# TRANSPORTATION AND LOGISTICS MANAGEMENT CAPABILITIES AND PROJECT PERFORMANCE IN GCC CONSTRUCTION: AN SEM STUDY


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## ABSTRACT

Gulf Cooperation Council (GCC) construction projects rely on import-heavy, multi-tier flows from port to site, where transportation and logistics management (TLM) often determines delivery reliability. This study asks: which TLM capabilities most enhance operational efficiency, integration, and overall supply chain performance and how do these capabilities translate to project outcomes? Constructs are defined via literature synthesis and expert panels, covering logistics planning and appointment scheduling, real-time visibility/track-and-trace, port/customs coordination, consolidation and staging, and last-mile/site logistics. A multi-country survey of owners, contractors, and logistics providers across KSA, UAE, Qatar, Oman, Bahrain, and Kuwait will measure these constructs. Confirmatory factor analysis establishes reliability and validity; structural equation modeling estimates direct, indirect, and mediating effects via delivery reliability and coordination quality on schedule adherence and logistics cost, with model fit assessed by SRMR and multigroup tests by country and delivery method. Expected findings are that visibility and appointment-based scheduling, combined with port-to-site coordination and consolidation/staging, reduce material-flow variability and idle time, and improve on-time delivery and



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cost performance. The study delivers a prioritised capability roadmap and practical TLM strategies for GCC construction.

**Keywords:** transportation and logistics management, GCC construction, structural equation modeling, on-time delivery

# 1 INTRODUCTION

Gulf Cooperation Council (GCC) constructions are generally dependent on extensive supply chains for the importation of the majority of structural and finishing materials . Partly due to this, the projects are vulnerable to global disruptions, which cause rapid fluctuation in lead times and a general increase in transportation costs, while the on-site teams expect stable, just-in-time flows [1]. However, the GCC governments, as part of their logistics and industrial strategies, are simultaneously throwing massive amounts of money into the development of ports, free zones, and multimodal corridors. Through these initiatives, the network capacity has been expanded; however, existing studies continue to highlight persistent challenges such as fragmented planning and weak coordination, which hinder effective integration among project stakeholders across the port-to-site supply chain [2], [3]. Thus, the transfer of goods and logistics from the port to the site is one of the critical and undeveloped factors impacting project performance. Construction supply chain studies show that reliability of material flow, visibility of information, and co-operative planning are mostly responsible for time and cost outcomes; however, the operational mechanisms are seldom measured at the project level [4]. Despite the application of SEM in examining the relationship between logistics implementation and project performance through coordination efficiency, the literature lacks explicit identification of discrete TLM capabilities and empirical investigation within the GCC context [5].

This paper bridges the gap in research by analysing how separate bundles of TLM capabilities, logistics planning and appointment scheduling (LPAS), real-time visibility (VIS), port/customs coordination (PCC), consolidation and staging (CONS), and last mile/site logistics (LMSL), impact the project performance. The performance lens looks at two widely accepted outcomes: schedule adherence (SA) and logistics cost performance (LCP). Building on previous work, this study presents two mediating constructs that embody the operational mechanisms through which capabilities are converted into outcomes: delivery reliability (DR), which is defined as the regularity of arrival times and lead time variability, and coordination quality (CQ), which is defined using clarity of roles, information sharing, and timely issue resolution among actors.

Using an empirical approach, the paper draws upon survey data collected from 183 owners, contractors, and logistics service providers involved in GCC construction projects. A questionnaire is used to distinguish the five capability domains, the two mediators, and the two performance outcomes by the implementation of multi-item Likert-type measures which have been refined through expert feedback and a pilot study. The data are processed via SEM to estimate the direct and indirect effects, and assess the relative importance of capability domains. The results demonstrate that delivery reliability is the strongest factor for both schedule and logistics cost outcomes, whereas last mile/site logistics and consolidation rank as the most significant upstream capabilities.

This research makes two main contributions. To start with, it is one of the earliest multi-country, project-level quantitative assessments of port-to-site TLM capabilities in GCC construction, moving from a simple "logistics challenges" approach to a more elaborated, capability-based model. Furthermore, it offers a prioritised roadmap for practitioners that marks out the best capabilities for improving reliability, coordination, and downstream cost and schedule performance. The remainder of the paper is structured as follows: the next section reviews the relevant literature and develops the conceptual model, followed by a description of the research methodology, presentation of the empirical results, and a discussion of the theoretical and practical implications for the GCC construction sector.

