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Leveraging Lean Techniques for Road Construction Efficiency in Qatar

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Abstract

Question: How can Lean Construction techniques improve efficiency, workflow reliability, and resource performance in Qatar's road construction projects?

Purpose: To evaluate the current inefficiencies in Qatar's road construction sector and assess the effectiveness of Lean Construction methods in addressing project delays, cost overruns, and resource inefficiencies.

Research Method: A mixed-methods approach was employed, combining a practitioner survey, in-depth stakeholder interviews, and a case study of a government road agency's Lean pilot project using LPS®, Kanban, and VSM.

Findings: The study found systemic inefficiencies in Qatar's road projects, with project delays and resource waste being prevalent. Despite moderate awareness, Lean techniques such as the Last Planner System®, Kanban boards, and Flow of Activities tracking demonstrated measurable improvements in schedule adherence (PPC increasing from ~60% to 80–85%), material savings (~15% reduction), and productivity (~10% increase). Key barriers identified included resistance to change, limited Lean knowledge, and inconsistent management support.

Limitations: While the study focuses on Qatar's road sector, the challenges and benefits identified are consistent with global Lean Construction experiences, supporting broader applicability. Contextual differences may influence implementation strategies, warranting further research in varied project environments.

Implications: Lean Construction offers a viable pathway for improving project delivery and supporting Qatar's Vision 2030 sustainability goals, provided there is strong leadership, targeted training, and supportive policy frameworks to overcome adoption barriers.

Value for Practitioners: Practitioners gain evidence-based insights into benefits of Lean tools in reducing delays, improving workflow reliability, and enhancing resource efficiency

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within Qatar's road projects, with practical strategies for overcoming implementation challenges.

Keywords: Lean Construction, Road Projects, Qatar, Last Planner System®, Kanban, VSM, Project Efficiency, Waste Reduction

Paper type: Full Paper

Introduction

The construction industry faces significant challenges in delivering projects on time, within budget, and with minimal waste, despite its essential role in national development. Various studies highlight critical delay factors, inefficiencies in traditional practices, and the industry's potential for sustainable development (Fei 2021). Road infrastructure projects are particularly prone to inefficiencies, including delays, cost overruns, and resource wastage, which are exacerbated in rapidly developing contexts like Qatar due to tight schedules and complex stakeholder environments (Ojo 2019, Emam 2015).

Although Lean Construction has conceptual roots in the Toyota Production System, it emerged as a distinct field through efforts within the construction community to overcome recurrent failures in weekly production assignments and the limitations of viewing production solely as a transformation process. Building on the Transformation–Flow–Value (TFV) critique of transformation-dominant thinking, pioneers such as Koskela, Ballard and Howell reframed construction as a socio-technical production system requiring reliable workflow, collaborative control and continuous learning (Koskela 1992, Ballard and Howell 1998, Ballard 2000, Abdelhamid 2004). Lean Construction is therefore not merely a waste-elimination toolkit but an organizational culture of commitment-based planning, scientific problem-solving and continuous improvement, grounded in value generation, respect for people and learning from production failures (Mossman 2018, Abdelhamid and Copeland 2022). Tools such as the Last Planner System® (LPS®), Value Stream Mapping and visual management operationalize these principles by improving workflow reliability, enabling constraint removal and supporting Plan–Do–Check–Act (PDCA) learning cycles rather than simply reducing visible waste.

In Qatar, the government's significant investments in infrastructure as part of its Vision 2030 agenda have heightened the need for efficient project delivery (Moradi 2023, Al Balkhy et al. 2021). However, pilot initiatives under the Public Works Authority (Al-Buenain et al. 2020) have shown promising results, demonstrating Lean's potential to improve schedule adherence and resource utilization in Qatar's road sector (Al-Buenain et al. 2020, Alchamaa and Abushaqra 2023). This study aims to assess the current inefficiencies in Qatar's road construction projects and evaluate the effectiveness of Lean Construction techniques in addressing these challenges. Using a mixed-methods approach combining practitioner surveys, stakeholder interviews, and a case study of a government road agency's Lean implementation, the study provides empirical insights into the benefits and barriers associated with Lean adoption in Qatar. By connecting these findings with global Lean Construction literature, the paper aims to contribute to the discourse on effective Lean implementation strategies in road infrastructure projects, offering practical guidance for policymakers, practitioners, and

researchers seeking to enhance project delivery and sustainability in Qatar and similar contexts.

Literature Review

Lean Construction originates from the Toyota Production System and emphasises reducing waste while enhancing value across project delivery processes (Koskela 1992). It reframes construction as a production system requiring continuous improvement, collaboration, and flow reliability (Ballard 1998, Ballard 2000). Globally, tools such as the Last Planner System® (LPS®), Value Stream Mapping (VSM), Kanban, and 5S have delivered measurable benefits in workflow reliability, waste reduction, and productivity improvement (Shang and Low 2014).

Various tools operationalise Lean principles in construction, including the Last Planner System® (LPS®) for collaborative planning and improved Percent Plan Complete (PPC), Value Stream Mapping (VSM) for identifying inefficiencies, Kanban for workflow transparency, and 5S for site organisation (Ballard 2000, Shang and Low 2014). Root Cause Analysis (RCA) supports continuous improvement by addressing systemic issues, while Just-in-Time (JIT) delivery minimises material waste (Aziz 2013). Globally, these tools have been linked with reductions in project delays and rework, improvements in productivity, and enhanced site safety(O. Salem 2005, Pawlak 2024).

Lean Construction has been successfully implemented across diverse contexts, including the US, UK, and Asia, demonstrating its effectiveness in complex projects (Shang and Low, 2014). However, challenges persist, with studies highlighting barriers such as fragmented supply chains, lack of Lean knowledge, cultural resistance to change, and the perception of high initial implementation costs (Valente et al. 2020, Moradi 2023). Overcoming these barriers requires strong leadership commitment, targeted training, and demonstration of Lean benefits through pilot projects, facilitating gradual cultural and procedural shifts(O. Salem 2005).

Road infrastructure projects, characterised by tight schedules and complex stakeholder interfaces, are prone to inefficiencies that Lean Construction can address (Mohammadi, 2020). LPS® has shown promise in improving schedule adherence, while VSM and Kanban contribute to resource optimisation and workflow stability in road projects(Ballard 2000, Shang and Low 2014). Successful case studies have reported reductions in project durations and improvements in quality through Lean adoption in large-scale transport projects.

