



Impacts of COVID-19 on Sri Lankan Road Projects: Multi-Class Delay and Resilience Analysis

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Abstract

Road infrastructure delivery in lower-middle-income economies was severely tested by the COVID-19 pandemic, yet whether impacts differ across road classes and governance roles remains unclear. This paper investigates 55 Sri Lankan Road projects—Classes A, B, C, expressway and rural—active during the peak disruption window (Q4 2020–Q3 2021). A paired-response survey generated 110 matched client- and contractor-side questionnaires, supplemented by semi-structured interviews. Detrended Correspondence Analysis, independent-samples t-tests, one-way ANOVA and Pearson correlations mapped latent impact clusters and quantified stakeholder divergence. Mean schedule slippage ranged from 14 % to 27 % with no significant road-class effect ($p > 0.5$). Contractors reported markedly higher health risk (56 % vs 36 %), deeper cash-flow stress (43.8 % vs 29.2 %) and only 6 % remote-work capability compared with clients' 44 %. Labour attrition (14–27 %) and material shortages (< 5 %) were lower than published benchmarks for the UK (≈ 40 –60 %) and Nepal (≈ 35 %), indicating that finance and workforce health—rather than inputs—were the principal bottlenecks. Adaptive measures such as precast adoption (45 %), staggered shifts and digital progress certification correlated moderately with shorter delays ($r = 0.52$ –0.63). The study contributes (i) a stakeholder–road-class impact matrix to prioritise contingency support, (ii) a crisis-optimised rapid-survey protocol applicable in data-scarce settings, and (iii) policy guidance embedding pandemic-specific force-majeure clauses and real-time payment certification to hard-wire resilience. Findings extend project-resilience theory and inform emergency-financing frameworks for future systemic shocks.

Keywords: pandemic disruption; schedule overrun; labour attrition; cash-flow stress; governance divergence; lower-middle-income context

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1. Introduction

The COVID-19 pandemic was declared a global emergency by the World Health Organization. It caused unprecedented economic losses worldwide and created severe socio-economic impacts globally. The crisis was deemed the worst economic threat since the Great Recession. COVID-19's economic impact exceeded the 2008-2009 financial crisis. It was a disaster comparable to the 1918 Spanish Flu pandemic in terms of global scale and economic disruption. The extensive economic damage from COVID-19 forced international organizations to revise their 2020 economic forecasts downward [1, 2]. The World Bank predicted global GDP would shrink 5-7%. Many countries saw sharp GDP declines. This dwarfed the economic impact of previous major epidemics like SARS, MERS, and Ebola [2-4]. Transport sectors experienced immediate disruption, with mobility restrictions requiring fundamental changes to road, rail and aviation operations during extended emergencies[5-9]. Subsequent waves pivoted from acute disruption to the harder task of retro-fitting infrastructure for safe, flexible and resilient use—a challenge magnified in low- and middle-income countries where fiscal buffers are thin [10, 11].

Sri Lanka's construction industry, which contributed approximately 9.4% of GDP in 2012 and averaged 6-8% of GDP during 2010-2019, experienced severe disruption across multiple dimensions [12-14]. Its value-added plunged 20.9% in 2022, with 90% of work stalled by September 2022 [15]. The wider economy's real GDP growth slipped to -3.57% in 2021, exposing chronic liquidity shortages, untenable credit conditions, rising bankruptcies, and widespread client and contractor financial distress—the primary drivers of project delays [15, 16]. Supply-chain vulnerabilities amplified the economic damage through multiple pathways. Import restrictions and border closures increased cement and clinker prices, affecting the 60% of building materials that Sri Lanka imports. Simultaneously, lockdown measures rendered perishable construction supplies unusable, necessitating costly disposal and replacement cycles. Multiple concurrent crises compounded the pandemic's impact: ongoing recovery from the 2019 Easter bombing attacks, political instability, and a severe fuel-electricity shortage collectively halted 90% of construction work by late September 2022. The road subsector, overseen by the Road Development Authority (RDA), faced an equity dilemma: project scales ranged from kilometre-long rural upgrades to expressway megaprojects, making one-size-fits-all policy responses prone to unintended consequences [15, 17, 18].

