Structural Pressure in Commissioning: A Cross-Role Analysis of Engineering Project Delivery.

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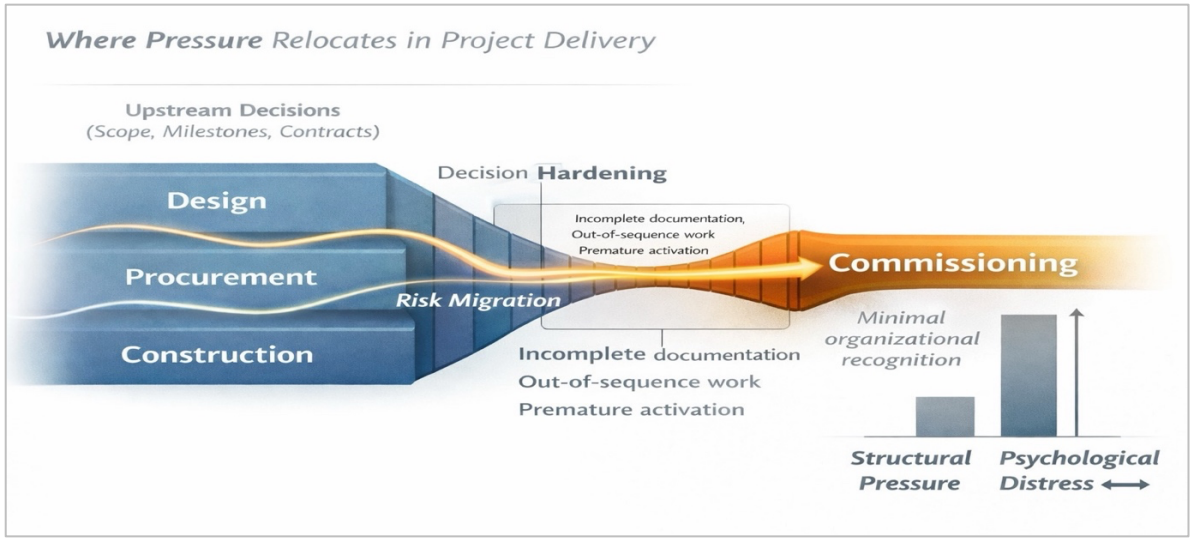
Graphical abstract



Abstract

Commissioning marks the final transition from construction to operation in engineering projects, yet the workplace pressures faced by commissioning engineers remain under-examined in construction governance research. This study investigates whether commissioning engineers experience distinct structural pressures relative to other engineering roles. A global cross-sectional survey of engineering professionals (N = 335) was conducted, including a commissioning subsample (n = 81). Universal pressure and organisational culture measures were compared across roles using Mann-Whitney U tests with effect sizes, and a commissioning-specific behavioural module captured late-stage integration conditions. Commissioning engineers reported significantly higher structural pressure than other roles, particularly for extended working hours (86.4% vs 54.7%, r = .42) and role expansion (81.5% vs 60.2%, r = .29). Commissioning-specific data revealed near-universal exposure to documentation incompleteness and out-of-sequence execution. Despite an elevated workload, no significant differences in psychological distress emerged, whereas perceptions of leadership support and communication transparency were significantly lower. The pattern is consistent with lifecycle compression being absorbed through labour intensification during system activation rather than resolved structurally. The findings position commissioning as a governance-relevant integration phase; aligning documentation maturity, sequencing

readiness, and milestone controls with activation requirements may reduce reliance on discretionary labour during late-stage delivery. This study provides rare cross-role empirical evidence, positioning commissioning as a structurally exposed phase within construction delivery systems and extending lifecycle governance discussions beyond early-stage decision-making.