Regional studies in the Middle East have highlighted similar patterns of Lean Construction adoption and challenges. For example, (Al-Aomar 2012) analysed Lean Construction practices in Abu Dhabi and found limited implementation alongside a range of waste categories. Likewise, (Watfa and Sawalha 2021) identified multiple critical success factors for Lean adoption in the UAE, emphasising managerial and organisational enablers. More recently, (Warid and Hamani 2023) examined the application of the Last Planner System® (LPS®) in UAE projects, demonstrating its feasibility when properly managed despite cultural and operational challenges. These studies collectively underscore that Lean principles are recognised as valuable in the region but face significant barriers to full implementation.

Qatar's rapid infrastructure growth, driven by Vision 2030 and major events, has heightened the need for efficient and sustainable project delivery (GCO, n.d.). However, despite its potential, Lean adoption in Qatar remains limited, facing challenges including hierarchical organisational structures, communication barriers in multinational workforces, and a lack of client-driven Lean requirements(Al-Emadi 2024). Recent pilot initiatives by government agencies, such as the Public Works Authority, have demonstrated improvements in project performance through the application of LPS®, Kanban, and other Lean tools (Al-Buenain et al. 2020). These developments align with Qatar's goals of reducing waste and enhancing resource efficiency, underscoring Lean Construction's relevance to the region's infrastructure objectives.

While Lean Construction's benefits are well documented globally, empirical studies assessing its effectiveness within Qatar's road construction sector are limited. There is a need to understand how Lean practices can address chronic inefficiencies in Qatar's infrastructure delivery while overcoming local implementation barriers. This study addresses this gap by evaluating current inefficiencies in Qatar's road projects and assessing the potential of Lean tools to improve schedule adherence, reduce waste, and enhance productivity. The findings aim to inform policymakers and practitioners on strategies for effective Lean adoption in road infrastructure projects, contributing to Qatar's sustainability and efficiency goals. A summary of the key Lean Construction tools and their benefits is shown in Table 1 below.

Table 1 Summary of key Lean Construction tools and their benefits relevant to road projects

Lean Tool	Purpose	Documented Benefits	References
Last Planner System® (LPS®)	Collaborative planning	Improved PPC, reduced delays	Ballard (2000); Ballard & Howell (1998)
Value Stream Mapping (VSM)	Identify inefficiencies	Reduced waste, cycle time reduction	Aziz & Hafez (2013)
Kanban	Visual workflow management	Improved task flow and transparency	Shang & Low (2014)
5S	Site organization	Improved safety, reduced waste	Aziz & Hafez (2013)
Just-In-Time (JIT)	Timely material delivery	Reduced inventory, site congestion	Shang & Low (2014)
Root Cause Analysis (RCA)	Systemic problem-solving	Continuous improvement	Salem et al. (2005)

Methodology

A cross-sectional survey was conducted among professionals in Qatar's road construction industry to assess the application of Lean techniques. Data was collected via a structured questionnaire distributed to engineers, project managers, supervisors, and other practitioners across public and private road projects. In total, 71 individuals participated in the study (n=71). The sample included a mix of contractors, consultants, and government personnel, reflecting diverse roles in road project delivery. The questionnaire covered topics such as awareness of Lean principles, current practices (e.g. Last Planner usage), perceived waste categories, and adoption challenges. Responses were analyzed quantitatively (descriptive statistics of survey items) and qualitatively (open-ended feedback), allowing comparison with the success factors and barriers identified in literature. Ethical approval and informed consent procedures were followed. The methods ensured rigorous data collection by using established Lean constructs and by explicitly reporting the sample size (n=71) and demographics of the participants.

Research question and objectives

This study is guided by the following research question:

"How can Lean Construction techniques be applied to enhance efficiency and minimize waste in Qatar's road construction projects?"

To address this question, the study set out to achieve the following objectives:

- Assess the current state of efficiency and identify key challenges affecting Qatar's road construction sector.
- Examine practitioner awareness and adoption of Lean Construction techniques within the sector.
- Evaluate the practical application and effectiveness of specific Lean tools, including the Last Planner System®, Kanban, and Value Stream Mapping, in a road construction project context.
- Identify barriers and enabling factors that influence the successful implementation of Lean practices in Qatar's road construction industry.
- These objectives ensured that the research remained focused on practical outcomes while aligning with the study's aim of supporting Lean adoption for improved project delivery in Qatar.

Research design

A combination of quantitative and qualitative methods was used to ensure comprehensive analysis:

- An online survey targeting practitioners in the road construction sector.
- Semi-structured interviews with key stakeholders.
- A case study examining a government road agency's pilot implementation of Lean practices.

- This triangulation provided a robust dataset linking perceptions, experiences, and measured impacts of Lean adoption.

Survey

A structured survey was distributed to engineers, site managers, and project supervisors to capture:

- Perceptions of current project performance.
- Awareness and utilisation of Lean Construction techniques.
- Challenges and expectations are associated with Lean practices.
- A total of 71 valid responses were received, providing insight into current sector practices and practitioner views.

Interviews

Semi-structured interviews were conducted with project managers, Lean champions, and senior engineers from public and private organizations. The interviews explored:

- Experiences with Lean implementation.
- Perceived barriers and enablers.
- Outcomes observed from Lean practices on site.
- Interviews were transcribed and analyzed thematically to identify patterns and lessons relevant to the local context.

Case study

A case study was conducted on a government road agency project implementing Lean tools, including:

- The Last Planner System® for collaborative planning.
- Kanban boards for workflow visualization.
- Flow of Activities tracking for real-time progress monitoring.
- Project Key Performance Indicators (KPIs) such as Percent Plan Complete (PPC), material usage, productivity rates, and safety incidents were compared before and after Lean implementation to assess measurable impacts.

Data analysis

Survey data were analyzed using descriptive statistics to identify trends and practitioner perspectives. Interview data were coded and thematically analyzed, focusing on benefits, challenges, and implementation strategies. Case study data were assessed to quantify Lean's practical benefits in schedule reliability, material savings, and productivity improvements.

This methodological approach ensured alignment with the study's objectives while providing empirical evidence to inform practitioners and policymakers on effective Lean implementation in Qatar's road construction sector.

Results

Current State of Project Efficiency and Challenges in Qatar

The survey first gauged respondents' perceptions of road project performance in Qatar. A significant finding is that the majority view current efficiency levels as average. Over half (52%) of the professionals rated the efficiency of road construction projects as "*satisfactory*" (meeting basic expectations but needing improvement), and only 10% felt projects were "exceptionally efficient". About a quarter (24%) considered them "very efficient," while roughly 14% labelled them below expectations or poor. These ratings as shown in Figure 1 indicate that there is broad acknowledgment of *room for improvement* in how road projects are executed.