International studies document similar pandemic impacts on construction sectors but rarely examine road-class-specific or stakeholder-differentiated effects. UK evidence links COVID-19 to acute labour attrition and subcontractor insolvency; Indonesian and Nepali reports flag chronic materials bottlenecks and idle equipment. Comparative surveys across Asia note that remote-work options cushioned client agencies more than contractors or on-site professionals. Yet these cross-country papers typically treat “construction” as a monolith, overlooking how road-type (A, B, C, expressway, rural) or governance role (client vs contractor) mediates pandemic effects [16, 19, 20].

Although COVID-19 construction research has expanded rapidly, three critical knowledge gaps persist. First,

road-type differentiation remains underexamined. Few studies distinguish between high-traffic A-class highways—characterized by stringent design standards, heavy material dependencies, and large crew requirements—and low-volume rural roads that operate under different logistical and workforce constraints. Second, stakeholder divergence is obscured by aggregated survey data, masking the contrasting experiences of government clients, who oversee budgets and policy, and contractors, who bear day-to-day operational risks and cash-flow pressures. Third, regional heterogeneity is scarcely mapped, despite pronounced variation in pandemic intensity across Sri Lanka's nine provinces; without fine-grained geographic analysis, it is impossible to tailor contingency finance arrangements, labour scheduling protocols, and supply-chain agreements to local conditions [21-23].

Untangling these dimensions is critical for tailoring contingency finance, labour scheduling and supply-chain agreements. Accordingly, the present study moves beyond sector-level generalisations and adopts a fine-grained, multivariate examination of how road class, stakeholder role and region jointly shaped pandemic outcomes.

Aim is to quantify how road class, stakeholder role (client vs contractor) and region jointly shaped COVID-19 impacts on Sri Lankan road projects during Q4 2020–Q3 2021. To operationalise this aim, the study pursues four tightly scoped objectives. First, we quantify the differential impacts of COVID-19 across five road classes (A, B, C, expressway, rural) and nine provinces by analysing survey data from 55 (drawn from an initial sample of 98) projects monitored during Q4 2020–Q3 2021. Second, we compare client and contractor perspectives on construction delays, labour losses, health outcomes, environmental disruptions, and financial pressures to identify areas of perceptual convergence and divergence. Third, we interrogate both reactive (e.g., site shutdown protocols) and proactive (e.g., modular precast adoption) mitigation strategies to catalogue best practices for enhancing project resilience. Finally, we benchmark Sri Lankan findings against international evidence on labour disruptions and supply-chain fragility, thereby situating our results within the broader global context.

We demonstrate that COVID-19 induced a 14–27% delay range across Sri Lankan road projects, with striking client–contractor perception gaps but surprisingly modest variation by road class; we then identify targeted adaptive practices that can hard-wire resilience into future road-infrastructure delivery.

The paper delivers three core contributions toward resilient road-infrastructure planning under systemic shocks: (i) a stakeholder–road-class impact matrix quantifying delay and disruption intensities by role and road category to prioritise targeted support, (ii) a crisis-optimised rapid-survey protocol with Cochran-verified statistical rigour ($n = 98$) suited to data-scarce conditions, and (iii) an evidence-based policy agenda embedding pandemic-specific force-majeure clauses, digitally certified progress payments, and region-specific stockpiling to pre-empt cash-flow and supply-chain fragility. By integrating fine-scale analytics with comparative insights, the paper provides a template for other lower-middle-income nations seeking to safeguard strategic road networks against future systemic shocks.

2. Materials & Methods

The investigation canvassed 16 of Sri Lanka's 25 administrative districts, ensuring at least one district from each of the nine provinces and spanning the full climatic and socio-economic gradient that influences road-construction

practice. Data collection spanned the last quarter of 2020 through the third quarter of 2021—the period in which pandemic-related restrictions were most volatile. Within this window, the Road Development Authority (RDA) supervised 1,013 live projects—spanning flagship expressways (Central, Ruwanpura), the 100,000 km rural-link upgrade, and the province-led i-Road programme—constituting the sampling frame for this cross-sectional survey. Roads were stratified into five technical classes (A, B, C, expressways, rural) to allow class-sensitive inference [24]. A sketch map (Figure 1) situates the sampled districts and highlights the density of projects along the Western and Central corridors, echoing the cartographic style adopted in Sample 4.