Keywords: Commissioning; Construction governance; Project lifecycle; Project integration; Delivery pressure; Documentation maturity; Workforce management

1. Introduction

Large engineering and infrastructure projects are characterised by temporal compression, milestone hardening and escalating delivery pressure as completion approaches (Flyvbjerg, 2014). Project governance research has extensively examined front-end decision-making, cost overruns, optimism bias, and strategic misrepresentation (Flyvbjerg, 2014; Winch, 2010). However, comparatively less attention has been paid to how delivery pressure manifests during the final transition from construction to operation. Yet it is precisely at this interface — where systems are energised, verified and handed over — that technical, organisational and coordination risks converge.

The commissioning phase represents the final opportunity to reconcile planned systems with operational reality. During commissioning, complex engineered systems are tested under live or near-live conditions, documentation is validated against physical installations, interdependent subsystems are integrated, and regulatory requirements must be satisfied. Commissioning is therefore both technically decisive and temporally constrained. It is the point at which the cumulative effects of earlier design, procurement and construction decisions become operationally visible. Figure 1 illustrates the structural position of commissioning within the project lifecycle and the downstream convergence of unresolved uncertainty at activation.

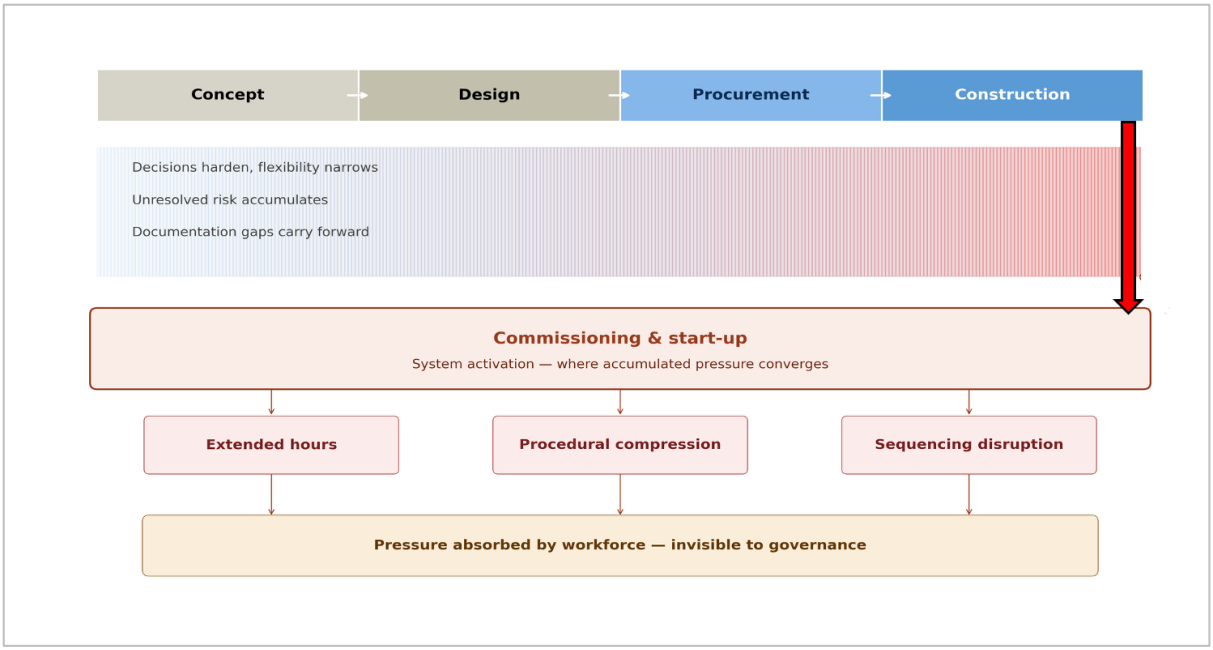


Figure 1. ***Risk migration and pressure accumulation across project lifecycle phases, converging at commissioning.***

Despite its importance, commissioning occupies a marginal position within much of the project management literature (Davies and Mackenzie, 2014). Research has tended to emphasise front-end loading, governance structures and construction performance (Davies and Mackenzie, 2014; Winch, 2010), while operational research focuses on long-term asset management once systems are in service. Commissioning sits between these domains: neither purely project nor purely operations, but a transitional phase where delivery pressures intersect with operational accountability (Turner and Pidgeon, 1997). Large-scale empirical examination of commissioning-specific workplace pressures remains limited.