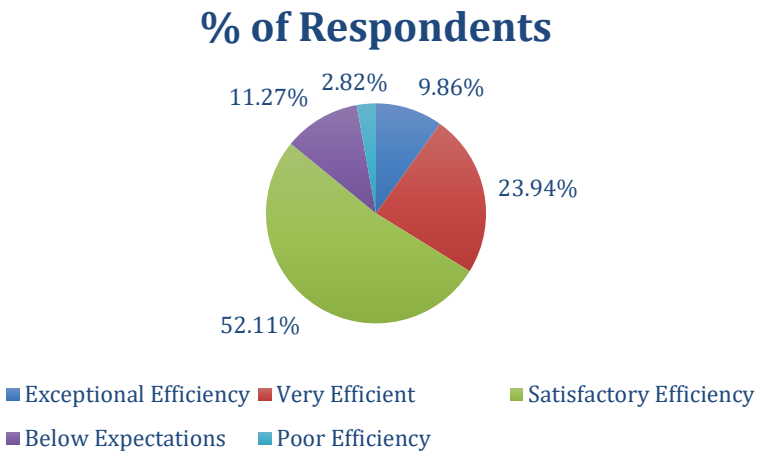


Figure 1 Perceived efficiency levels of road construction projects in Qatar (n = 71). Source: Practitioner survey, 2023.

When asked about the biggest challenges facing road construction in Qatar, the most common issue cited was project delays (Figure 2), selected by about 75% of respondents. This resonates with documented reports of chronic schedule overruns in the region. The next most frequent challenge was cost overruns (55%), followed by resource wastage (34%) and quality control issues (32%). Interestingly, poor communication (30%) and labor shortages (20%) were also noted by a significant subset. The prevalence of delays and cost issues aligns with global construction problems, but the relatively high mention of resource waste suggests that inefficiency in how materials and manpower are utilized is clearly visible to practitioners in Qatar.

Verifying this, 77% of respondents reported that delays occur "frequently" in road projects, with the remainder saying "occasionally"; virtually none said delays are rare. Additionally, about 74% have encountered either excessive material waste or inefficient resource utilization on projects. These figures are quite stark and underline that inefficiency is not a trivial or isolated problem but a systemic one in Qatari road construction.

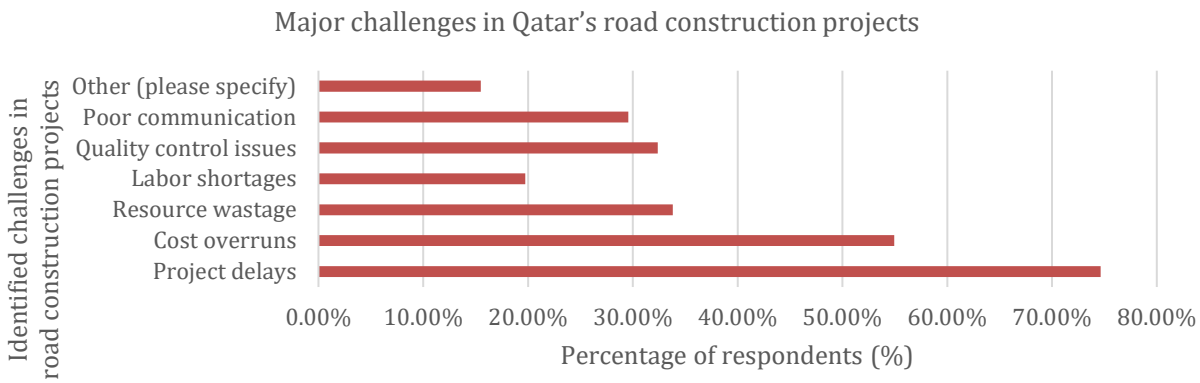


Figure 2 Major challenges identified by professionals in Qatar's road construction sector (% of respondents, n = 71). Source: Practitioner survey, 2023.

The survey also asked which phase of road construction faces the most significant challenges. The *execution* phase was identified by the largest share of respondents (68%), followed by design (42%) and planning (41%). This suggests that while front-end planning and design issues exist, the on-site execution is where problems peak, likely manifesting as schedule slippage, coordination breakdowns, etc. Lean Construction often targets the execution phase (through better planning, coordination, and control), so focusing on execution aligns with where professionals see the biggest headaches as shown in Figure 3 below.

Awareness and Adoption of Lean Techniques

One of the central questions of the survey was to assess the level of **awareness of Lean Construction techniques** among industry professionals. The results reveal a moderate awareness overall, with significant variation across specific tools. Figure 4 (derived from survey data) shows the percentage of respondents familiar with each technique.

RCA being the most recognized is logical as it's commonly used in quality and safety contexts even outside of a Lean program. The high awareness of JIT may reflect exposure to the term in supply chain discussions, while moderate awareness of 5S indicates that about half the industry has heard of basic Lean workplace organization. Notably, less than half knew of the Last Planner System® – a cornerstone Lean practice which implies a knowledge gap on specialized Lean Construction methods. This gap in awareness is indeed one of the barriers; if key decision-makers are unfamiliar with LPS® or VSM, they are unlikely to implement them. The relatively low familiarity with Kaizen suggests that the ethos of continuous improvement is not yet ingrained in the industry's vocabulary. These findings echo the literature that cites *lack of Lean awareness* as a primary barrier.

Despite the occasional awareness, respondents who are familiar with Lean techniques generally view them positively. When asked, *"From your experience, how effective are Lean Construction techniques in addressing construction inefficiencies?"*, about 69% responded either "very effective" (50.7%) or "extremely effective" (18.3%). Nearly 30% said "somewhat effective," and only one respondent (<2%) chose "not so effective" (none said "not at all effective"). This is an important finding: it indicates that those who have used or seen Lean in

action tend to believe in its benefits. There is a positive perception among practitioners with Lean exposure that Lean techniques can indeed combat inefficiencies. This positive feedback loop is crucial: it suggests that demonstration and education could convert more people to Lean proponents if they witness the effectiveness firsthand.