Targeted sampling followed a two-step procedure. First, Cochran's finite-population correction determined the minimum sample size of 98 projects required for 95% confidence level, 10% margin of error, and conservative variance assumption ($S = 0.5$). The governing equations are reproduced in a boxed inset (Equations 1–2) to mirror the mix-design textbox presentation in Sample 3. Second, purposive invitations were sent to individuals in decision-making or site-supervisory roles across 98 systematically selected projects meeting these statistical requirements. Project-level clearance was ultimately granted for 55 of these; from each approved project we surveyed one client-side and one contractor-side professional; this yielded 110 fully completed questionnaires (response rate = 77%), evenly split between RDA officials and contractor staff. Additional face-to-face interviews with labourers supported verbal data capture, while on-line consultations with Project Directors, Chief Engineers and Site Engineers triangulated management-level perspectives. The resulting dataset thus reflects the complete hierarchical chain from policy to execution.

The research instrument comprised a three-part questionnaire supported by semi-structured interview guides and organized in a hierarchical format progressing from general to specific inquiries. Part A captured respondent and project profiles—recording each participant's district, road class, contract value, and role (e.g., RDA official or contractor staff). Part B comprised a logistical-disruption log, quantifying work-refrain days, labour attrition, and material shortages experienced on each project. Part C employed dual-crisis diagnostics, combining 5-point Likert scales with open-ended prompts to probe health-risk management, financial strain, schedule slippage, remote-work feasibility, and emergent innovations. This multi-tiered design ensured both quantitative robustness and the flexibility to explore nuanced, context-specific responses in crisis conditions.

A pilot with eight RDA engineers verified clarity; minor wording adjustments reduced ambiguity and sentence length, consistent with the plain-language recommendations in Sample 1. The final instrument required ≈ 25 minutes to complete on-line; skip logic ensured only context-relevant items were displayed.

Responses were pre-processed in IBM SPSS v22; outliers beyond ± 3 SD were inspected and retained if contextually plausible. Numeric variables were log-transformed using $y = \log(10 \cdot y + 1)$ to curb right skew. Assumptions of normality and homoscedasticity were verified via Kolmogorov–Smirnov and Levene tests, respectively, prior to inferential analyses.

The study's analytical framework comprised three sequential tiers, with all tests two-tailed at $\alpha = 0.05$ and effect sizes (Cohen's d , η^2) reported. First, exploratory ordination via Detrended Correspondence Analysis (DCA) in CANOCO 4.5 grouped projects by delay-%, labour-loss-%, and financial-loss indices, revealing latent impact

clusters. Second, independent-samples t-tests quantified client–contractor divergences, while one-way ANOVA with Tukey’s post-hoc adjustment assessed road-class and provincial variations. Third, Pearson correlations (weak $r = 0.30\text{--}0.49$; moderate $r = 0.50\text{--}0.69$; strong $r \geq 0.70$) gauged associations between mitigation measures and outcomes to support inference robustness.

Research ethics clearance was obtained from the SLIIT Engineering Faculty Board (Ref 2021/CE/032). Participation was voluntary, identities anonymised, and data stored on password-protected servers. A validation phase (mid-2022 – mid-2023) revisited key respondents to verify earlier answers once the acute emotional climate had subsided, thereby counteracting recall bias and reinforcing internal validity.

3. Results

Detrended Correspondence Analysis (DCA) of 110 responses from 55 projects revealed three distinct clusters (Figures 1-3): Class A projects and some rural projects grouped in the left quadrant, Class B projects and contractor responses concentrated centrally, and expressway projects with remaining rural outliers distributed in the right quadrant. Client observations occupied the left half-plane while contractor data centred on the origin, evidencing a moderate stakeholder split but limited separation by road class or province.