1.1 Commissioning as a structurally downstream phase

From a lifecycle perspective, commissioning is inherently downstream. By the time commissioning begins, scope, budgets, milestones and contractual relationships are largely fixed. Decisions affecting documentation completeness, design maturity, sequencing logic and resource allocation have already been embedded upstream. Commissioning engineers, therefore, operate within constraints set earlier in the project lifecycle.

Project governance scholarship recognises that decision latitude narrows as projects progress. Early commitments become resistant to revision, and schedule flexibility diminishes as milestones harden (Winch, 2010). Under such conditions, unresolved uncertainty does not disappear; it shifts across phases. Design ambiguities may surface during integration; documentation gaps tolerated during construction may become critical during verification; and accumulated schedule compression may converge at activation, where activities are sequential and interdependent.

This structural positioning suggests that commissioning may function as a site of risk absorption within projects. Where upstream coordination failures or schedule compression

are not resolved earlier, the burden of reconciliation may fall on those responsible for testing and activation. Empirical quantification of this phenomenon, however, remains limited.

1.2 Pressure normalisation and late-stage adaptation

High-pressure environments also generate adaptive work practices. Research on normalisation of deviance demonstrates how repeated procedural departures can become routine under sustained production pressure (Vaughan, 2016). Similarly, resilience engineering highlights how practitioners adapt locally to reconcile safety, efficiency and delivery demands (Hollnagel, 2018; Woods, 2006).

Within commissioning contexts, such adaptation may involve proceeding with incomplete documentation, executing tasks out of sequence, accelerating verification steps or accepting higher levels of uncertainty than originally intended. While these practices may sustain visible schedule adherence, they may also redistribute labour intensity and concentrate risk exposure at the point of system activation.

Importantly, such conditions need not be experienced subjectively as a crisis. Professional commitment and technical engagement may coexist with elevated structural pressure; research on job demands and resources suggests that high demands need not undermine engagement when professional resources and role identity are strong (Deci and Ryan, 2000). This raises an empirical question: does commissioning involve heightened structural pressure relative to other engineering roles, and if so, is it associated with greater psychological strain, or has it become embedded within role expectations?

1.3 Empirical gap

Although case studies acknowledge commissioning challenges, large-scale empirical evidence remains scarce (Whyte et al., 2016b). Workforce studies rarely disaggregate experiences by lifecycle phase, and commissioning-specific pressures are typically treated as anecdotal rather than systematically examined.

As a result, it remains unclear whether commissioning engineers experience distinct structural pressures compared with other engineering roles, and whether such pressures are accompanied by identifiable organisational or well-being consequences.

This study addresses that gap through analysis of a global cross-sectional survey of engineering professionals (N = 335), including a commissioning subsample (n = 81). The survey incorporated universal measures across roles, alongside a commissioning-specific behavioural module that captured late-stage integration conditions (Ayres et al., 2026b).

1.4 Research questions and contribution

The study is guided by two research questions: RQ1: What workplace pressures do commissioning engineers experience during project delivery?
RQ2: How do these pressures differ from those experienced by other engineering roles?

By addressing these questions, the paper contributes to construction governance research in three ways. First, it provides phase-specific empirical evidence that positions commissioning

as a distinct delivery condition rather than an undifferentiated extension of construction performance. Second, it extends lifecycle governance discussions by suggesting that documentation immaturity, sequencing disruption and labour intensification converge during activation rather than being evenly distributed across phases. Third, the identification of a dissociation between elevated structural pressure and psychological distress raises questions regarding professional normalisation and the organisational visibility of late-stage pressure absorption. Collectively, the findings support positioning commissioning as a governance-relevant integration phase within construction delivery systems rather than solely as a procedural endpoint.