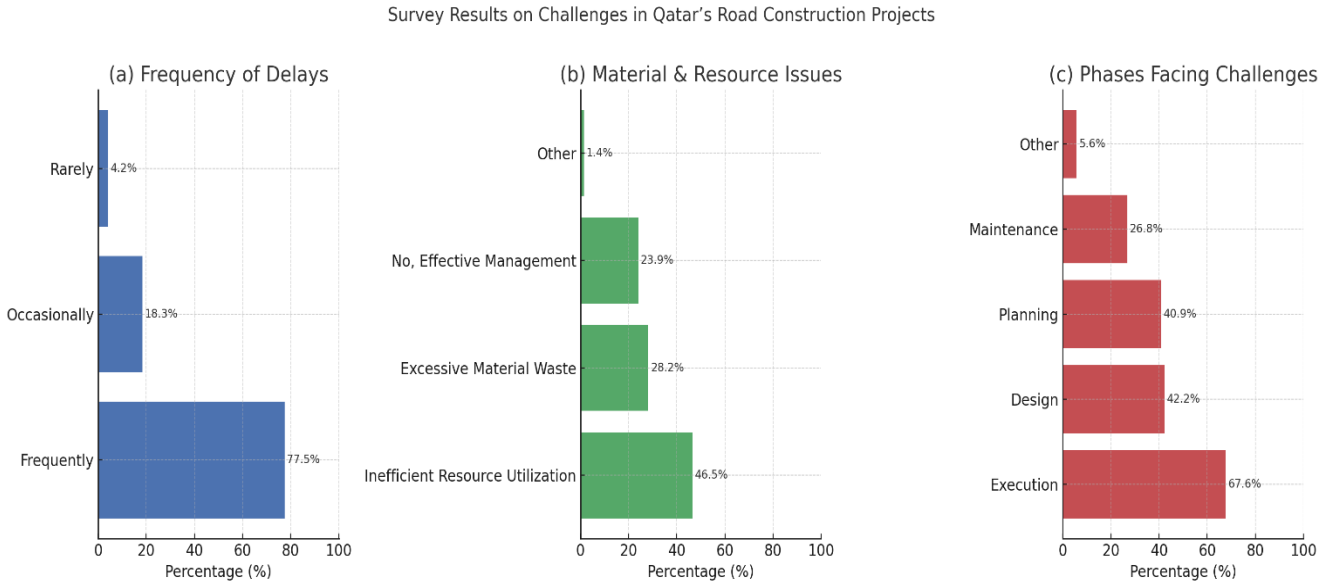


Figure 3 Frequency of delays encountered in road construction projects in Qatar (% of respondents, n = 71). Source: Practitioner survey, 2023.

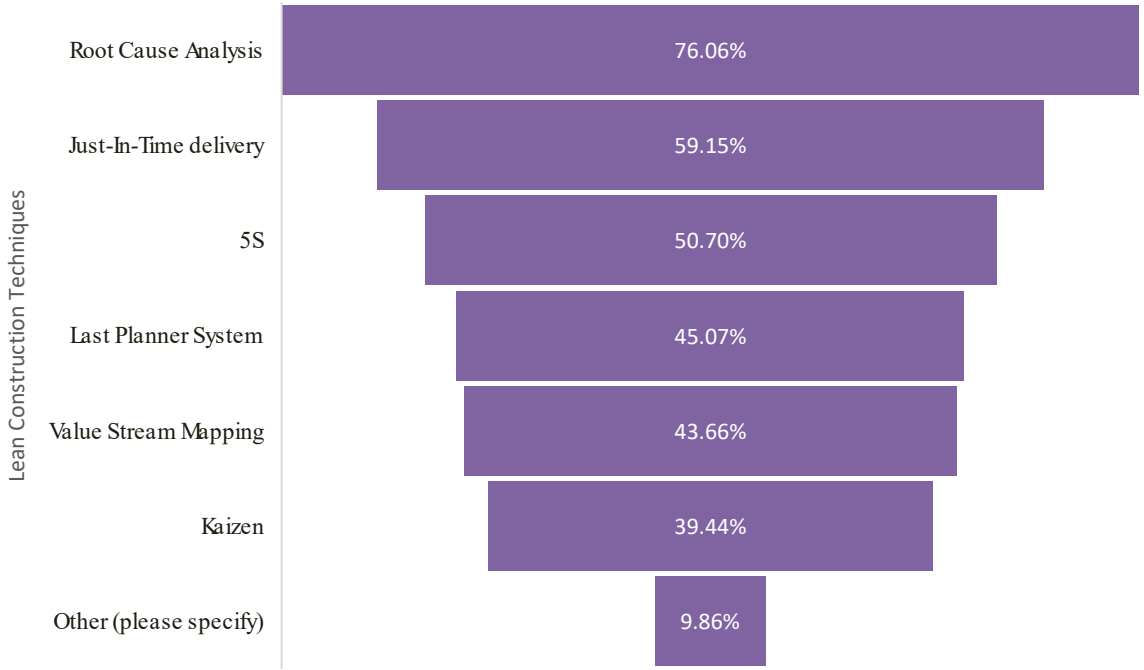


Figure 4 Practitioner awareness levels of selected Lean Construction techniques (% of respondents, n = 71). Source: Practitioner survey, 2023.

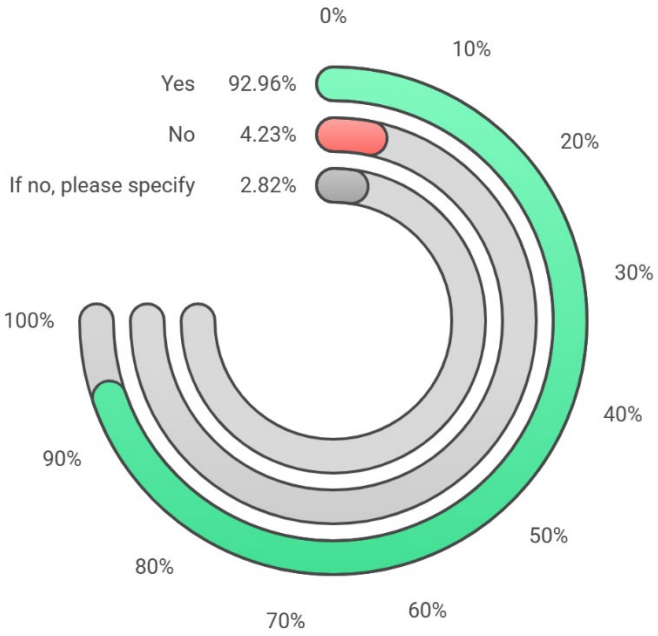
The survey also asked respondents what **outcomes they would expect from integrating Lean techniques** in road projects (a multi-select question). The top expected outcomes were: *Reduction in project delays* (85% of respondents), *Cost savings* (75%), *Reduction in waste* (66%), *Enhanced project quality* (61%), and *Improved resource allocation* (52%). Stakeholder satisfaction and improved work environment were noted by approximately 50–60% as well. These expectations align perfectly with what Lean Construction strives to deliver. It shows that the concept of Lean (even if not fully understood in terms of tools) resonates with what practitioners *want* on-time, on-budget projects with less waste. The fact that "reduction in delays" tops the list by far is reflective of the chronic delay issue; professionals are essentially saying, "if Lean can help us finish on time, we want it." Figure 5 presents these outcomes.

