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Lean Construction Implementation in Libya's Construction Firms: The Roles of Organisational Culture and Digital Readiness

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Abstract:
Lean Construction (LC) implementation in Libya's construction sector is shaped by a conflict-affected, reconstruction-oriented environment in which organisational conditions and digital capability may condition process improvement efforts. This study examines how externally oriented dimensions of organisational culture, namely adhocracy culture and market culture, and digital readiness relate to LC implementation in public and private construction firms in Misrata, Libya. Accordingly, the study proposes a model in which these culture dimensions influence LC both directly and indirectly through digital readiness. Data were gathered through a cross-sectional survey of managers and engineers, yielding 89 usable responses from 114 distributed questionnaires (response rate ≈ 78%). All constructs were measured using 5-point Likert scales and analysed using partial least squares structural equation modelling (PLS-SEM) in SmartPLS. The measurement model demonstrates satisfactory indicator loadings, internal consistency, convergent validity, and discriminant validity. In the structural model, adhocracy culture, market culture, and digital readiness each show positive and statistically significant direct effects on LC, jointly explaining about 51% of the variance in LC implementation. However, digital readiness does not mediate the relationships between either adhocracy culture or market culture and LC. Overall, the results suggest that, in the current Libyan construction context, cultural orientations and digital capability operate as parallel and complementary drivers rather than as a sequential causal chain. The findings underscore the central role of culture in enabling lean practices, while indicating that digital readiness is emerging but remains a secondary lever for strengthening LC implementation in this context.
Keywords: Lean Construction; Organisational Culture; Adhocracy Culture; Market Culture; Digital Readiness; Libyan Construction Firms.

Introduction

Lauri Koskela (2000) reframed construction projects as production systems in which value generation, flow, and transformation must be managed concurrently, noting that conventional project management often gives insufficient attention to waste reduction and the reliability of workflow. Building on this perspective, lean construction research indicates that practices such as the Last Planner System, visual management, and value stream mapping can strengthen schedule reliability, reduce variability, and improve cost and quality performance when they are implemented in an integrated and disciplined manner (Ballard & Tommelein, 2021; Moradi & Sormunen, 2023; Garcés, Forcael, Osorio, Castañeda & Sánchez, 2025). At the same time, systematic reviews suggest that uptake remains uneven and frequently incomplete, particularly in developing countries, where organisational, contractual, and institutional constraints can

limit implementation beyond what technical capability alone would predict (Moradi & Sormunen, 2023; Hyarat & Pellicer, 2024). This pattern implies that understanding lean construction adoption requires attention not only to methods and tools but also to the organisational conditions that shape whether such methods can be sustained.

Within this line of reasoning, Karen Cameron and Robert Quinn's (2011) Competing Values Framework (CVF) treats organisational culture as a key determinant of how firms interpret and respond to change initiatives, distinguishing orientations along the dimensions of flexibility versus control and internal versus external focus. In construction settings, evidence suggests that adhocracy cultures, which prioritise experimentation and external scanning, and market cultures, which emphasise results and competitiveness, can influence both the intensity and the form of process-improvement initiatives (Bogale, 2024; Ackon, 2024; Osman, Liu & Wang, 2023). Studies of project-based organisations further indicate that outward-looking and learning-oriented cultures may be more supportive of collaboration, innovation, and data-driven problem solving, which align with core lean principles (Ackon, 2024; Osman *et al.,* 2023). However, because culture can also vary in how it manifests across firms and projects, its role is plausibly contingent on context and institutional setting rather than uniformly deterministic.

In parallel, digital transformation has become a prominent agenda in construction, with attention directed to Building Information Modelling (BIM), collaborative platforms, data analytics, and broader Construction 4.0 technologies as mechanisms for improving coordination and transparency (Rinchen, Banihashemi & Alkilani, 2024; Vararean-Cochisa & Marinescu, 2025). Naji, Gunduz, Alhenzab, Al-Hababi and Al-Qahtani (2024) conceptualise digital transformation readiness as a multi-dimensional construct encompassing leadership commitment, strategy, ICT infrastructure, data governance, and workforce skills that enable organisations to implement digital solutions at scale (Naji *et al.,* 2024). Related work also suggests that readiness can function as a connecting mechanism between cultural or structural conditions and downstream outcomes. For example, Zhen, Yousaf, Radulescu and Yasir, (2021) show that organisational readiness mediates the relationship between digital culture, digital capabilities, and innovation outcomes, implying that readiness may translate underlying organisational conditions into realised benefits. For lean construction specifically, this reasoning indicates that digital readiness could enable information-intensive practices such as model-based planning, real-time progress tracking, and integrated constraint analysis, although the strength of this enabling role is likely to depend on how coherently digital tools are embedded in planning and control routines (Garcés *et al.,* 2025; Rinchen *et al.,* 2024).

These issues are particularly salient in Libya, where the construction sector is dominated by government and state-controlled entities and has been shaped by prolonged conflict, fragmented governance, and capacity constraints. These conditions are associated with persistent delays, cost overruns, and material waste in public projects (Khalil, Al-Ghafly & Alhajlah, 2021; Mabrouk, 2024). Exploratory studies on BIM and related digital tools report growing awareness of potential benefits, yet implementation remains limited, commonly attributed to resource constraints, the absence of national standards, and weak client demand (Solla, Eshtiwi & Jabrel, 2023). Research on lean construction in Libya similarly suggests that while lean ideas are recognised conceptually, they are seldom institutionalised within formal planning and control routines; organisational culture, low digital capability, and institutional instability are repeatedly identified as key obstacles (Mabrouk, 2024; Khalil *et al.,* 2021). Collectively, this evidence supports the view that managerial and institutional conditions may be at least as consequential as technical know-how in shaping whether lean and digital initiatives progress beyond early adoption.