2. Literature Review

2.1 Lifecycle governance and decision hardening

Project governance research has consistently emphasised the importance of early-stage decision-making in shaping downstream outcomes. Concepts such as front-end loading, scope definition, and strategic alignment underscore the disproportionate influence of early commitments on cost, schedule, and performance trajectories (Flyvbjerg, 2014; Winch, 2010). Once initial decisions are embedded in contractual arrangements, funding structures, and stakeholder expectations, subsequent flexibility narrows. The ability to revisit assumptions diminishes as design progresses into procurement and construction.

This process can be understood as decision hardening: the progressive embedding of commitments that become increasingly resistant to revision (Winch, 2010). Milestones acquire contractual and reputational significance; delivery dates become politically salient; and cost baselines crystallise. While such hardening can provide necessary structure and accountability, it also constrains the system's adaptive capacity in later phases.

Importantly, decision hardening does not eliminate uncertainty. Instead, it redistributes it temporally. Risks that remain unresolved during design or construction cannot simply disappear; they must be managed at some later stage (Turner and Pidgeon, 1997). In complex projects, this often coincides with system integration and activation. As physical construction gives way to functional testing, latent design assumptions and coordination gaps become operationally exposed (Davies and Mackenzie, 2014).

However, less attention has been given to how hardened upstream commitments shape the working conditions of professionals responsible for commissioning and start-up (Davies and Mackenzie, 2014). If milestones are fixed and flexibility exhausted, adaptation may shift toward labour intensity and procedural acceleration rather than schedule renegotiation. This interaction has rarely been examined empirically at the level of individual professional experience.

2.2 Risk migration and downstream absorption

The notion that risk migrates across organisational or temporal boundaries is well established in sociotechnical research (Turner and Pidgeon, 1997). Systems rarely fail at the point of initial deviation; rather, small misalignments accumulate and interact over time (Turner and Pidgeon, 1997). In project environments, coordination gaps, documentation deficiencies, or optimistic planning assumptions may remain latent until late integration stages reveal their operational consequences.

The resilience engineering literature similarly emphasises how frontline practitioners reconcile competing performance demands under conditions of resource constraints (Hollnagel, 2018; Woods, 2006). When delivery pressure intensifies, actors adapt locally to sustain progress. These adaptations may involve re-sequencing work, informal problem-solving, or temporary deviation from formal procedures. While often necessary to maintain momentum, such adaptations can alter the distribution of workload and exposure across roles.

In the context of commissioning, these dynamics are particularly salient. Commissioning activities are inherently interdependent and sequential: systems cannot be energised until prerequisites are met; performance cannot be verified without complete documentation; and safety clearance often depends on coordination across disciplines. When upstream tasks are incomplete or documentation remains partial, commissioning teams may face the choice between delay and adaptation. Under pressure to meet milestones, adaptation may dominate.

Such adaptations may become routine under sustained pressure to deliver (Vaughan, 2016). In project environments where schedule adherence is highly valued, practices such as proceeding with incomplete documentation, conducting out-of-sequence testing, or accelerating verification steps may shift from anomaly to expectation.

Critically, professional commitment and problem-solving identity can coexist with procedural compression, complicating interpretations of structural pressure as necessarily accompanied by psychological distress.

Empirical quantification of such dynamics at the level of specific lifecycle phases remains limited, with much of the literature relying on retrospective failure analysis rather than systematic cross-project data (Perrow, 2011; Whyte et al., 2016b).

2.3 Commissioning in project management research

Commissioning occupies an analytically awkward position within the existing literature. Three adjacent bodies of scholarship address aspects of large engineering projects, yet none treat commissioning as a primary unit of analysis, and their combined coverage leaves the commissioning phase largely unexamined.