Figure 5 Expected outcomes from adopting Lean Construction practices in Qatar's road sector (% of respondents, n = 71).Source: Practitioner survey, 2023

However, expecting outcomes is different from actually implementing practices. The survey indicated that implementation of Lean in practice remains limited. Only 23% of respondents reported that they have worked on a project that formally adopted Lean Construction practices (not counting isolated use of tools like RCA) – this statistic is gleaned from a combination of responses and follow-up clarifications (the survey had an item on whether their organization had any Lean initiative, which yielded a similar proportion). This reinforces that Lean is still in nascent stages in Qatar, mostly at the awareness or trial phase rather than full integration.

One interesting question gauged openness to improvement frameworks: *"Would you support the development of a resilience-based framework for road construction projects in Qatar?"* – essentially asking if they are open to new structured approaches for project improvement. An overwhelming 93% said Yes, as shown in Figure 6. This suggests that the industry is receptive to change and improvement frameworks in principle; the challenge is

translating that goodwill into concrete Lean adoption. It is possible that many respondents interpreted "resilience-based framework" as something beneficial, coupled with other results, it can be read as a general support for improvement initiatives.



Note: Percentages represent categorical survey responses (Yes / No / If no, please specify); circular visualisation is used for proportional comparison

Figure 6 Practitioner support for the development of a structured improvement framework for road construction projects in Qatar (% of respondents, n = 71). Source: Practitioner survey, 2023.

Qualitative Insights: Benefits and Challenges of Lean Implementation

To complement the quantitative survey results, qualitative interviews were conducted with project managers, engineers, and key stakeholders involved in Lean pilot initiatives within Qatar's road construction sector. These interviews provided deeper insight into how Lean techniques translated into practice on-site, the tangible benefits observed by practitioners, and the challenges faced during implementation. The findings illustrate not only the operational improvements achievable through Lean but also highlight the human and organizational factors influencing success. Table 2 summarizes the key benefits, challenges, and enabling strategies identified through these stakeholder narratives, offering practical perspectives to guide future Lean adoption.

Overall, these qualitative findings underscore that while Lean Construction offers clear operational and organizational benefits, its successful implementation depends on overcoming cultural, skill, and management challenges within the project environment. The insights gathered provide practical evidence that with targeted training, leadership commitment, and pilot initiatives to build momentum, Lean practices can deliver measurable improvements in schedule adherence, resource efficiency, and project quality within Qatar's road construction

sector. These learnings directly inform the discussion on scaling Lean adoption across the industry to support broader efficiency and sustainability goals.

Table 2: Summary of Lean Implementation Insights from Qualitative Interviews

Aspect	Details
Observed Benefits	▪ Improved schedule control (PPC ↑ from ~60% to 80%) ▪ Enhanced site coordination (daily huddles, Kanban) ▪ Resource efficiency (10–15% reduction in idle equipment time) ▪ Quality and safety improvements (via 5S, RCA)
Challenges Faced	▪ Cultural resistance to new practices ▪ Skill and knowledge gaps requiring training ▪ Inconsistent management support ▪ Limited supply chain engagement
Enabling Factors	▪ Targeted training programs ▪ Pilot projects for demonstration ▪ Leadership commitment ▪ Creation of lean champions

Case Study: Lean Implementation in a Government Road Agency's Projects

In a significant road upgrade project selected for this Lean pilot, the government road agency systematically introduced a strategic bundle of Lean tools and methodologies designed to optimize project efficiency, predictability, and overall performance. The core elements of this Lean intervention included:

- **Last Planner System® (LPS®):** This collaborative planning and scheduling system served as the foundational backbone, fostering commitment-based planning among project participants.
- **Weekly Percent Plan Complete (PPC)** Tracking: A key performance indicator (KPI) used to rigorously monitor and evaluate the reliability of planned activities against actual completion, driving continuous improvement in planning accuracy.
- **Visual Project Performance Centre**: An electronic dashboard system established in the site office, providing real-time, transparent visualization of key project metrics, progress, and potential issues for immediate team awareness and action.
- **Flow of Activities Charts**: These visual tools were employed for granular progress monitoring, enabling the identification of bottlenecks, optimizing workflow, and ensuring a smoother progression of tasks.
- **Regular Root Cause Analysis (RCA):** A systematic problem-solving approach applied to investigate any deviations from the plan, quality issues, or safety incidents, facilitating proactive learning and the implementation of corrective actions to prevent recurrence.

Observed Outcomes of Lean Implementation

Following the implementation of the aforementioned Lean methodologies, several notable improvements were observed and documented (summarized in Figure 7):

- **Schedule Performance Enhancement**
  - The project's schedule performance demonstrated a significant and consistent improvement. Percent Plan Complete (PPC) was used as an indicator of planning reliability within the case study; the PPC definition, calculation protocol, and monitoring period are provided in Appendix A. The initial Percent Plan Complete (PPC) typically averaged around 60%. However, within approximately four months of the Lean implementation, the PPC consistently stabilized in the range of 80–85%. This marked improvement directly correlated with the project's ability to recover from earlier delays, culminating in the successful completion of Phase 1 on time. This achievement stands in stark contrast to the historical trend of similar projects undertaken by the agency, which frequently experienced delays.
- **Resource Efficiency and Savings**
  - The adoption of structured planning and Lean principles led to tangible efficiencies in resource utilization. Internal reports and interviews indicated an estimated 15% reduction in the over-ordering of materials, particularly for high-volume items such as concrete and asphalt. Concurrently, workforce productivity, assessed by the quantity of work completed per labor hour, saw an estimated increase of approximately 10%. While these figures are acknowledged as estimates, they provide strong evidence of a positive trend in optimizing resource allocation and reducing waste.
- **Safety Performance Improvement**
  - While the project recorded zero lost-time injuries during the Lean implementation period, this outcome should be interpreted cautiously. Safety performance is influenced by multiple contextual factors, including organisational safety culture, regulatory oversight, and parallel safety initiatives. Interviewees indicated that improved site organisation, clearer task sequencing, and enhanced communication often associated with Lean practices such as 5S and daily coordination contributed indirectly to safer working conditions. However, safety improvements cannot be attributed solely to Lean implementation.

Challenges Encountered During Implementation

Despite the successes, the implementation journey was not without its challenges. The initial weeks of Last Planner meetings, for instance, were described as "chaotic and frustrating" until roles and processes became clearer through persistent effort and training. Furthermore, a significant challenge involved the necessity to replace one subcontractor who demonstrated a consistent refusal to cooperate with the new Lean system. This decisive

action, however, was critically enabled by the strong backing and support from the client (the governmental authority), underscoring the importance of top-level commitment.