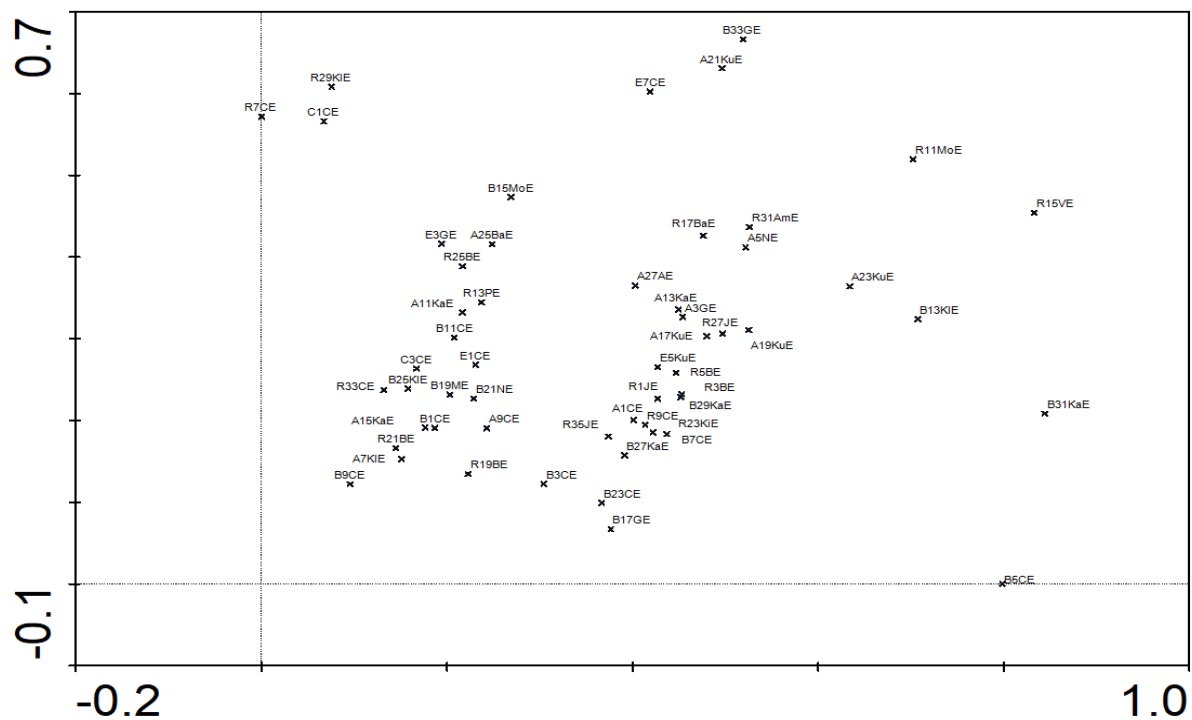


Figure 1: Detrended Correspondence Analysis of client responses.