## 2 LITERATURE REVIEW

Construction supply chains typically have a fragmented structure, are composed of project-specific organisations, and possess a temporary site-specific production system which brings to the fore the coordination and logistics integration as the key determinants of project performance [4]. TLM , due to its limiting buffers, portable resources, and variations in environments, is the most essential element for ensuring materiel deliveries to the places and times they are required. An examination of construction logistics has pointed out that ineffective planning, low transparency, and weak cooperation among organisations are the major reasons for unreliability and productivity decrease, especially in GCC import-dependent situations [1], [2], [6], [7]. Recent studies have begun to examine TLM practices and capabilities in greater depth, moving beyond general discussions of logistics challenges to more systematic and capability-based analyses.

LPAS is widely recognised as a critical mechanism for aligning upstream supply flows with site capacity constraints. Studies on delivery time windows and slot-booking systems indicate that structured appointment scheduling reduces arrival variability, mitigates yard congestion, and aligns deliveries with work-package [8]. By levelling the traffic that is coming into the site and linking the slots-to-site capacity, LPAS can cut down on labour idling and equipment downtime, which are inefficiencies that have been highlighted in the GCC construction supply chains time and again [2]. However, appointment systems without real-time visibility and effective last-mile control are limited in responding to disruptions. VIS complements these systems by reducing uncertainty through track-and-trace, predictive ETAs, and exception alerts. In import-dependent regions such as the GCC, visibility gaps are linked to delivery delays, missed milestones, and higher expediting costs [1]. Accordingly, VIS serves as both an information-sharing and risk-mitigation capability. In import-dependent contexts, PCC is equally critical, as advance documentation, digital pre-clearance, and coordinated terminal operations reduce dwell time, demurrage, and yard congestion, thereby lowering logistics costs and minimising schedule delays [9]. Work conducted in the GCC indicates that customs clearance and port handling variability persist as a recurrent constraint, especially when incoming large shipment volumes have to be scheduled through tight delivery windows for significant projects [2]. Effective PCC enhances predictability and stability across port-to-site flows. CONS at off-site hubs reduce upstream variability by enabling kitting, sequencing, and load transfer operations, thereby minimising partial loads and site congestion while supporting just-in-time delivery [10].

Effective consolidation improves labour productivity and reduces re-handling by ensuring materials are delivered in the correct sequence and quantity. However, it increases coordination demands among project actors if roles and information flows are not clearly defined. As sites become more congested, LMSL capabilities such as controlled access routing, phased deliveries, and coordinated unloading are critical for enhancing safety and delivery reliability [11], [12], [13]. The performance constructs examined in this study are grounded in established supply chain and operations theory. CQ, defined in terms of role clarity, information sharing, joint planning, and timely issue resolution, has been associated with improved operational alignment and enhanced project performance in both construction and broader supply chain contexts [14], [15]. DR is a primary SCOR metric and a crucial component of logistics performance indices; empirical research has discovered that reliability, rather than speed, is the driving factor for cost, schedule, and productivity outcomes in logistics-intensive sectors [16]. SA and LCP are the most common key performance indicators in construction and project management, with previous studies confirming their sensitivity to variability, flow disruptions, and logistics constraints [17], [18].

Despite the expanding body of research on construction logistics, critical gaps persist. Most studies focus on individual practices or isolated interventions rather than adopting an integrated model encompassing multiple TLM capability domains. Furthermore, limited research explicitly examines port-to-site logistics within the GCC context, despite the region's high import dependency and large-scale infrastructure development, which make logistics performance particularly critical [1], [2]. Also, mechanisms (LPAS, VIS, PCC, CONS, and LMSL) that affect performance outcomes such as delivery reliability and coordination quality are seldom examined within a holistic cause-and-effect framework. This study synthesises extant literature into an integrated framework comprising five core TLM capabilities (LPAS, VIS, PCC, CONS, and LMSL), two mediating constructs (DR and CQ), and two performance outcomes (SA and LCP).

The theoretical basis of the categorisation is represented in Table 1 and serves as a diagnostic tool for the SEM modelling. This, in turn, allows the study to quantify how the identified TLM capabilities, through delivery reliability and coordination quality, shape schedule adherence and logistics cost performance across GCC construction projects.