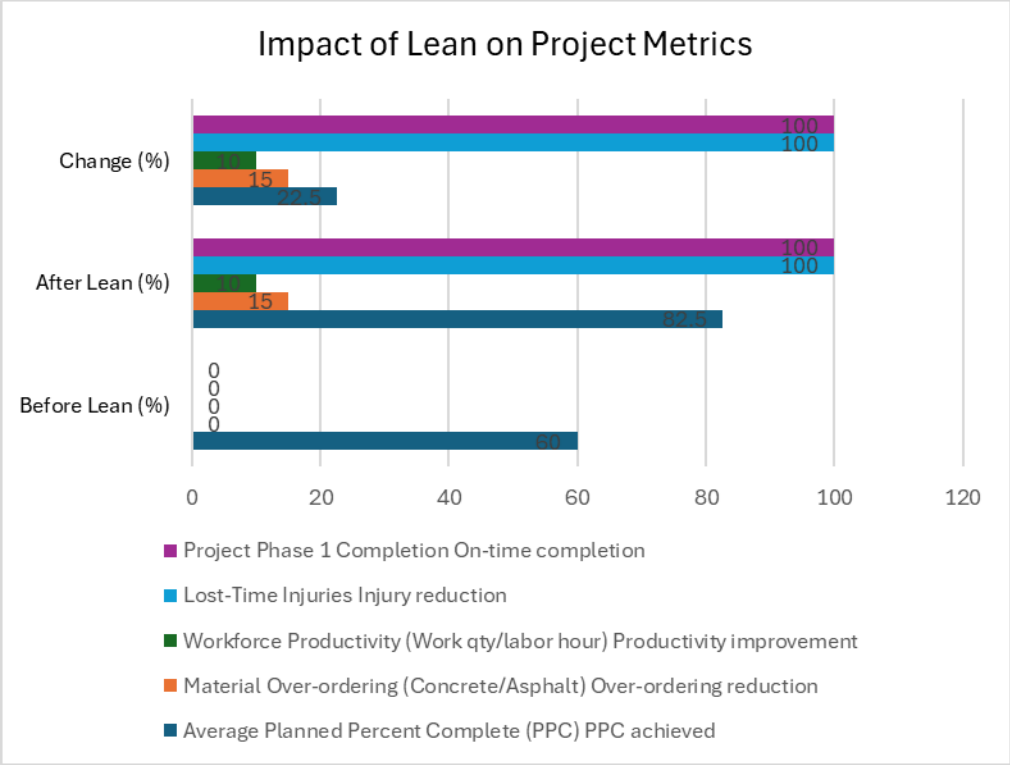


Figure 7 Impact of Lean Construction implementation on key project performance metrics in a government road project in Qatar. *Source: Project performance reports and weekly planning records (2023)*

Discussion and Implications

The case of this government road agency vividly demonstrates that Lean Construction principles are not only theoretically applicable but also highly effective within the Qatari construction context, yielding substantial and tangible benefits across schedule, resource, and safety metrics. This real-world validation significantly informed our broader analysis and subsequent recommendations. The successful outcomes underscore that effective Lean implementation necessitates persistent effort, continuous training for all stakeholders, and, crucially, unwavering support and endorsement from top management or the client. The agency's experience also provides valuable insights into the efficacy of specific Lean tools, with the Last Planner System® serving as a foundational backbone, complemented by Flow of Activities and Kanban (as noted by the project team) in driving project performance. This case study serves as a compelling reference point for future Lean adoption strategies within the region's infrastructure sector.

Discussion

Lean Construction is often mischaracterised as a philosophy of "doing more with less," reinforcing a narrow interpretation focused solely on waste reduction. In contrast, foundational Lean thinking emphasises learning, capability development, and reliable production through respect for people and scientific problem-solving (Rother 2009, Tapase 2019). Within construction, Lean seeks "less uncertainty and more reliability," achieved through commitment-based planning, proactive constraint removal, and structured reflection on performance gaps. The improvements observed in this study should therefore be interpreted not as efficiency gains driven by pressure or intensification, but as outcomes of improved production control and learning embedded in daily project routines.

This study aimed to evaluate the current state of efficiency in Qatar's road construction projects and assess the potential of Lean Construction techniques to address identified inefficiencies, aligning with global and regional sustainability and productivity goals. The mixed-methods approach, using surveys, stakeholder interviews, and a targeted case study, provided a comprehensive understanding of both perceived and actual project challenges and the impact of Lean implementation.

The survey results confirmed that inefficiencies, particularly project delays and resource wastage, are prevalent and systemic in Qatar's road projects, aligning with regional studies highlighting chronic schedule overruns and cost inefficiencies (O. Salem 2005).The execution phase was identified as the most problematic, underscoring the need for interventions that directly address site-level coordination and workflow areas where Lean Construction has shown effectiveness in prior studies(Ballard 1998, Koskela 1992).

The observed improvements in schedule adherence, material utilization, and productivity are best understood through Lean Construction's production control and learning mechanisms rather than through waste reduction alone. The increase in PPC from approximately 60% to 80–85% reflects enhanced commitment reliability and improved coordination among planners, supervisors, and crews. Structured weekly planning, visual management, and systematic constraint removal enabled teams to surface problems earlier and respond through PDCA-based learning cycles. Similarly, reductions in material over-ordering and productivity gains emerged from better planning accuracy and shared understanding of work conditions, reinforcing Lean's socio-technical emphasis on collaboration and respect for people.

The survey results indicate that Qatar's road construction sector exhibits similar Lean adoption patterns to those reported in the region. Respondents generally recognized the importance of waste reduction and value generation, but many were unfamiliar with formal Lean terminology. This echoes the findings of (Binu and Gupta 2024), who found UAE engineers understood Lean concepts even if they could not name them. In the sample, roughly one-third of respondents reported using Lean techniques in their projects, consistent with (Al-Aomar 2012) observation of limited Lean familiarity (about 32% in Abu Dhabi). Participants did identify waste categories in road construction (such as rework, waiting, and over-specification) that align with the 27 waste categories described by (Al-Aomar 2012).

Key barriers cited by respondents included resistance to change, lack of motivation, and communication issues – the same cultural and organizational factors emphasized by (Binu and Gupta 2024, Abu Daqar 2025). For instance, several participants noted that traditional "can-do" culture and top-down decision-making hinder open discussion of problems – a sentiment also reported by (Ballard 1998) as a common retort to Lean initiatives. These findings suggest that, as in other Gulf contexts, the main obstacles to Lean in Qatar are people and process issues rather than a complete lack of awareness.

The qualitative interviews reinforced these findings, illustrating that Lean implementation, even at a pilot level, led to measurable improvements in schedule adherence (PPC increasing from ~60% to 80–85%), material savings (~15% reduction in over-ordering), and workforce productivity (~10% increase). These results mirror the outcomes reported in global case studies, such as those by (Alchamaa and Abushaqra 2023, Valente et al. 2020), demonstrating the adaptability and impact of Lean principles across contexts.