Taken together, the literature points to an interdependent triad in which organisational culture shapes openness to lean thinking and experimentation, digital readiness provides the

organisational and technological foundations for information-rich lean practices, and both are likely to influence the depth of lean construction implementation. Yet, quantitative evidence from conflict-affected, developing contexts that simultaneously models these relationships using validated reflective constructs remains limited. In response, the present study examines lean construction implementation in Libya's construction firms by assessing how adhocracy and market culture orientations act as organisational antecedents and how digital readiness mediates their effects. By doing so, the study addresses a documented gap at the intersection of lean construction, organisational culture, and digital transformation within the Libyan public construction domain (Cameron & Quinn, 2011; Naji *et al.,* 2024; Moradi & Sormunen, 2023; Mabrouk, 2024).

Literature Review

Lean Construction: Concepts, Principles, and Implementation in Construction Projects

Lean Construction (LC) has developed from Lauri Koskela's Transformation, Flow, and Value (TFV) theory into a mature stream of research arguing that construction projects function as production systems in which value, flow, and transformation must be managed jointly (Koskela, 2000; Moradi & Sormunen, 2023). Within this tradition, lean-based planning and control approaches, most notably the Last Planner System (LPS), alongside visual management and value stream mapping, are repeatedly associated with improved schedule reliability, reduced waste, and stronger project outcomes when they are implemented coherently rather than as isolated tools (Ballard & Tommelein, 2021; Moradi & Sormunen, 2023; Garcés *et al.,* 2025). However, the same body of evidence also shows a consistent tension.While benefits are well documented, implementation remains partial and uneven, particularly in developing regions, where organisational, contractual, and institutional barriers often constrain sustained adoption beyond what technical solutions alone can achieve (Moradi & Sormunen, 2023; Elbanna, 2024). This tension implies that LC implementation depth is likely shaped by broader organisational conditions that determine whether lean routines can be embedded and maintained in everyday planning and control.

Two sets of conditions are increasingly emphasised in this regard: organisational culture and digital transformation capabilities. The Competing Values Framework (CVF) positions culture as a central influence on how organisations interpret change and mobilise responses, while digital readiness captures whether organisations have the leadership, strategy, infrastructure, and skills required to operationalise technology-enabled forms of coordination and decision-making (Cameron & Quinn, 2011; Bogale, 2024; Naji *et al.,* 2024; Zhen *et al.,* 2021). Across construction and adjacent sectors, the literature suggests that culture shapes openness to experimentation and data-informed problem solving, whereas digital readiness affects the feasibility of deploying BIM, analytics, and integrated platforms that increasingly support information-intensive lean practices (Osman *et al.,* 2023; Chang, Ling, Yiu, Pelosi & Yang, 2024). Yet, despite this conceptual convergence, empirical evidence remains fragmented, especially in conflict-affected environments. In settings such as Libya, fragmented supply chains, governance challenges, and low technological adoption complicate both lean and digital initiatives, even as reconstruction pressures intensify the demand for productivity-enhancing reforms (Mabrouk, 2024; Eshtiwi *et al.,* 2023; Khalil *et al.,* 2021). Against this background, the present review examines three constructs, LC implementation, organisational culture (adhocracy and market types), and digital readiness, before synthesising their interrelationships and clarifying the gaps that motivate a quantitative model based on reflective measurement for Libyan construction firms.

Organisational Culture in Construction Firms

Organisational culture (OC) is commonly defined as shared values, assumptions, and norms that guide how organisational members interpret problems and enact acceptable ways of working (Bogale, 2024). In the CVF, culture is mapped along the dimensions of flexibility

versus control and internal versus external orientation, yielding four archetypes: clan, adhocracy, market, and hierarchy (Cameron & Quinn, 2011). The present study focuses on two externally oriented types that are theoretically salient for change and performance initiatives. Adhocracy cultures privilege flexibility, experimentation, and external scanning, whereas market cultures combine external focus with control and emphasise measurable results, competition, and target attainment (Cameron & Quinn, 2011). The CVF and its Organisational Culture Assessment Instrument (OCAI) are widely used to diagnose culture profiles in project-based settings, including engineering and construction organisations (Bogale, 2024).

Empirical findings in construction indicate that culture profiles are associated with outcomes such as safety climate, knowledge sharing, and project performance, but they also show that what appears "effective" is not uniform across contexts (Ackon, 2024; Osman *et al.,* 2023). For example, survey-based studies suggest that externally focused, result-oriented cultures can correlate with on-time delivery and profitability, whereas flexible and participative cultures can support learning, innovation, and collaborative problem solving (Ackon, 2024; Osman *et al.,* 2023). This pattern implies a plausible trade-off relevant to process-improvement programmes. Cultures that drive performance through targets may support disciplined execution, while cultures that legitimise experimentation may better support learning and adaptation. Reviews further note that construction organisations frequently display mixed culture profiles with competing subcultures across corporate, project, and site levels, which can complicate how change programmes are interpreted and enacted in practice (Bogale, 2024). Despite these insights, relatively few quantitative studies directly test how specific CVF dimensions, such as adhocracy and market orientations, drive the adoption of lean practices, particularly in developing-country construction sectors.

Digital Transformation and Digital Readiness in the Construction Industry

Digital transformation (DR) in construction refers to the strategic integration of technologies such as BIM, cloud collaboration, sensors, and analytics to redesign processes, roles, and business models, rather than merely digitising existing documents (Rinchen *et al.,* 2024; Vararean-Cochisa & Marinescu, 2025). Reviews of "Construction 4.0" research describe a growing emphasis on end-to-end data environments, model-based coordination, and platform collaboration as levers for productivity and transparency improvements (Vararean-Cochisa & Marinescu, 2025). In this setting, whether technology enables sustained operational improvement depends not only on access to tools, but also on the organisational capacity to implement them coherently.

Digital readiness captures this capacity. It is typically framed as a multi-dimensional construct encompassing leadership commitment, strategic alignment, ICT infrastructure, data governance, workforce skills, and a supportive culture for digital change (Naji *et al.,* 2024; Zhen *et al.,* 2021). A Delphi-based index for construction identifies clusters of readiness factors spanning management and governance, technological infrastructure, regulatory environment, and human resources, highlighting that "soft" organisational issues can constrain digital initiatives as much as hardware or software availability (Naji *et al.,* 2024). Empirical studies in AEC firms further indicate that higher digital readiness is associated with stronger digital competence, more extensive use of BIM and collaborative platforms, and improved project coordination (Chen *et al.,* 2024; Rinchen *et al.,* 2024). In addition, organisational readiness is theorised and tested as a mediating mechanism through which digital culture and capabilities translate into innovation outcomes (Zhen *et al.,* 2021). Overall, the literature converges on a socio-technical view in which readiness operates as a largely reflective latent construct capturing management, technology, and people-related conditions (Naji *et al.,* 2024; Zhen *et al.,* 2021). Yet construction-specific evidence remains dispersed, and quantitative work directly linking digital readiness to operational improvement programmes such as LC is still limited.