Project management research has generated substantial insight into front-end processes: governance structures, scope definition, cost estimation, strategic misrepresentation, and contractual arrangements (Flyvbjerg, 2014; Winch, 2010). This literature is predominantly focused on the design and approval phases of the project lifecycle, where decisions with the greatest leverage on outcomes are made. Where project management scholarship does address later phases, it tends to focus on construction performance, schedule variance, and handover protocols rather than on the activation and verification work that follows physical completion (Love et al., 2008). The workforce experiences of those responsible for commissioning — as distinct from construction or project management roles — rarely feature as an analytical focus.

Construction research similarly concentrates on the build phase (Hanna et al., 2005). Studies of rework, safety climate, labour productivity, and contractor performance focus on conditions during physical construction but typically end at practical completion. The transition from construction to operational status — the period during which commissioning occurs — is treated as a boundary rather than a site of inquiry. Where late-stage pressures are acknowledged, they are generally attributed to design changes, interface failures, or contractual disputes rather than examined through the lens of the workforce responsible for system activation (Whyte et al., 2016b).

Safety and reliability research engages most directly with the operational end of the lifecycle. This literature examines how systems perform once in service, how safety culture develops within operating organisations, and how major accidents emerge from organisational conditions (Hollnagel, 2018; Turner and Pidgeon, 1997; Vaughan, 2016). Its temporal focus is post-handover: the concern is with how operational organisations manage risk over time. Commissioning — the transitional period during which systems move from construction completion to operational status — occurs before this frame and is rarely examined as a distinct organisational context within safety scholarship.

Commissioning, therefore, sits in the space between these three literatures. It is downstream of project management's primary focus, upstream of safety research's primary focus, and orthogonal to construction research's primary concern with physical build. It is neither purely a project activity nor purely an operational one, but a transitional phase where the analytical categories of all three literatures partially apply and none fully hold. This structural position in the research landscape mirrors its structural position in projects themselves: consequential, temporally compressed, and insufficiently visible within the frameworks designed to govern it.

Within commissioning-specific scholarship, attention has focused on technical and procedural dimensions — verification protocols, readiness assessment frameworks, system integration sequencing, and handover documentation standards (CIBSE, 2018; ISO 9001, 2015). This work is valuable but primarily prescriptive: it describes how commissioning should proceed rather than examining how it is experienced by those responsible for delivering it under real project conditions. The organisational, governance, and workforce dimensions of commissioning have received comparatively little systematic attention.

No large-scale empirical dataset has quantified the structural workplace pressures experienced by commissioning engineers across sectors and countries (Whyte et al., 2016a). This is the gap the present study addresses.

2.4 Structural pressure and professional commitment

Project environments are frequently characterised by high workload and extended working hours, particularly near major delivery milestones (Hanna et al., 2005). Yet professional commitment and job satisfaction among engineers often remain strong. This raises a critical question: does elevated structural pressure necessarily correspond to deteriorating psychological outcomes, or can high-demand environments coexist with professional fulfilment?

Self-determination and professional identity research suggest that autonomy, technical challenge, and team cohesion can buffer the effects of workload intensity (Deci and Ryan, 2000). Within commissioning contexts, the technical complexity and visible impact of activating a system may contribute to intrinsic motivation. Engineers may derive satisfaction from resolving emergent problems and bringing projects to operational readiness.

However, strong professional commitment can also obscure structural imbalance (Trevelyan, 2014). If downstream actors consistently compensate for upstream deficiencies by working extended hours or adapting procedures, organisational learning may be muted. High satisfaction rates may mask systemic reliance on professional dedication as a substitute for structural alignment.

The intersection of structural pressure, professional commitment, and lifecycle governance has received limited empirical exploration within project management research. Understanding whether commissioning engineers experience elevated structural pressure —

and how this relates to job satisfaction and retention — therefore contributes to broader debates about sustainable project delivery.