However, challenges including cultural resistance, skill gaps, and inconsistent management support were also evident, emphasizing the need for targeted training, clear communication, and leadership commitment to enable Lean adoption. The case study of the government road agency highlighted that success was closely linked to persistent efforts, structured piloting, and top-level support, aligning with literature underscoring leadership as a critical enabler for Lean implementation (Ojo 2019, Al-Buenain et al. 2020).

Overall, the findings validate that Lean Construction can serve as a practical framework for improving project efficiency in Qatar's road construction sector. The results directly address the research objectives by demonstrating the current inefficiencies, the potential benefits of Lean, and the conditions required for successful implementation. This positions Lean as a viable strategy for supporting Qatar's national visions of sustainable infrastructure development and productivity enhancement.

Future research could focus on developing a contextualized Lean implementation framework tailored for the Gulf region, integrating resilience and digital Lean tools to address local challenges while aligning with global sustainability goals. Table 3 summarizes these barriers and corresponding strategies.

Conclusion and Recommendations

Conclusion

This study comprehensively examined the application and effectiveness of Lean Construction techniques within Qatar's road construction sector. Employing a robust mixed-methods research design, which incorporated practitioner surveys, stakeholder interviews, and an in-depth case study, the study uncovered substantial inefficiencies prevalent within the sector, notably project delays, excessive resource wastage, and inadequate inter-team coordination. Despite moderate practitioner awareness regarding Lean Construction principles, widespread adoption remains limited, underscoring significant knowledge and implementation gaps.

Table 3: Identified Barriers to Lean Implementation in Qatar's Road Construction and Corresponding Strategies

Category of Barrier	Specific Manifestations in Qatar's Context	Recommended Strategies for Overcoming	Theoretical / Contextual Link
Human & Cultural Factors	Resistance to change, lack of awareness, insufficient management support, inertia of established habits/attitudes.	Training & Education (practical, success stories), Leadership & Change Management (visible support, champions), Pilot Projects (gradual adoption).	Consistent with global findings aligns with Kotter's 8-step model and change management theories.
Communication & Language Issues	Multinational workforce, implied by survey respondents noting "poor communication" as a challenge.	Visual tools, bilingual materials, incorporating communication skills into lean training, use of technology (translation apps).	Critical for collaborative tools like Last Planner System®.
Lack of Integrated Stakeholder Collaboration	Subcontractors/external parties slow to adopt lean, traditional lowest bid/siloed contracts.	Evolving contract forms (partnering, joint risk-reward), adjusting procurement approaches to facilitate collaboration.	Lean demands collaboration; often hindered by traditional contracting. Government influence is strong here.
Skill Gap & Educational Needs	Lean not prominently taught in local engineering/CM programs, companies rely on workshops/consultants.	Incorporating lean into university curricula, professional development courses, external consultants, workshops.	Crucial for creating a lean-literate workforce.
Lack of Institutional/Policy Support	Industry "waiting for leadership/policy signals" (93% support for structured framework), lean not formalized.	Policy & Client Support (mandates, incentives from Ashghal), Integrating Lean into Processes & Standards (SOPs, KPIs).	Aligns with socio-technical systems thinking; government influence is catalytic for widespread adoption.

Nevertheless, empirical evidence from the case study demonstrated clear and measurable benefits resulting from the application of Lean Construction tools such as the Last Planner System® (LPS®), Kanban boards, and Value Stream Mapping (VSM). The pilot project notably improved schedule adherence, substantially increased resource efficiency, enhanced productivity, and significantly boosted site safety, providing compelling evidence of Lean

techniques' effectiveness in addressing chronic industry inefficiencies. Future research should focus on developing a Gulf-context Lean Construction implementation roadmap that integrates socio-technical principles with local institutional, cultural, and contractual conditions. Particular attention should be given to the role of public-sector clients in enabling Lean through procurement policies, performance metrics, and training requirements. Additionally, the integration of digital Lean tools—such as BIM-enabled visual management, real-time PPC dashboards, and data-driven learning systems—offers promising opportunities to scale Lean adoption and sustain continuous improvement across infrastructure programs.

Recommendations

Building upon the findings and insights generated by this research, several actionable recommendations are proposed to accelerate and solidify Lean Construction adoption in Qatar's road construction sector:

- Targeted Capacity-Building: Develop and implement comprehensive, structured training programs focused explicitly on Lean principles and tools. These programs should be tailored to meet the specific needs of various stakeholder groups, including senior management, engineers, frontline supervisors, and workers, thereby enhancing organizational-wide understanding and practical application of Lean methodologies.
- Leadership and Commitment: Foster strong leadership commitment to Lean adoption by clearly defining implementation goals and establishing accountability mechanisms at senior management levels. Organizations should actively promote and visibly support internal Lean champions, reinforcing Lean initiatives through dedicated resources and strategic communication.
- Policy and Incentives: Formulate and enforce robust governmental policies and regulatory incentives designed to motivate and facilitate Lean Construction practices across the industry. Influential clients, such as government road agencies, should leverage their procurement power by embedding Lean requirements and performance metrics into contractual frameworks.
- Communication and Collaboration: Strengthen communication and collaborative structures, particularly within multinational and multidisciplinary project teams. This can be achieved through multilingual training resources, visual communication tools, regular collaborative planning sessions, and fostering an organizational culture that promotes openness, transparency, and continuous improvement.
- Pilot Projects for Demonstration and Scaling: Continuously invest in and support pilot Lean Construction projects to demonstrate tangible benefits clearly and convincingly. Successful pilot outcomes should be systematically documented, analyzed, and communicated broadly within the industry to encourage adoption, create internal advocates, and facilitate knowledge dissemination.
- Monitoring and Continuous Improvement: Establish comprehensive monitoring and evaluation frameworks to track Lean adoption progress, document lessons learned, and facilitate continuous improvement. Regular performance reviews using

standardized Key Performance Indicators (KPIs) should inform iterative adjustments and refine Lean implementation strategies.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the case study focuses on a single government road agency project, which may limit generalisability to other organisational or contractual contexts. Second, portions of the data rely on practitioner self-reporting, which may introduce perception bias. Third, while before-and-after comparisons indicate positive trends, controlled experimental conditions were not feasible in an active construction environment. Despite these limitations, triangulation across surveys, interviews, and case evidence strengthens the credibility of the findings.

Future work

Future research should focus on developing a Gulf-context Lean Construction implementation roadmap that integrates socio-technical principles with local institutional, cultural, and contractual conditions. Particular attention should be given to the role of public-sector clients in enabling Lean through procurement policies, performance metrics, and training requirements. Additionally, the integration of digital Lean tools such as BIM-enabled visual management, real-time PPC dashboards, and data-driven learning systems offers promising opportunities to scale Lean adoption and sustain continuous improvement across infrastructure programmes.