**Table 1: Summary of constructs, indicators, and observable items**

| Construct | Indicator | Observable item (measured statement) | Relevant Literature |
|---|---|---|---|
| **LPAS** | LPAS1 | Inbound deliveries are assigned appointment windows and site slots. | |
| | LPAS2 | Arrivals are level-loaded across days/shifts. | |
| | LPAS3 | Appointments are synchronised with work packages/crews. | |
| | LPAS4 | Early/late/missed arrivals trigger standard re-scheduling rules. | |
| | LPAS5 | Appointment adherence is monitored and acted upon. | |
| **VIS** | VIS1 | Shipments are tracked in real time from port/yard to site. | |
| | VIS2 | Predictive ETAs are available and accurate. | |
| | VIS3 | Exception alerts (delays/deviations) are timely and reliable. | |
| | VIS4 | Milestones/geofence events are captured consistently. | |
| **PCC** | PCC1 | Pre-clearance/advance filing reduces holds. | |
| | PCC2 | Terminal coordination minimises dwell/demurrage. | |
| **CONS** | CONS1 | Materials are consolidated at off-site yards before delivery. | [1], [2], [7], [16], [18], [19], [20], [21], [22], [23] |
| | CONS2 | Kitting/packaging aligns with installation sequences. | |
| | CONS3 | Partial loads are minimised through consolidation planning. | |
| **LMSL** | LMSL1 | Site access/traffic plans are defined and enforced. | |
| | LMSL2 | Cranes/hoists/offloading resources are pre-booked to time slots. | |
| | LMSL3 | Last-mile routing accounts for restrictions/work zones. | |
| **CQ** | CQ1 | Roles/responsibilities for logistics are clear across parties. | |
| | CQ2 | Issues are escalated and resolved quickly. | |
| | CQ3 | Plans/changes are communicated in a timely, transparent way. | |
| **DR** | DR1 | Deliveries arrive within the agreed appointment window. | |
| | DR2 | Lead times from yard/port to site show low variability. | |
| **SA** | SA1 | Logistic related delays to milestones are rare. | |
| | SA2 | Activities start on time when logistics is a dependency. | |
| | SA3 | Workface planning proceeds without waiting for materials. | |
| **LCP** | LCP1 | Actual logistics spend is within budget. | |
| | LCP2 | Demurrage/detention costs are minimal. | |

# 3 METHODOLOGY

The methodology of this study was systematically structured to examine how TLM capabilities influence coordination quality, delivery reliability, and project performance outcomes within GCC construction supply chains. As illustrated in the Methodology Framework (Figure 1), the research followed a sequential process. The study began with a focused review of the literature to define the nine latent constructs, develop their measurement indicators, and establish the hypothesised relationships. The questionnaire was subsequently refined through pilot testing and expert validation to enhance clarity and contextual appropriateness. The final survey was then distributed to relevant stakeholders across GCC countries. After data screening and preparation, the dataset was analysed using partial least squares structural equation modelling (PLS-SEM) to evaluate the measurement properties and test the proposed structural relationships, including direct and mediated effects.

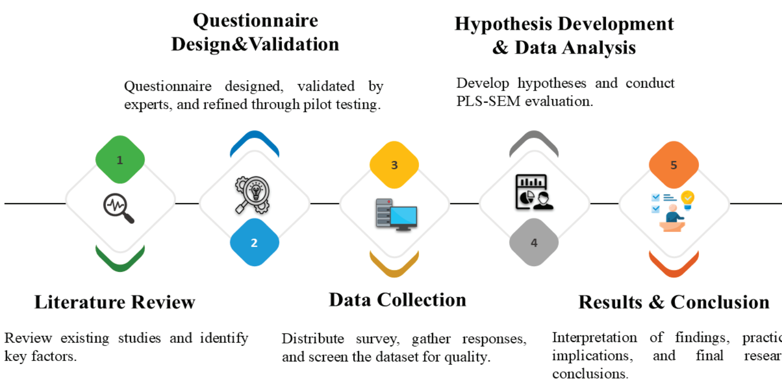


**Figure 1: Methodology framework**

## 3. 1 Questionnaire development and validation

The questionnaire was developed by converting the constructs identified in the literature into measurable indicators appropriate for the GCC construction logistics context. The survey consisted of two sections: a respondent-profile section and a construct-measurement section. All items were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Prior to large-scale distribution, the survey was refined through a pilot study and subsequently reviewed by 15 industry experts to enhance clarity, ensure contextual relevance, and revise or remove items that were ambiguous or conceptually overlapping. This process strengthened the content validity of the measurement framework.