Organisational Culture and Lean Construction Implementation

Across the LC literature, cultural and behavioural factors are consistently reported as major barriers alongside technical and contractual challenges. Recurrent themes include resistance to change, siloed mindsets, low trust, and patterns of accountability that discourage learning, all of which can undermine sustained collaborative planning and continuous improvement (Moradi & Sormunen, 2023; Hyarat & Pellicer, 2024; Elbanna, 2024). These arguments are consistent with the premise that effective use of LPS and related practices requires norms that support transparency, cross-functional coordination, and learning from failure, rather than attributing variability to individual blame (Moradi & Sormunen, 2023). From this perspective, culture is not merely a contextual background variable but a plausible condition for whether lean routines are enacted as intended.

The CVF provides a structured way to specify which cultural orientations may be more compatible with LC. Adhocracy cultures emphasise flexibility, external focus, and experimentation, which align with innovation and process redesign, while market cultures prioritise targets, performance metrics, and competitive pressure that can support disciplined execution (Cameron & Quinn, 2011; Bogale, 2024). Survey evidence from construction settings links externally oriented culture profiles to stronger project performance and greater openness to new management practices, although the most favourable culture types appear context dependent (Ackon, 2024; Osman *et al.,* 2023). Conceptually, this implies that lean principles can plausibly draw on both orientations: adhocracy may support empowerment, front-line problem solving, and rapid experimentation, whereas market orientation may reinforce performance measurement and customer value focus (Cameron & Quinn, 2011; Bogale, 2024). At the same time, the literature cautions that market logics can conflict with lean objectives when they encourage short-term local optimisation, such as maximising crew utilisation, rather than system-level flow (Moradi & Sormunen, 2023).

Despite these theoretically meaningful distinctions, many LC studies still treat "culture" as a general enabler or barrier rather than decomposing it into CVF dimensions and testing their distinct effects on LC implementation depth (Elbanna, 2024; Bogale, 2024). This leaves uncertainty about how specific culture profiles, including combinations of adhocracy and market orientations, shape lean adoption in construction firms.

Digital Readiness as an Enabler of Lean Construction Practices

Recent reviews increasingly frame digitalisation and LC as intertwined, with BIM, 4D/5D planning, and dashboards providing an information backbone for flow control, pull planning, and waste identification (Garcés *et al.,* 2025; Rinchen *et al.,* 2024). BIM and lean integration studies, for instance, suggest that model-based coordination can reduce clashes, rework, and delays, thereby strengthening lean-related gains in time, cost, and quality (Garcés *et al.,* 2025). However, these benefits implicitly rely on organisational capabilities that allow such tools to be used consistently and at scale.

Digital readiness is therefore positioned as a conditioning factor because it encompasses leadership, strategy, ICT infrastructure, data standards, and workforce skills required to implement integrated approaches beyond isolated projects (Naji *et al.,* 2024; Vararean-Cochisa & Marinescu, 2025). Construction-specific readiness frameworks underscore the need for stable data environments, interoperable platforms, and trained practitioners to support constraint analysis, look-ahead planning, and real-time monitoring that underpin LPS and related lean practices (Naji *et al.,* 2024; Rinchen *et al.,* 2024). Empirical evidence from AEC firms associates higher digital readiness with stronger digital competence, broader BIM and platform adoption, and improved coordination, implying a feasible pathway through which readiness can support leaner production systems (Chen *et al.,* 2024). Complementing this, broader management research conceptualises organisational readiness as a mediating mechanism that converts digital culture and capabilities into innovation outcomes (Zhen *et al.,*

2021), a logic that can be extended to LC implementation. Nevertheless, empirical studies rarely model digital readiness explicitly as an enabler or mediator between organisational conditions and LC implementation; many treat lean and digitalisation as separate initiatives or focus primarily on technology adoption outcomes (Garcés *et al.,* 2025; Vararean-Cochisa & Marinescu, 2025). This unresolved linkage motivates examining digital readiness as a mediating construct connecting culture and LC practices in construction firms.

Organisational Culture, Digital Readiness, and Lean Construction in Developing and Conflict-Affected Contexts

In developing-country construction sectors, LC and digital initiatives are frequently shaped by structural constraints such as weak institutions, limited training, unstable supply chains, and adversarial contracting, which can dilute the effects of process-improvement programmes even when the underlying methods are well established (Hyarat & Pellicer, 2024; Elbanna, 2024). Studies in Middle Eastern and North African contexts similarly report that low awareness of lean concepts, hierarchical and blame-oriented cultures, and fragmented governance undermine collaborative planning and continuous improvement (Hyarat & Pellicer, 2024; Moradi & Sormunen, 2023). These conditions are relevant because they imply practical implementation challenges that extend beyond tool selection, including difficulties in sustaining cross-organisational coordination and maintaining stable planning routines.

Digital transformation faces parallel constraints. Inadequate ICT infrastructure, limited standards, and shortages of digitally skilled professionals can lead to BIM and platform technologies being applied on a project-by-project basis rather than institutionalised across firms (Naji *et al.*, 2024; Vararean-Cochisa & Marinescu, 2025). In Libya, exploratory BIM studies report that practitioners recognise potential benefits for coordination and cost control, but implementation remains nascent due to resource limitations, weak client demand, and the absence of national mandates or guidelines (Eshtiwi *et al.*, 2023). More broadly, research on construction performance in Libya highlights persistent delays, cost overruns, and material waste linked to governance challenges, capacity gaps, and weak enforcement of regulations (Mabrouk, 2024; Khalil *et al.*, 2021). These systemic constraints imply that organisational culture and low digital readiness may jointly limit the depth of LC implementation. At the same time, there is increasing pressure to enhance productivity and transparency as part of post-conflict reconstruction and infrastructure renewal, creating scope for reforms that combine cultural change, digital capability building, and lean practices (Khalil *et al.*, 2021; Naji *et al.*, 2024). Yet firm-level quantitative evidence on how specific culture profiles and digital readiness jointly shape LC implementation in such contexts remains scarce.