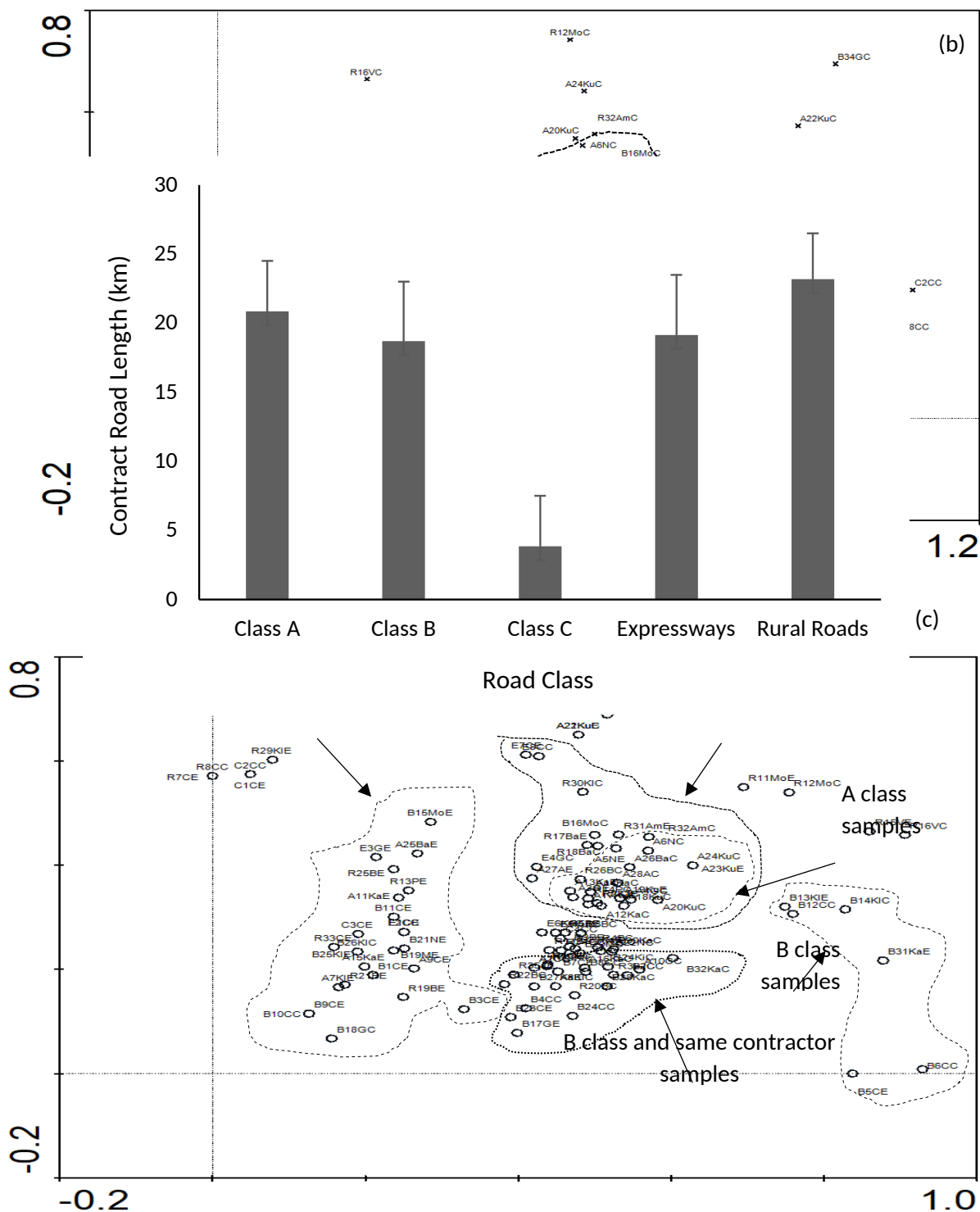


Figure 2: Detrended Correspondence Analysis of contractor responses.

Figure 3: Detrended Correspondence Analysis of combined client and contractor responses.

Across the inventory, contracts averaged 20.2 km in length and 16 months in duration; Classes A, B, expressway and rural assignments lay between 18 – 24 km, whereas Class C work averaged only 3.85 km (Figure 4). One-way ANOVA detected no significant length differences among road classes ($P > 0.9$). While the overall correlation between project length and duration was weak ($r = 0.12$; $P = 0.02$), Class C projects demonstrated a strong linear

relationship between these variables ($r = 0.98$; $P = 0.02$).

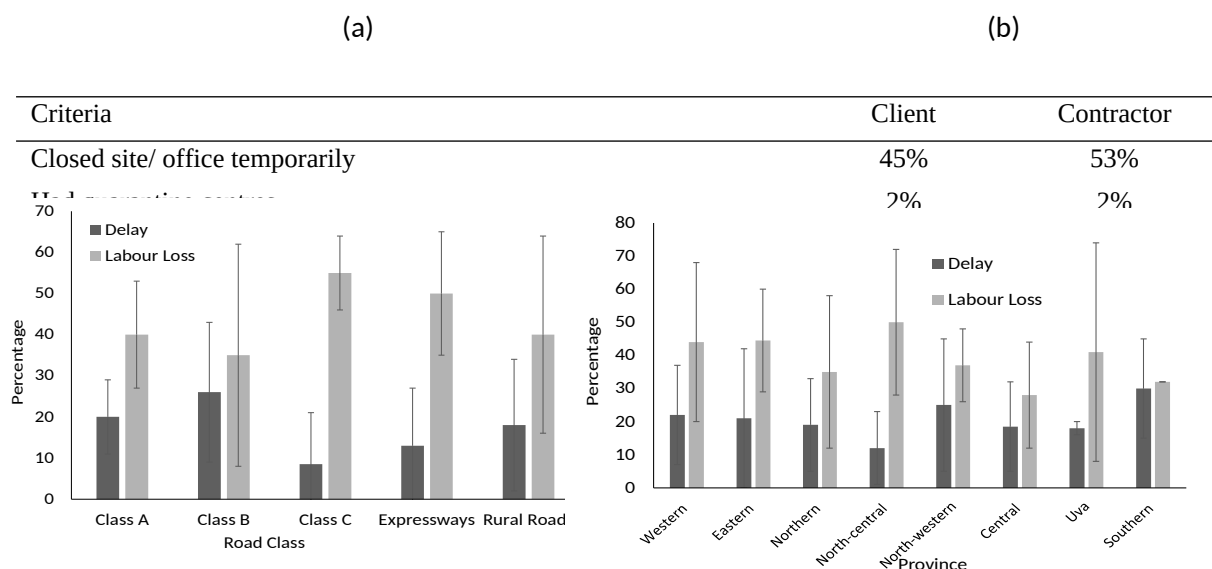
Figure 4: Road class vs. contract length.