### 3.2 Data collection

The final survey was distributed to construction and logistics stakeholders across GCC countries, including owners, contractors, and logistics providers. Following data screening for completeness and response quality, incomplete and low-quality submissions were excluded, resulting in 183 valid questionnaires retained for analysis. The proposed model comprises nine latent constructs, and the final sample size satisfies established minimum requirements for PLS-SEM. According to the widely cited 10-times rule, the minimum sample should be at least ten times the largest number of structural paths directed at any single construct in the model [23]. The available data set meets this requirement. In addition, analytical minimum-sample estimation approaches for PLS-SEM confirm that samples above these lower-bound thresholds are adequate for stable and reliable model estimation [24].

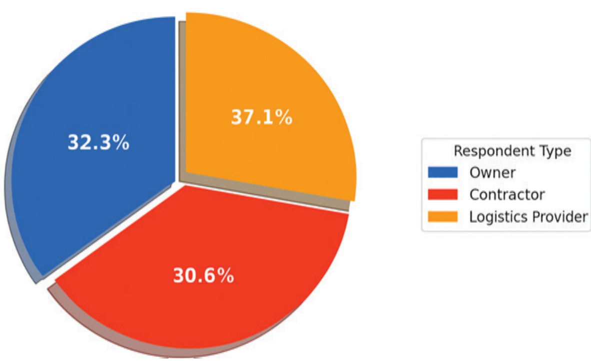


**Figure 2: Distribution of respondents by organisation type**

### 3.3 Hypothesis development and data analysis

The study hypotheses were formulated based on the literature review and the underlying theoretical framework, specifying empirically testable relationships among transportation and logistics management TLM capabilities, coordination quality, delivery reliability, and project performance outcomes. These relationships are illustrated in the conceptual framework shown in Figure 3. The model was estimated using (PLS-SEM), an appropriate technique for analysing multi-construct latent-variable models with an emphasis on variance explanation. A two-stage evaluation procedure was applied. First, the measurement model was assessed for reliability and validity using standardised loadings, Cronbach's alpha, composite reliability, average variance extracted (AVE), and discriminant validity criteria. Second, the structural model was examined using bootstrapped significance testing (5,000 resamples) and explained variance ($R^2$) for the outcome variables[25].

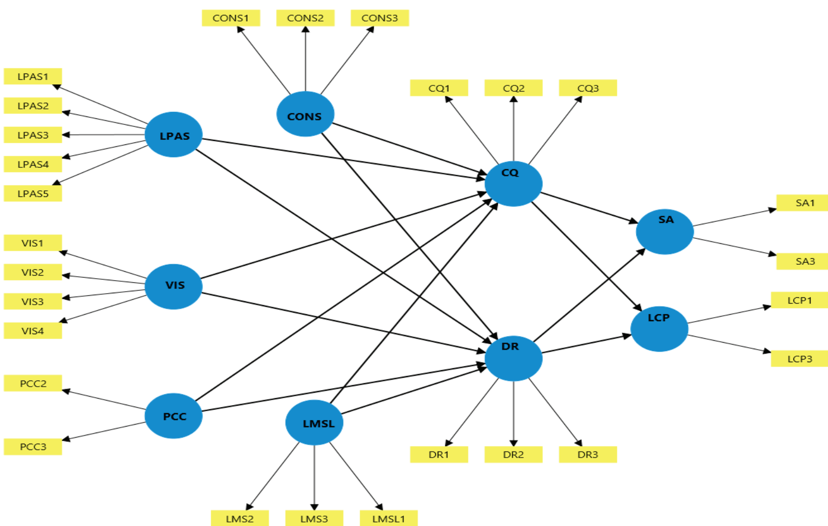


**Figure 3: Hypothesis development using SEM**

# 4 RESULTS

In this part, we present the results of the SEM analysis carried out to investigate the impact of TLM capabilities on coordination quality, delivery reliability, and project performance outcomes in GCC construction projects. The key results are grouped based on the SEM output available, which include the structural model, direct and indirect effects, indicator reliability, internal consistency, convergent validity, and model fit indices.