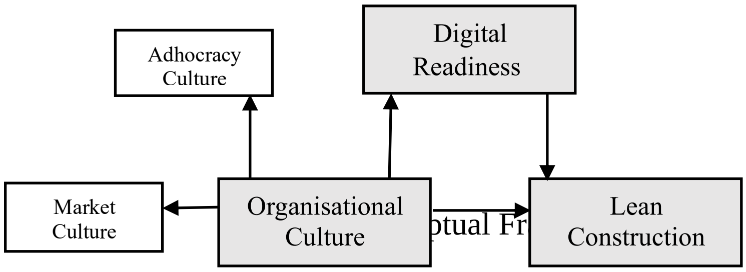
Summary of the Literature and Identified Research Gaps

The literature indicates that LC, grounded in TFV production theory and operationalised through tools such as LPS, can improve time, cost, quality, and customer satisfaction when implemented coherently (Koskela, 2000; Ballard & Tommelein, 2021; Garcés *et al.*, 2025). Nevertheless, systematic reviews consistently report patchy adoption, with cultural resistance, limited management commitment, and institutional barriers particularly acute in developing construction sectors (Moradi & Sormunen, 2023; Elbanna, 2024; Hyarat & Pellicer, 2024). Organisational culture research using the CVF suggests that adhocracy and market orientations influence innovation, performance, and openness to new management practices in project-based organisations, including construction firms (Cameron & Quinn, 2011; Bogale, 2024; Ackon, 2024; Osman *et al.,* 2023). However, LC research rarely measures these culture dimensions explicitly or tests their differential effects on implementation depth. Digital transformation studies conceptualise digital readiness as a multi-dimensional, largely reflective construct capturing leadership, strategy, infrastructure, and skills, and associate it with digital competence and innovation outcomes (Naji *et al.,* 2024; Chen *et al.,* 2024; Zhen *et al.,* 2021). Yet digital readiness is seldom integrated into LC adoption models, despite the growing

reliance of lean practices on BIM-based planning, analytics, and real-time monitoring (Garcés *et al.*, 2025; Rinchen *et al.*, 2024). In Libya and similar conflict-affected contexts, evidence remains mainly descriptive or qualitative, with limited quantitative work using validated reflective scales to examine how culture and digital readiness jointly shape LC implementation (Mabrouk, 2024; Eshtiwi *et al.,* 2023; Khalil *et al.*, 2021). This gap underpins the present study's focus on testing a structural model in which adhocracy and market cultures act as antecedents and digital readiness mediates their effects on LC implementation in Libyan construction firms.

Conceptual Framework and Hypotheses

Having considered much evidence from prior empirical research and the identified theoretical gaps in the previous sections, there is a need to develop a conceptual framework for this study. This framework illustrates the role of Digital Readiness as a mediating variable on the relationship that exists among the three variables: Adhocracy Culture, Market Culture, and Lean Construction Implementation. The relationships are represented in Figure 1.



H1: Significant positive relationship exists between Adhocracy Culture and the adoption of Lean Construction among the Libya's Construction Firms.

H2: Significant positive relationship exists between Market Culture and adoption of Lean Construction among the Libya's Construction Firms.

H3: Significant positive relationship exists between Digital Readiness and the adoption of Lean Construction among the Libya's Construction Firms.

H4: There is a significant mediating effect of Digital Readiness on the relationship between Adhocracy Culture and Lean Construction adoption among Libyan construction firm

H5: There is a significant mediating effect of Digital Readiness on the relationship between Market Culture and Lean Construction adoption among Libyan construction firms.

Methodology

To estimate the proposed research model and assess the hypothesised relationships among the latent variables, this study employed partial least squares structural equation modelling (PLS-SEM) using SmartPLS 4. This analytical approach is appropriate in contexts where prediction is a central objective, the model includes multiple latent constructs and structural paths, and the data may not satisfy multivariate normality assumptions. The empirical context comprised public and private construction firms in Misrata, Libya.

In line with established PLS-SEM procedures, the measurement model was evaluated before assessing the structural model. All constructs were specified as reflective, meaning that the indicators were treated as manifestations of their underlying latent variables. For the reflective measurement model, indicator reliability was assessed through outer loadings, internal consistency reliability through composite reliability and rho_A, and convergent validity through the average variance extracted (AVE). Discriminant validity was examined using the

heterotrait-monotrait (HTMT) criterion and its inference procedure. To improve the transparency and robustness of the estimates, consistent PLS (PLSc) results were also reported as a robustness check.

Given the prediction-oriented emphasis of PLS-SEM, out-of-sample predictive performance was further evaluated using PLSpredict. Structural path coefficients and their statistical significance were estimated through a non-parametric bootstrapping procedure, consistent with current reporting guidance. Although these procedures strengthen the credibility of the measurement and structural assessments, the findings should still be interpreted with appropriate caution because they are based on survey responses and statistical associations rather than experimental control.

Questionnaire's scale

Attitudes in survey research are commonly measured using Likert-type rating scales that trace back to Likert's original method. Accordingly, this study employed a 5-point format (1 = strongly disagree to 5 = strongly agree). Psychometric evidence indicates that scales with four to seven response categories typically achieve strong reliability and validity, whereas adding more categories often yields minimal gains while increasing respondent burden. A 5-point scale is therefore commonly viewed as a pragmatic balance between measurement quality, clarity, and respondent effort (Likert, 1932; Sullivan & Artino, 2013; Preston & Colman, 2000; Lozano, García-Cueto & Muñiz, 2008; Aybek & Toraman, 2022).