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Appendix 1

This appendix provides supplementary methodological detail to support transparency and traceability, consistent with Lean Construction Journal guidance. It includes the survey instrument and sampling frame, the Percent Plan Complete (PPC) measurement protocol used in the case study, and clarification of case study data sources and time windows. These materials are provided to enable replication and interpretation of results without duplicating content presented in the main text.

A.1 Survey Questions

Please read and confirm the below		
Answer Choices	**Responses**	
I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily		
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights.		
I understand that any personal information collected during the study will be anonymised and remain confidential		
I agree to take part in the above study.		
Answered		
Skipped		

Your role in the construction industry:

Answer Choices	Responses	
Project Manager		
Engineer		
Contractor		
Consultant		
Supplier		
Other (please specify)		
Answered		
Skipped		

How many years of experience do you have in the construction industry?		
Answer Choices	Responses	
Less than 5 years		
5-10 years		
11-20 years		
More than 20 years		
Answered		
Skipped		

Have you worked on road construction projects in Qatar?		
Answer Choices	Responses	
Yes		
No		
Answered		
Skipped		

How would you assess the efficiency of road construction projects in Qatar?

Answer Choices	Responses	
Exceptional Efficiency - Projects are optimized outstandingly with minimal need for improvement.		
Very Efficient - Projects are largely efficient, with only minor areas needing enhancement.		
Satisfactory Efficiency - Projects meet basic expectations but have room for moderate improvement.		
Below Expectations - Projects are inefficient and require substantial improvements.		
Poor Efficiency - Projects are significantly inefficient, falling short of expectations and needing major enhancements in all aspects.		
Answered		
Skipped		

What do you consider the biggest challenges in road construction projects in Qatar?		
Answer Choices	Responses	
Project delays		
Cost overruns		
Resource wastage		
Labor shortages		
Quality control issues		
Poor communication		
Other (please specify)		
Answered		
Skipped		

which of the following lean techniques are you aware of? (Select all that apply)

Answer Choices	Responses	
Just-In-Time delivery		
Last Planner System®		
Value Stream Mapping		
Kaizen		
Root Cause Analysis		
5S		
Other (please specify)		
Answered		
Skipped		

From your experience, how effective are Lean Construction techniques in addressing construction inefficiencies?		
Answer Choices	Responses	
Extremely effective		
Very effective		
Somewhat effective		
Not so effective		
Not at all effective		
Answered		
Skipped		

How would you rate the importance of systematized management of resources in construction projects?		
Answer Choices	Responses	
Critical (Most Important)		
Significant		
Moderate		
Insignificant		
Trivial (Least Important)		
Answered		
Skipped		

In your opinion, which areas of resource management need the most improvement in Qatar's road projects?		
Answer Choices	Responses	
Material sourcing		
Inventory management		
On-site material handling		
Equipment utilization		
Workforce allocation		
Other (please specify)		
Answered		
Skipped		

What outcomes do you expect from the integration of lean techniques in road construction projects? (Select all that apply)		
Answer Choices	Responses	
Reduction in project delays		
Cost savings		
Reduction in waste		
Improved resource allocation		
Enhanced project quality		
Stakeholders satisfaction		
Enhanced work environment		
Other (please specify)		
Answered		
Skipped		

Would you support the development of a resilience-based framework for road construction projects in Qatar?		
Answer Choices	Responses	
Yes		
No		
if no (please specify)		
Answered		
Skipped		

Which of the below phase of road construction faces the most significant challenges in Qatar?		
Answer Choices	Responses	
Planning		
Design		
Execution		
Maintenance		
Other (please specify)		
Answered		
Skipped		

How often do delays occur in road construction projects in Qatar?		
Answer Choices	Responses	
Frequently		
Occasionally		
Rarely		
Answered		
Skipped		

Have you encountered issues related to material waste or inefficiency in resource utilization during road construction? If yes, please describe.		
Answer Choices	Responses	
Yes, excessive material waste		
Yes, inefficient resource utilization		
No, effective management		
Other (please specify)		
Answered		
Skipped		

What are the common safety concerns or incidents observed during road construction activities in Qatar?		
Answer Choices	Responses	
Accidents due to inadequate safety protocols		
Incidents related to heavy machinery operations		
Unsafe working conditions		
Minimal safety concerns, stringent measures		

Other (please specify)		
Answered		
Skipped		

In your experience, have there been instances of rework or errors that significantly impacted project timelines or costs? Please elaborate.		
Answer Choices	Responses	
Yes, frequent rework		
Yes, occasional errors		
No, rare impact		
Other (please specify)		
Answered		
Skipped		

Do you recommend the implementation of Integrated Project Delivery in Road projects in Qatar?		
Answer Choices	Responses	
Yes		
No		
Answered		
Skipped		

Section 1: Awareness and Understanding

1. How familiar are you with Lean Construction principles?
2. What does “Lean Construction” mean to you?
3. Can you name any Lean techniques or tools commonly used in road projects?

Section 2: Current Practices

4. Are Lean techniques currently being applied in your organisation’s road projects? If yes, which ones?
5. Have you ever used the Last Planner System® (LPS®) in your projects? If yes, what was your experience?
6. How are project planning and scheduling typically handled in your projects?

Section 3: Perceived Benefits

7. What benefits do you think Lean Construction could bring to road construction projects in Qatar?
8. Do you believe Lean can help reduce waste and improve efficiency in your projects? Why or why not?

Section 4: Barriers and Challenges

9. What challenges have you experienced or observed in implementing Lean techniques?

10. Do cultural factors (such as traditional "can-do" mindset or top-down decision-making) affect Lean adoption in your projects? How?
11. Are there any resource or organisational barriers to Lean implementation (e.g., training, management support)?

Section 5: Enablers and Recommendations

12. What factors do you think are necessary for successful Lean implementation in Qatar's road sector?
13. How can management support or training programmes improve Lean adoption?
14. What suggestions would you give to encourage wider Lean application in road construction projects?

Section 6: General Information

15. What is your role in the project?
16. How many years of experience do you have in the construction industry?
17. Have you previously worked on projects outside Qatar? If yes, did you observe any differences in Lean practices?

A2. Percent Plan Complete (PPC)

Percent Plan Complete (PPC) was used as an indicator of planning reliability within the case study project. PPC was calculated weekly during Last Planner System® meetings as the ratio of completed planned commitments to total commitments made for that week. Planned commitments were defined as tasks agreed by the last planners during weekly planning meetings. Baseline PPC values (approximately 60%) were observed prior to Lean implementation, while post-implementation PPC values (80–85%) were recorded over a four-month monitoring period following the introduction of Lean practices. PPC results were used by the project team as a learning signal to support constraint removal, corrective action, and continuous improvement, rather than as a performance enforcement metric.