## 4.1 Indicator reliability

In the SEM presented in Figure 4, all indicators belonging to the constructs (LPAS, VIS, PCC, CONS, LMSL, CQ, DR, SA, and LCP) achieved standardised loading values above the critical threshold of 0.70, thereby confirming their reliability. The VIS indicators had values from 0.817 to 0.843, the LMSL indicators between 0.823 and 0.857, the DR indicators between 0.753 and 0.839, and the CQ indicators ranged from 0.857 to 0.931. This signifies that the observed variables are not only sufficient but also reliable in representing the latent constructs in the model.

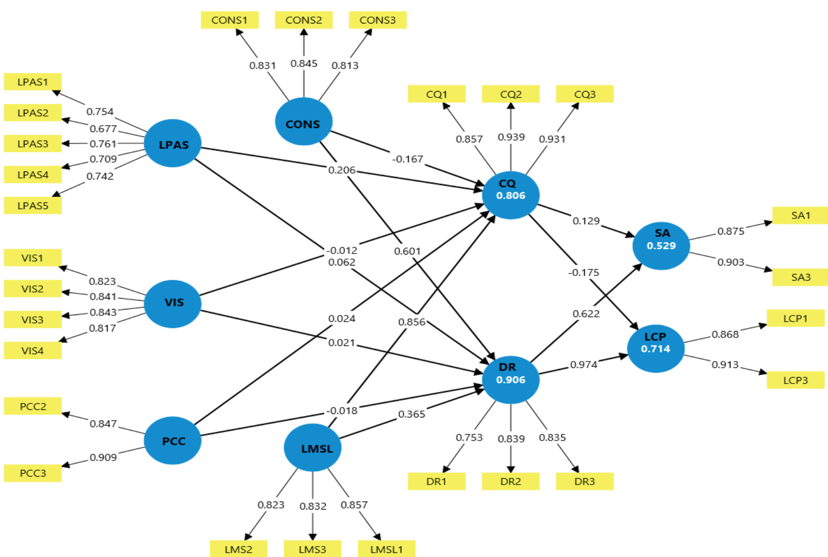


**Figure 4: Validated framework using SEM**

## 4.2 Internal consistency and convergent validity

The internal consistency of the constructs was assessed using Cronbach's alpha and Composite Reliability (CR), while convergent validity was evaluated through the Average Variance Extracted (AVE). All reported values meet or exceed the recommended thresholds ($\alpha \geq 0.70$, CR $\geq 0.70$, AVE $\geq 0.50$), indicating satisfactory measurement properties.

Notably, Coordination Quality (CQ) achieved $\alpha = 0.895$ and AVE = 0.827, Logistics Cost Performance (LCP) reported AVE = 0.793, and Delivery Reliability (DR) recorded AVE = 0.656, demonstrating strong internal consistency and adequate convergent validity across the constructs. Figure 5 summarises these results and supports the reliability and validity of the measurement model.