To reduce social-desirability responding and common-method bias, we assured anonymity, used neutral wording, and separated predictor and outcome measures within the instrument. These procedural remedies are intended to reduce evaluation apprehension and create psychological or temporal separation between constructs, which leading methodological reviews identify as effective approaches for limiting shared-method effects in self-report surveys (Podsakoff, MacKenzie, Lee & Podsakoff, 2003; Tourangeau & Yan, 2007; Krumpal, 2013; DeCastellarnau, 2018; Podsakoff, Podsakoff, Williams, Huang & Yang, 2024).

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Table 1: Summary of Variables and Measurement of Indicators

Items	Variable & Dimensions	Scale	No. of questions
Lean Construction	Lean Construction	5-points	4
Organisational Culture	Market Culture	5-points	5
	Adhocracy Culture	5-points	5
Digital Readiness	Digital Readiness	5-points	3

Table 2: Sources of Measurement of Indicators

S/N	Variables	Sources	Remarks
1.	Adhocracy Culture	(Cameron & Quinn, 2011; Deshpandé, Farley & Webster, 1993; Hartnell, Ou & Kinicki, 2011; Helfrich, Li, Mohr, Meterko & Sales 2007)	Adapted
2.	Market Culture	(Cameron & Quinn, 2011; Deshpandé *et al.*, 1993; Hartnell *et al.*, 2011; Helfrich *et al.*, 2007)	Adapted
3.	Lean Construction	(Hamerski, Saurin, Formoso & Isatto, 2024; Pérez, Lagos & Alarcón, 2022; Salem, Solomon, Genaidy & Luegring 2005)	Adapted
4.	Digital Readiness	(Chen *et al.*, 2024; Godager, Mohn, Merschbrock, Klakegg & Huang 2022; Naji *et al.*, 2024; Pérez et al., 2022; UK BIM Framework, 2020 to 2024)	Adapted

Survey Administration, Sample Size, and Response Rate

A structured, self-administered questionnaire survey was employed to capture managers' and engineers' perceptions of Lean Construction implementation within public and private construction firms in Misrata, Libya. This design was considered appropriate because it allows standardised measurement across dispersed organisational units while remaining feasible in a construction-industry setting where access and time constraints can limit more intensive data-collection approaches.

The questionnaire was distributed to 114 managers and engineers, and 89 complete and usable responses were returned, yielding an effective response rate of 78.1%. To ensure that the empirical test had sufficient statistical sensitivity for the intended model, the minimum required sample size was determined a priori using G*Power 3.1. The calculation specified a linear multiple regression model with up to three predictors, assuming a medium effect size ($f^2 = 0.15$), $\alpha = 0.05$, and power = 0.85, which indicated a minimum of approximately 87 observations (Faul, Buchner, Erdfelder & Lang, 2007; Faul, Erdfelder, Buchner & Lang, 2009). On this basis, the realised sample (n = 89) marginally exceeded the a priori threshold and was therefore considered adequate for the planned regression/PLS-SEM analyses.

However, the margin above the minimum remains small. As a result, while the sample is aligned with the a priori power requirement for detecting effects of the assumed magnitude, statistical power to detect smaller effects may still be limited. In addition, findings should be interpreted cautiously in terms of external validity because the data were collected in a single wave and reflect the specific institutional and operational conditions of the construction context in Misrata, Libya (Hair, Hult, Ringle, Sarstedt, Danks & Ray, 2021; Kock & Hadaya, 2018; Hair, Hult, Ringle & Sarstedt, 2022).

Findings

Profile of the Firm and the Respondents

The final sample consists of 89 usable responses obtained from managers and engineers working in Libyan construction firms. Table 3 summarises the profile of the participating firms and respondents, including their job positions, tenure with the current organisation, gender, and

overall work experience, as well as key firm characteristics such as ownership type, geographical location, and firm size (number of employees). This descriptive profile provides essential contextual information about the organisations and individuals from whom the data on organisational culture, digital readiness, and lean construction implementation were collected.

Table 3: Demographic Profile of the Respondents and Firm Size of the Sampled Companies

Respondents	Frequency	Percentage %
Work experience		
1-5 Years	16	18.0
6-10 years	9	10.1
More than ten years	64	71.9
Gender		
Male	76	85.4
Female	13	14.6
Workforce		
<100	33	37.1
101 - 250	31	34.8
251 - 500	13	14.6
>500	12	13.5

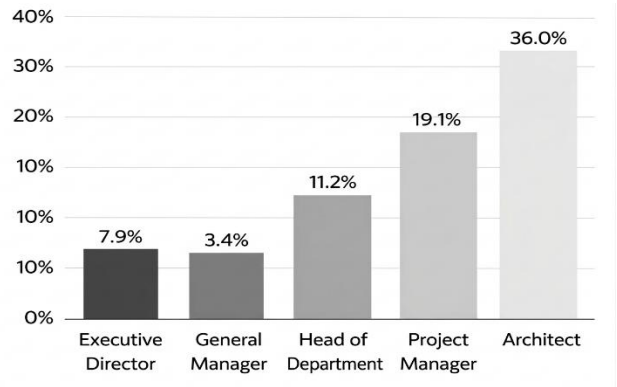

Figure 2. Respondents' position in the company.

Collinearity Statistics (VIF)

Before examining the structural relationships, collinearity among the predictor constructs in the structural model, with lean construction implementation as the endogenous variable, was assessed using variance inflation factor (VIF) values. In PLS-SEM, VIF values below about 3.3 to 5.0 are generally taken to indicate that multicollinearity is not a serious concern (Hair *et al.,* 2021; Hair *et al.,* 2022; Kock, 2015). As shown in Table 4, all VIF values for Adhocracy Culture, Market Culture, and Digital Readiness are clearly below these recommended thresholds, indicating that collinearity is not problematic in the model.

Table 4: Collinearity Statistics (Inner VIF Values)

Items	VIF
Digital Readiness	1.018
Adhocracy Culture	2.369
Market Culture	2.395

Assessment of Measurement Model

The evaluation of the measurement model (outer model) includes assessing indicator (item) reliability, content validity, internal consistency reliability, convergent validity, and discriminant validity (Hair *et al.*, 2022; Fornell & Larcker, 1981).

