a mean of 24.48% and extend implementation duration by a mean of 17.54%, with cost and schedule growth positively and

significantly correlated (r = 0.566). These impacts did not differ significantly between completed and ongoing projects, and scope-change/widening orders emerged as both the most frequent and among the costliest category of change. The magnitude of impact observed substantially exceeds benchmarks reported for mature-market highway programs, underscoring the importance of strengthened front-end planning and change-order governance in fast-track national infrastructure programs.

Based on these findings, the study offers the following recommendations for road authorities and infrastructure agencies operating in comparable contexts:

- Adopt contingency reserves of approximately 20–25% of original contract value for major highway and bridge contracts, calibrated to the empirical distribution of cost overrun observed in comparable prior projects.
- Strengthen front-end planning and traffic-demand forecasting prior to contract award, to reduce the incidence of discretionary scope-expansion change orders after construction has begun.
- Establish a centralized, itemized change-order registry (recording issuing party, root cause, approval date, and individual cost/time impact) to enable more granular root-cause analysis than aggregate before/after project records permit.
- Apply early, structured technical and financial review to proposed change orders prior to authorization, given evidence that impact is largely fixed at the point of approval rather than escalating further during construction.
- Manage schedule contingency as a distinct risk category from cost contingency, particularly for change orders involving third-party coordination such as service facilities and safety infrastructure.

7. Limitations and Future Research

This study has several limitations that should be considered when interpreting its findings. First, the dataset reports aggregated before/after cost and duration values rather than itemized, date-stamped change-order logs; it was therefore not possible to control for the number of discrete change orders per project, their individual initiating party, or the time elapsed between contract award and change-order issuance variables shown to matter in the North American literature (Anastasopoulos et al., 2010; Shrestha et al., 2022). Second, the analysis is correlational; while cost and schedule growth are shown to be significantly associated, causal direction and confounding project-level factors (e.g., contract type, procurement method, geographic region, contractor capacity) could not be modeled with the available variables. Third, the sample, while substantial (n = 50) and drawn from a major national infrastructure program, is limited to a single country and a single road authority, which may constrain generalizability to other institutional or regulatory contexts. Future research should pursue itemized change-order registries to enable multivariate regression controlling for project size, contract type, procurement method, and region; incorporate qualitative interviews with project owners, consultants, and contractors to validate the cause-category classification used here; and extend the comparative analysis to other MENA-region road authorities to test whether the elevated cost-overrun magnitudes observed in this study reflect a broader regional pattern or characteristics specific to the Egyptian program.

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