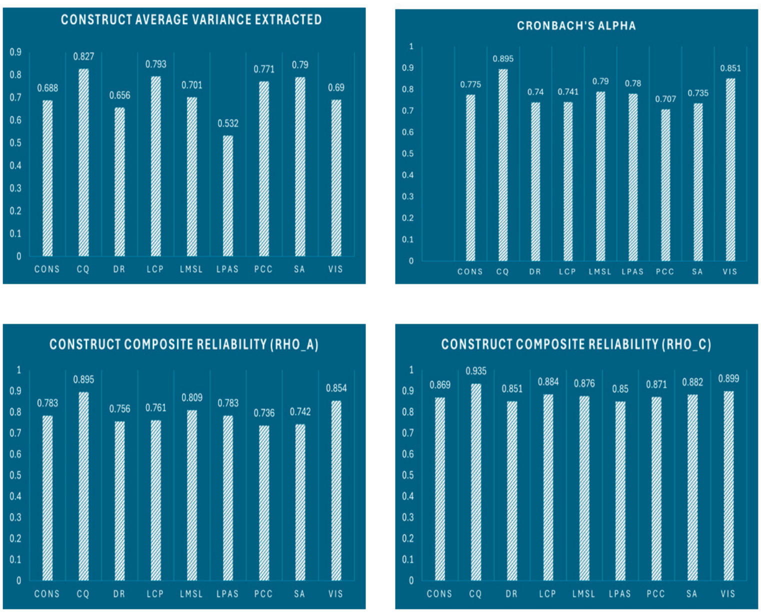


**Figure 5: Construct reliability and convergent validity results**

## 4.3 Direct effects of latent variables

Table 2 (Direct Effects) summarises the direct statistically significant relationships, where the strongest effects were noticed in DR → LCP (β = 0.974) and DR → SA (β = 0.622). Thus, delivery fidelity has been confirmed as the main predictor for the logistics cost performance and schedule adherence. The most important capability-to-coordination link was LMSL → CQ (β = 0.856), while the role of the consolidation branch in improving delivery reliability was pointed out by the coefficient of CONS → DR (β = 0.601). On the other hand, the connection of CONS → CQ (β = –0.167) manifested the negative coordination effect. In such a way, the consolidation processes might increase the coordination load or make the procedures more complex. LPAS, VIS, and PCC showed statistically significant but comparatively weaker effects, meaning that their involvement was more in the form of support rather than as a main direction in this sector.

**Table 2: Statistically significant direct relationships**

| Paths | β (Path Coefficient) | T-value | P-value |
|---|---|---|---|
| CONS -> CQ | -0.167 | 3.001 | 0.003 |
| CONS -> DR | 0.601 | 6.715 | < 0.001 |
| CQ->LCP | -0.175 | 3.825 | 0.002 |
| CQ -> SA | 0.129 | 3.042 | 0.003 |
| DR -> LCP | 0.974 | 4.588 | 0.001 |
| DR -> SA | 0.622 | 3.886 | 0.002 |
| LMSL -> CQ | 0.856 | 7.226 | < 0.001 |
| LMSL -> DR | 0.365 | 6.963 | < 0.001 |
| LPAS->CQ | 0.206 | 4.401 | 0.001 |
| LPAS -> DR | 0.062 | 5.354 | < 0.001 |
| PCC->CQ | 0.024 | 6.321 | < 0.001 |
| PCC -> DR | -0.018 | 4.304 | 0.001 |
| VIS -> CQ | 0.0012 | 3.137 | 0.003 |
| VIS -> DR | 0.021 | 7.353 | < 0.001 |

## 4.4 Indirect effects of latent variables

Indirect pathways highlighted in Table 3 disclosed several TLM capability dimensions that affect performance outcomes through the mediation of delivery reliability and coordination quality. Delivery reliability was the most impactful mediating construct accounting for significant indirect effects for both LMSL and CONS on the two performance outcomes. These results, in turn, keep the original theoretical expectation of the model intact: TLM capabilities mainly improve project outcomes by elevating the reliability and coordination of material flow, instead of relying on direct effects solely.

**Table 3: Statistically significant indirect relationships**

| Paths | T statistics | P values |
|---|---|---|
| CONS -> LCP | 4.88 | < 0.001 |
| CONS->SA | 5.86 | < 0.001 |
| LMSL->LCP | 6.04 | < 0.001 |
| LMSL->SA | 3.06 | 0.003 |
| LPAS->LCP | 4.32 | 0.001 |
| LPAS->SA | 3.11 | 0.003 |
| PCC->LCP | 2.97 | 0.004 |
| PCC->SA | 4.04 | < 0.001 |
| VIS -> LCP | 3.13 | 0.003 |
| VIS->SA | 3.44 | 0.002 |

## 4.5 Model fit evaluation

Model fit indices shown in Table 4 provide a strong basis for the fact that SEM has achieved a good fit with the data. The value of SRMR of 0.073 is below the recommended cutoff of 0.08, which shows adequate fit. The NFI value of 0.804 indicates an acceptable level of model fit for exploratory research, while the $R^2$ value of 0.800 demonstrates strong explanatory power, with the model accounting for 80% of the variance in performance outcomes. The indices are evidence that the structural relationships being estimated are true, robust, and appropriate.