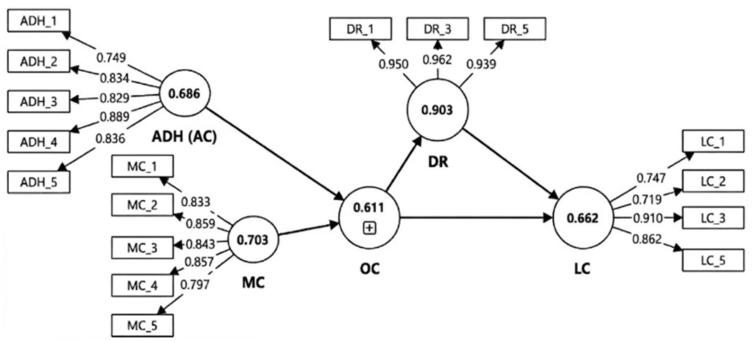

Figure 3. Evaluation of Measurement Model Through PLS Algorithm

4.1 Convergent Validity

Convergent validity was evaluated by examining the standardised indicator loadings, Cronbach's alpha, Dijkstra-Henseler's rho_A, composite reliability (CR), and the average variance extracted (AVE) for each reflective construct. In line with recommended PLS-SEM guidelines, indicator loadings of 0.70 or higher are considered satisfactory, as they indicate that more than 50% of the variance in the observed variable is explained by the latent construct (Hair *et al.*, 2022). Moreover, AVE values should be at least 0.50 to demonstrate that a construct explains more than half of the variance of its indicators, while reliability coefficients (Cronbach's alpha, rho_A, and CR) should ideally exceed 0.70 (Fornell & Larcker, 1981; Dijkstra & Henseler, 2015). As shown in Table 5, all retained items exhibit strong and significant loadings on their respective constructs, AVE values are above the 0.50 threshold, and Cronbach's alpha, rho_A, and CR values are all well above 0.70. These results provide clear evidence of adequate convergent validity for the measurement model.

Table 5: Construct Reliability and Validity

Items	Loading	Cronbach's Alpha	rho_A	CR	AVE
DR	0.939 - 0.962	0.945	0.955	0.965	0.903
AC	0.749 - 0.829	0.883	0.900	0.916	0.687
MC	0.797 - 0.858	0.892	0.907	0.922	0.703
LC	0.719 - 0.910	0.824	0.856	0.887	0.664

Note; (D.R.) Digital Readiness, (A.C.) Adhocracy Culture, (M. C.) Market Culture, (L.C.) Lean Construction.

Discriminant Validity

Discriminant validity was assessed using the Fornell-Larcker criterion and the heterotrait-monotrait (HTMT) ratio of correlations. According to the Fornell-Larcker criterion, the square root of the AVE for each construct should be greater than its correlations with any other construct in the model (Fornell & Larcker, 1981; Hair *et al.,* 2022).As shown in Table 6, the square roots of the AVE (reported on the diagonal in bold) are consistently higher than the corresponding inter-construct correlations, indicating that each construct shares more variance with its own indicators than with other constructs. In addition, HTMT values were all below the conservative 0.90 threshold, providing further evidence of adequate discriminant validity among Digital Readiness, Adhocracy Culture, Market Culture, and Lean Construction (Henseler, Ringle, & Sarstedt, 2015; SmartPLS, 2024).

Table 6: Discriminant validity results based on Fornell-Larker criterion

Items	DR	AC	MC	LC
DR	**0.950**			
AC	-0.040	**0.829**		
MC	-0.112	0.759	**0.838**	
LC	0.152	0.629	0.597	**0.815**

Note; (D.R.) Digital Readiness, (A.C.) Adhocracy Culture, (M. C.) Market Culture, (L.C.) Lean Construction.

Assessment of Significance of the Structural Model

The assessment of the structural model (the inner model) was conducted after all conditions of the outer model assessment had been satisfied. The path coefficients among the latent constructs in the structural model were then estimated. The significance of these path coefficients was tested using a non-parametric bootstrapping procedure (Hair *et al.,* 2022), where 5,000 bootstrap samples are recommended as a rule of thumb for model estimation in PLS-SEM (Hair *et al.,* 2022; Nitzl, Roldán & Cepeda, 2016). Figure 4 depicts the structural model with the inclusion of the mediating effects.

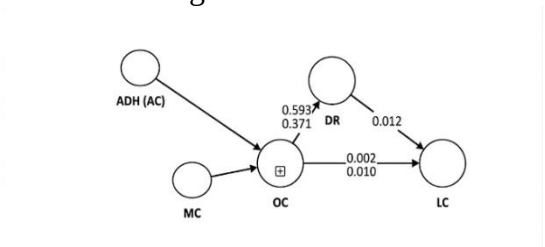

Figure 4. Structural Model with Mediating Effects

Table 7: Results of Bootstrapping for Structural Model Evaluation

Hypothesis	Variables	Beta (ß)	T-Value	P-Value	Findings
H1	AC -> LC	0.373	3.243	0.002	Supported **
H2	MC -> LC	0.300	2.630	0.010	Supported **
H3	DR -> LC	0.249	2.567	0.012	Supported **
H4	AC->DR -> LC	0.020	0.534	0.593	Not Supported
H5	MC->DR -> LC	- 0.037	0.894	0.371	Not Supported

Note: **Significant at 0.05 (p-value), Note; (D.R.) Digital Readiness, (A.C.) Adhocracy Culture,

(M. C.) Market Culture, (L.C.) Lean Construction.

Overall, the structural model results indicate that Adhocracy Culture, Market Culture, and Digital Readiness exert significant direct effects on Lean Construction implementation, whereas the indirect (mediated) effects of Adhocracy and Market Culture through Digital Readiness are not statistically supported. (Figure 4).

H1: There is a significant positive direct relationship between Adhocracy Culture and Lean Construction adoption among Libyan construction firms.

H2: There is a significant positive direct relationship between Market Culture and Lean Construction adoption among Libyan construction firms.

H3: There is a significant positive direct relationship between Digital Readiness and Lean Construction adoption among Libyan construction firms.