Mean schedule slippage ranged from 14 % to 27 % across classes; although Class B showed the highest average delay (Figure 5). one-way ANOVA found that these differences were not statistically significant ($P > 0.5$). During national lockdowns 31% of projects could not work on-site, but subsequent overtime and labour-reinforcement allowed 22% to finish without delay. Wage increases by A, B and expressway contractors did not measurably curb labour attrition (n.s.), indicating that health-risk and mobility constraints—rather than pay rates—dominated retention dynamics during lockdowns.

Figure 5: Percentage delay and percentage labour loss by (a) road class and (b) province.

Remote delivery capability diverged sharply—44% of client personnel versus 6% of contractor staff could work off-site (t-test, $P < 0.01$)—a gap that helps explain contractors' higher reported cash-flow stress despite broadly similar material-supply conditions. Pandemic-induced mental-health strain was reported by 90% of all respondents, with no significant client-contractor difference ($P = 0.11$).

Table 1: Respondents' opinions on various factors.



Binary scoring (Table 1) confirmed near-universal acknowledgment of negative impacts: 96% of clients and 100% of contractors rated overall effects as “yes”. Health concerns were more prevalent among contractors (56% vs 36%; $P = 0.04$) and so were direct financial losses (43.8% vs 29.2%; $P < 0.01$). Material shortages remained

marginal (< 5%) and statistically trivial.

Table 2: Actions taken when COVID-19 cases occurred on site.

Factor	Scale	Client score	Contractor score
Overall impacts of work at the site	Yes (1) Maybe (2)	1.04±0.4	1.0±0.01
Impacts on the progress of work at the site	Yes (1) No (0)	0.92±0.6	0.96±0.4
Impacts on health and safety	Yes (2) No (1)	1.36±0.6	1.56±0.5
Environmental Impacts	Yes (1) No (0)	0.15±0.3	0.29±0.4
Availability of material	Yes (0) No (1)	0.02±0.2	0.04±0.15
Financial loss	Yes (2) No (1)	1.4±0.2	1.7±0.2

COVID-19 cases were logged on two-thirds of sites; when detected, both parties applied rapid closure or partial shutdown protocols with similar frequencies (Table 2). Looking forward, respondents prioritised (i) staggered shifts, (ii) on-site isolation hubs, and (iii) pre-fabrication of bridge beams as the top three adaptation strategies (Tables 3-4).

Table 3: Adaptation strategies to overcome lagging of project timeline.

Criteria	Client	Contractor
Hired more employees	33%	38%
Allocated more resources	2%	2%
Increased working hours	45%	49%
Worked on weekends	56%	58%
Enhanced planning	2%	2%
Worked as teams	2%	2%
Granted EOT	4%	0%
Hired more sub-contractors	0%	2%

Table 4: New construction methods.

Criteria	Client	Contractor
Work from home	2%	0%
Worked according to duty rosters	2%	2%
Had online meetings	2%	2%
Pre-casting	45%	45%
Employed less workers and increased working hours	13%	24%
Modular construction	7%	13%
Worked as teams	2%	4%
Improved the construction sequence	0%	2%
Increased production	2%	0%

Table 5: Benefits to road construction projects.

Criteria	Client	Contractor
Increase in efficiency	27%	13%
Introduction of new construction methods	11%	42%
No traffic hence work was made easier	7%	5%
New meeting technologies	2%	0%
Decrease of utility bills	29%	15%
Enhanced monitoring	2%	0%
Saving of time and cost due to online activities	2%	2%
Pre-casting saved time	2%	0%

4. Discussion

The study hypothesized that pandemic impacts would vary significantly by road class. However, the data revealed schedule delays of 14-27% across all classes and provinces, with no statistically significant differences between road types, indicating that pandemic-induced schedule slippage was largely independent of road classification. The strongest fracture appeared along stakeholder lines: contractors bore higher health risk (56% vs 36%), deeper cash-flow stress (43.8% vs 29.2%), and could move only 6% of their staff online, compared with the clients' 44% remote capability. These contrasts validate our hypothesis of a client–contractor divergence while refuting a road-type effect.