**Table 4: Model fit indices**

| Model fit | Saturated model | Estimated model |
|---|---|---|
| SRMR | 0.073 | 0.073 |
| d_ULS | 1.402 | 1.402 |
| d_G | 2.514 | 2.524 |
| NFI | 0.872 | 0.804 |
| $R^2$ | 0.798 | 0.800 |

# 5 DISCUSSION

Evidence from SEM analysis shows that TLM capabilities not only have different effects but also have substantial effects on coordination, delivery reliability, and project outcomes in GCC construction projects. The capability that has the most significant effect on the coordination quality is LMSL, which has a coefficient of $\beta = 0.856$. This means that organising site logistics well, with the help of planning, control of access, and optimal routing, can bring about a major improvement in the overall coordination process. This finding agrees with operational problems faced in the GCC construction environment, as the sites that are congested and have limited access require last-mile practices to be very efficient. Meanwhile, the connection between CONS and delivery reliability is also crucial since it positively affects delivery reliability ($\beta = 0.601$) and negatively affects coordination quality ($\beta = -0.167$). Taken together, these findings indicate that while off-site kitting, staging, and consolidation stabilise material flows, they may increase coordination complexity due to additional process stages and handoffs. The coefficient variations underscore the need to integrate consolidation practices with clear communication protocols and role alignment to mitigate coordination inefficiencies.

The mediating constructs performed as expected. DR stood out as the most successful mediator in the model, which in turn, influenced logistics cost performance ($\beta = 0.974$) and schedule adherence ($\beta = 0.622$). The values certify that the reduction of delivery variability and the improvement of on-window arrival performance contribute significantly to the stated outcomes of downstream projects. CQ was found to have a more modest but equally relevant effect, by positively influencing the schedule adherence ($\beta = 0.129$) and negatively affecting the logistics cost performance ($\beta = -0.175$), meaning that coordination improvements should be mainly concentrated on schedule efficiency rather than cost efficiencies in this setting. LPAS, VIS, and PCC were found to be less potent, yet direct effects were markedly decreased, thereby confirming their role in enabling conditions rather than major stand-alone drivers. Low coefficients $|\beta|$ (generally $|\beta| < 0.10$) indicate that the improvements of the scheduling discipline, visibility, and port procedures play more of a supportive role rather than being independent factors for performance change.

The overall discussion suggests a logistics environment that is characterised by the stability of the flow through CONS and LMSL, combined with a coordination mechanism that improves performance. These findings extend the logistics management literature by offering empirical evidence from the GCC construction context and highlighting the performance advantages of reliability-focused and site-centric logistics capabilities.

# 6 CONCLUSION

This research employed structural equation modelling to probe how the capabilities of TLM can impact project performance in GCC construction settings. The findings provide evidence that DR is the key mediating mechanism, showing exceptionally strong influence on both logistics cost ($\beta = 0.974$) and schedule performance ($\beta = 0.622$). These findings confirm that precise delivery scheduling and the reduction of lead-time variability are the most significant determinants of project performance improvement, suggesting that embedding reliability-oriented logistics practices should be considered a strategic priority for construction projects across the GCC region.

In the context of upstream capabilities, Last-Mile/Site Logistics (LMSL) proved to be the most potent performance driver, significantly affecting the coordination quality ($\beta = 0.856$) and, in addition, the delivery reliability ($\beta = 0.365$) positively. It contains a message about the need for systematic site logistics planning, controlled access routing, and appropriate communication/coordination mechanisms, which can change upstream planning into effective site deliveries. CONS also contributes significantly to the process by reliability ($\beta = 0.601$) enhancement, but its negative influence on coordination ($\beta = -0.167$) indicates that these strategies are to be complemented with clear communication channels and well-aligned responsibilities to prevent operational friction.

The other capability areas like port/customs coordination, visibility systems, and appointment scheduling are indicated by lower coefficients, which means that, even though these functions are still very important to logistics flow, most of the project performance improvements can be ascribed to site-proximal capabilities and reliability-driven interventions.

With an overall explanatory power of $R^2 = 0.800$, the validated model demonstrates that the integrated framework effectively captures how logistics capabilities converge to influence performance. The results provide a practical roadmap for industry practitioners by illustrating that prioritising last-mile logistics, optimising consolidation processes, and strengthening reliability management will yield the most substantial improvements in both cost and schedule performance.

Future research could extend these insights by comparing capability impacts across project types, exploring country-specific operational differences within the GCC, or incorporating emerging digital technologies into the capability framework.

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