Effective Size and Predictive Relevance

In PLS-SEM, R^2 values of 0.25, 0.50, and 0.75 are typically viewed as weak, moderate, and substantial levels of explanatory power (Hair, Hult, Ringle & Sarstedt, 2019; Hair *et al.*, 2022). In this study, the R^2 value for LC is 0.510, indicating that the exogenous constructs jointly explain about 51% of the variance in LC, which reflects a moderate level of explanatory power approaching substantial. Moreover, the cross-validated predictive relevance (Q^2) for LC was greater than zero, confirming that the model exhibits acceptable predictive relevance for Lean Construction.

Table 8: Variance Explained in the Endogenous Latent Variable

Latent Variable	Variance Explained (R^2)
Lean Construction	0.510

Test of The Mediating Effect

The mediating role of Digital Readiness in the relationships between Adhocracy Culture (AC), Market Culture (MC), and LC was examined using the bootstrapping procedure with 5,000 resamples. Mediation is supported when the indirect effect is statistically significant ($p < 0.05$) and the confidence interval does not include zero. As shown in Table 9, the indirect effect of AC on LC through DR is small and not significant ($\beta = 0.020$, $t = 0.534$, $p = 0.593$). Similarly, the indirect effect of MC on LC via DR is negative and not significant ($\beta = -0.037$, $t = 0.894$, $p = 0.371$). These results indicate that Digital Readiness does not mediate the effects of Adhocracy Culture or Market Culture on Lean Construction. The influence of AC and MC on LC is therefore mainly direct rather than indirect through DR.

Table 9: Specific Indirect Effects and Mediation Results

Indirect path	Indirect effect (β)	t-value	p-value	Mediation decision
AC -> DR -> LC	0.020	0.534	0.593	Not supported
MC -> DR -> LC	- 0.037	0.894	0.371	Not supported

Note; (D.R.) Digital Readiness, (A.C.) Adhocracy Culture, (M. C.) Market Culture, (L.C.) Lean Construction.

Overall, the findings provide no empirical evidence of a mediating role of Digital Readiness in the relationships between organisational culture dimensions and Lean Construction, as also illustrated in the structural model diagrams (Figure 4).

H4: Digital Readiness does not exert a significant mediating effect on the relationship between Adhocracy Culture and Lean Construction adoption among Libyan construction firms.

H5: Digital Readiness does not exert a significant mediating effect on the relationship between Market Culture and Lean Construction adoption among Libyan construction firms.

Discussion

The structural model indicates that Adhocracy Culture, Market Culture, and Digital Readiness each have significant positive direct effects on Lean Construction implementation, and together they explain around half of the variance in lean implementation. In organisational research, this level of explained variance is commonly interpreted as moderate to substantial, particularly for models that connect relatively distal organisational conditions to operational practices (Koskela, 2000; Hair *et al.,* 2019; Hair *et al.,* 2022). Importantly, these results speak directly to the study's motivating gap by offering quantitative evidence within a conflict-affected construction setting on how culture and digital preparedness relate to lean implementation depth, rather than treating adoption as a purely technical matter. In doing so, the findings reinforce Koskela's foundational argument that lean outcomes depend not only on tools, but also on the wider production system and organisational context in which those tools are enacted (Koskela, 2000; Moradi & Sormunen, 2023).

The positive direct effects of Adhocracy and Market Culture are consistent with the Competing Values Framework, which suggests that externally oriented cultures, whether expressed through flexibility and experimentation in adhocracy or through performance orientation and control in market culture, can shape how organisations mobilise and sustain change programmes (Cameron & Quinn, 2011; Bogale, 2024; Ackon, 2024). Interpreted through a lean lens, these cultural orientations plausibly support the behavioural and managerial conditions that lean requires. Adhocracy may enable rapid learning and experimentation with routines that stabilise flow and reduce variability, whereas market orientation may reinforce discipline around targets, measurement, and performance accountability. The fact that both dimensions are significant points to a complementary cultural basis for lean implementation in this context, rather than a single cultural pathway.

The significant direct effect of Digital Readiness further indicates that technological and organisational preparedness to deploy BIM, collaborative platforms, and analytics is already functioning as an enabler of lean practices within construction organisations in Misrata, Libya (Naji *et al.*, 2024; Rinchen *et al.*, 2024; Garcés *et al.*, 2025). This is consistent with the framing of digital transformation readiness as a multi-dimensional capability spanning leadership commitment, infrastructure, and skills (Naji *et al.,* 2024), and it aligns with the broader argument that organisational readiness can bridge digital culture and innovation outcomes (Zhen *et al.,* 2021). However, the model also shows that digital readiness does not operate as a statistically supported mediating mechanism for the effects of culture on lean implementation, because the indirect paths through Digital Readiness are small and insignificant. Within the study's logic, this pattern implies that culture and digital readiness currently exert their influences largely in parallel.

The lack of mediation is substantively informative in the Libyan setting. It suggests that cultural orientations toward flexibility, external focus, and performance can translate into lean behaviours directly, even when digital transformation remains limited in maturity. One plausible reading consistent with the contextual constraints already documented is that digital transformation is still at an early stage and has not yet achieved sufficient depth to fully channel cultural influences through digital capability-building pathways (Eshtiwi *et al.,* 2023; Mabrouk, 2024; Khalil *et al.*, 2021).

This nuance qualifies more universalised claims that digitalisation and lean are necessarily tightly coupled. Instead, in developing and conflict-affected environments, cultural and managerial reforms may precede digital investments or progress alongside them, rather than

being systematically transmitted through them (Garcés *et al.,* 2025; Vararean-Cochisa & Marinescu, 2025).

From a methodological standpoint, the strong indicator loadings, reliability coefficients, and evidence of convergent and discriminant validity support the decision to model the constructs as reflective and to use PLS-SEM for prediction-oriented analysis with a relatively small sample (Hair *et al.,* 2019; Hair *et al.,* 2022). Overall, the results extend lean construction research by providing quantitative evidence that specific culture dimensions and digital readiness jointly shape Lean Construction implementation in public and private construction firms in Misrata, Libya, while also challenging assumptions about the universal mediating role of digital capabilities in the lean and digital relationship.