Labour attrition in Sri Lankan road projects (14-27%) was lower than the 40-60% attrition reported for UK housing construction and the 35% loss documented for Nepalese road projects, where international border restrictions prevented migrant worker return [25]. Material shortages were statistically negligible locally, whereas Indonesian toll-road projects cited up to 25% cost jumps for imported bitumen [26-28]. Sri Lankan contractors therefore wrestled less with inputs and more with finance and workforce health, a pattern typical of lower-middle-income contexts that rely on domestic supply chains but fragile cash cycles.

Urquhart & Whyte's governance-obligation lens argues that risk is increasingly shifted to contractors through tight tender obligations [29]. Our findings illustrate the result: during lockdowns, payment certification halted, but wage liabilities, standing-time for plant, and penalty exposure persisted. Contractors' heavier self-reported financial burden aligns with governance-obligation theory, demonstrating how contractual asymmetry amplified pandemic shocks. Embedding force-majeure clauses that explicitly cover pandemics would re-balance that risk.

The study's findings support several actionable recommendations for enhancing road infrastructure resilience under mobility restrictions. First, for high-complexity projects—specifically B-class roads and expressway packages requiring substantial concrete volumes and specialized labor—project managers should incorporate contingency buffers within baseline schedules. By pre-authorising schedule float and escrowing dedicated funds for these critical segments, authorities can mitigate the high costs and delays associated with labour remobilisation. Second, digitised progress-certification mechanisms are imperative: while only 4% of clients perceived any impediment to remote certification, 96% of contractors experienced acute cash-flow pressures. Implementing measurement books coupled with drone-verified quantity take-offs would ensure that certificates—and thus payments—continue to flow uninterrupted during lockdowns. Finally, widespread adoption of modular

and precast elements emerged as a key resilience lever; contractors utilising off-site fabrication reported faster recovery and fewer health interruptions. To institutionalise this gain, national authorities should develop and promulgate a standardised design catalogue for modular culverts and bus bays, thereby streamlining approvals and scaling up off-site production capacity.

Despite these practical insights, the study is subject to several methodological constraints that warrant cautious interpretation. On the positive side, the survey yielded 110 valid responses—exceeding the Cochran minimum of 98 and achieving a 95% confidence level—and employed a triangulation of mixed metrics (ANOVA, DCA, Pearson correlation) to robustly identify stakeholder divergence and delay patterns. Nonetheless, all indicators were self-reported, introducing potential optimism bias in participants' assessments. Additionally, the cross-sectional design captures only the pandemic's first year, omitting knock-on effects such as subsequent inflationary pressures. Spatial generalisability is also limited: rural-road projects across nine districts were not represented, constraining the applicability of findings beyond the surveyed corridors.

Building on these strengths and acknowledging the limitations, several avenues for future inquiry present themselves. First, a longitudinal panel extending through 2023–25 would reveal whether the early resilience observed in 2020 reverses under sustained cost escalations. Second, system-dynamics modelling of cash-flow loops between the Road Development Authority (RDA) and tier-2 contractors could test alternative payment-certification scenarios and optimise fund disbursement under mobility constraints. Third, comparative studies applying the pandemic-response template to climate-hazard events—such as cyclone-induced stoppages—would refine contingency playbooks across shock types. Finally, integrating wearable-device data with site rosters would enable real-time mental-health analytics, quantifying workforce strain and productivity trade-offs under crisis conditions.

Collectively, these avenues will deepen understanding of how governance structures and digital tools can cushion Sri Lanka's road sector against the next systemic shock.

5. Conclusion

COVID-19 imposed 14–27% schedule overruns across all 55 authorised Sri Lankan road projects, with no statistically significant road-class effect but a marked stakeholder divide—contractors faced higher health impacts, had just 6% remote-work capacity versus clients' 44%, and reported deeper cash-flow strain.

Implementing a real-time monitoring dashboard that integrates the DCA-derived stakeholder–road-class impact matrix with weekly labour and financial data streams would enable the Road Development Authority to target contingency funds, remote-certification tools and mental-health services to projects with the largest client–contractor disparities. Limitations include self-reporting and the cross-sectional window; tracking the same projects beyond 2021 and layering exogenous indices (fuel prices, inflation, extreme-weather alerts) would test durability and refine predictive readiness for future systemic shocks.

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