Research Implications

Theoretically, the findings advance lean construction and organisational culture research by showing that Adhocracy Culture and Market Culture have distinct yet complementary direct effects on Lean Construction implementation, rather than operating primarily through Digital Readiness (Cameron & Quinn, 2011; Bogale, 2024; Ackon, 2024). This usefully extends Competing Values Framework applications in construction beyond broad claims about a generally "supportive culture." Instead, the results suggest that two externally oriented cultural logics can matter at the same time . flexibility and experimentation may help organisations adapt routines and learn through implementation, while an external performance orientation may reinforce disciplined execution and attention to measurable outcomes. Importantly, the absence of a significant mediating role for Digital Readiness also qualifies assumptions commonly made in digital-transformation models. In early-stage digital contexts, readiness may function more plausibly as an additional predictor of process improvement than as a primary conduit through which cultural effects are transmitted (Naji *et al.,* 2024; Zhen *et al.,* 2021).

From a practical standpoint, the evidence implies that leaders in public and private construction firms in Misrata, Libya, should be cautious about assuming that technology initiatives alone will translate into lean outcomes. Instead, the pattern of results indicates a need to work deliberately on cultural conditions that are compatible with lean implementation, including adhocracy-type behaviours such as empowering project teams, encouraging experimentation, and treating setbacks as opportunities for learning, alongside maintaining a market-like focus on meeting time, cost, and quality targets (Cameron & Quinn, 2011; Osman *et al.,* 2023). In operational terms, interventions such as cross-functional planning workshops, Last Planner System training, and structured after-action reviews are relevant because they can provide concrete routines through which lean-congruent norms are reinforced in day-to-day practice, rather than remaining aspirational (Ballard & Tommelein, 2021; Moradi & Sormunen, 2023). At the same time, the positive role of Digital Readiness indicates that investment in enabling capabilities, such as upgrading ICT infrastructure, formalising BIM protocols, and strengthening data-analytics skills, may be necessary to support more advanced lean tools, particularly those that depend on integrated and timely information flows (Rinchen *et al.,* 2024; Garcés *et al.,* 2025).

For policymakers, public clients, and other industry stakeholders, the findings underline that organisational reforms are likely to be constrained if procurement and regulatory arrangements continue to reward short-term, local optimisation over system-level performance. The evidence therefore supports aligning procurement and regulatory frameworks with lean and digital objectives through collaborative contracting arrangements, model-based information exchanges, and performance indicators that prioritise system-level flow rather than fragmented project-level incentives (Mabrouk, 2024; Khalil *et al.,* 2021). Within this agenda, supportive national guidelines on BIM and lean, targeted capacity-building programmes, and incentives for pilot projects are relevant levers for helping the sector move from isolated experiments

toward more institutionalised Lean Construction practices supported by digitally ready organisations (Eshtiwi *et al.*, 2023; Vararean-Cochisa & Marinescu, 2025).

Limitations and Paths for Future Research

Several limitations should be considered when interpreting these findings, and they also point to clear priorities for subsequent work. First, the cross-sectional survey design constrains the strength of causal inference that can be drawn about the relationships among organisational culture, digital readiness, and Lean Construction. Although the structural model is theoretically grounded, the evidence cannot exclude reverse or reciprocal causality. Longitudinal designs or repeated surveys are therefore needed to assess whether and how changes in culture and digital readiness translate into lean outcomes over time.

Second, the data were obtained from managers and engineers in public and private construction firms in Misrata, Libya, which limits the generalisability of the results. The cultural, institutional, and operational conditions of the construction context in Misrata may differ from those in other Libyan cities, international markets, or more stable environments. Replicating the model in other settings, including other Libyan regions, neighbouring countries, or broader construction contexts, would enable more informative comparisons and provide a stronger test of the robustness of the relationships identified here.

Third, the study relies on self-reported perceptions of organisational culture, digital readiness, and Lean Construction implementation. Such measures may be influenced by social-desirability bias or common-method variance, even though procedural remedies were applied during questionnaire design. Future research could strengthen inference by combining survey responses with objective indicators such as schedule adherence, cost growth, rework rates, or digital-maturity assessments, and by collecting data from multiple respondents within each firm or project.

Fourth, the model is deliberately bounded, focusing on a single mediator (Digital Readiness) and two culture dimensions (Adhocracy and Market Culture). Other organisational factors, such as leadership styles, supply chain integration, project governance, or learning mechanisms, may also act as mediators or moderators in shaping Lean Construction implementation. Future work could extend the model by incorporating additional constructs, examining non-linear effects, or testing multi-group differences across firm size, project type, or region.

Finally, qualitative case studies or mixed-method designs could usefully complement the quantitative results by examining how cultural and digital conditions are enacted in day-to-day project practices, and how organisations that succeed in implementation manage the practical challenges of applying Lean Construction in conflict-affected environments.

Conclusions

This study examined how organisational culture and digital readiness relate to Lean Construction implementation in public and private construction firms in Misrata, Libya. The results indicate that Adhocracy Culture, Market Culture, and Digital Readiness each have significant positive direct effects on Lean Construction, together explaining a substantial share of the variance. Taken together, the findings suggest that flexibility and experimentation, an external performance orientation, and a baseline level of technological preparedness can all contribute to translating lean principles into practice within a challenging construction environment.

At the same time, the analysis shows no evidence that Digital Readiness mediates the effects of Adhocracy or Market Culture on Lean Construction. This pattern implies that, under current conditions in the Libyan construction context, cultural orientations and digital capability tend to function as parallel and complementary drivers rather than operating as a sequential causal chain. Theoretically, this nuance sharpens how the lean and digital relationship may be understood in developing and conflict-affected settings. Practically, it indicates that progress

is more likely when organisations address cultural and digital enablers in tandem, rather than assuming that technology investments can substitute for unsupportive norms.

Overall, the study offers quantitatively grounded insight into the enabling roles of specific cultural profiles and digital readiness for Lean Construction in Misrata, Libya, while pointing to the need for further research to extend and deepen these conclusions across settings and conditions.

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