2.5 Research positioning

Taken together, the literature suggests three interrelated dynamics relevant to commissioning: decision hardening and lifecycle constraint, which limit late-stage flexibility; risk migration and local adaptation, which redistribute unresolved uncertainty downstream; and professional normalisation, which may mask structural pressure within committed technical communities.

Yet large-scale, role-differentiated empirical evidence linking these dynamics to commissioning-specific workplace experiences remains scarce (Whyte et al., 2016b). The present study addresses this gap.

3. Method

3.1 Survey design

Data were drawn from a global cross-sectional survey of engineering professionals conducted between January and February 2026 (N = 335). The instrument comprised universal modules administered to all respondents and role-specific modules delivered through skip-logic routing based on self-identified primary role. Universal modules captured workplace pressure, peer influence, psychological outcomes, and organisational context (Ayres et al., 2026a, 2026b). Respondents who identified as Commissioning/Start-up (n = 81) were routed to a commissioning-specific module comprising 14 behavioural frequency items. All respondents completed identical universal measures prior to role-specific branching. Total completion time across pathways was approximately 10–15 minutes. Participation was voluntary and anonymous; informed consent was obtained prior to survey commencement. No personally identifiable data was collected.

3.2 Commissioning-specific measures

The commissioning-specific items were developed through an iterative process combining literature review with practitioner-informed construct refinement. Domain expertise in large-scale infrastructure commissioning contexts — including over two decades of professional commissioning and start-up experience held by the lead author — informed the operationalisation and wording of the items. Prior to deployment, content relevance and clarity were reviewed by practising engineers representing each role-specific module, who assessed item relevance, wording, and alignment with operational practice (Ajzen, 2006; Ayres et al., 2026a; Haynes et al., 1995). Feedback-informed targeted refinements to item wording and explanatory text. A technical pilot (N = 52) conducted before full-scale deployment confirmed the integrity of the branching logic and correct routing across all role pathways; no structural modifications to the instrument were required following the pilot analysis. Pilot responses were not retained or included in the study dataset. Items addressed documentation completeness, premature testing, out-of-sequence execution, defect management, permit bypassing, and safety risk acceptance. All items were framed as observable work practices rather than attitudinal judgments and were measured on a five-point frequency scale (1 = Never, 5 = Very often).

3.3 Universal comparative measures

Seven universal items common to all roles were used for cross-role comparison, including pressure to work beyond contracted hours, unrealistic expectations, role expansion, and

psychological outcomes (Bakker and Demerouti, 2007; Karasek, 1979). These were measured using five-point Likert agreement scales. Four organisational culture items — assessing perceived leadership support, communication transparency, treatment of mistakes, and encouragement of independence — were also included as universal measures and used in the cross-role comparison reported in Section 4.5 (Zohar and Luria, 2005).

3.4 Analytical approach

Nonparametric Mann-Whitney U tests were conducted to compare commissioning respondents with all other roles, given the ordinal nature of the data (Field, 2013). Effect sizes are reported as rank-biserial correlations (r), where r = .10 indicates a small effect, r = .30 a medium effect, and r = .50 a large effect (Cohen, 2013). The cross-sectional design precludes causal inference; findings are interpreted as associative. Where percentage differences between groups appear small, statistically significant rank-based differences may reflect distributional shifts across the full ordinal response scale rather than differences confined to the collapsed threshold.

Table 1. Sample profile: commissioning subsample compared with the full survey sample.

Characteristic	Commissioning (n=81)	Full Sample (N=335)
Gender: Man	75.3%	68.4%
Gender: Woman	23.5%	31.3%
Gender: Prefer not to say	1.2%	0.3%
Work setting: Mostly site-based	96.3%	49.9%
Employment: Contractor / Consultant	64.2%	26.3%
Age 35–44 (largest group)	34.6%	25.1%
Age 18–24	6.2%	14.0%
Education: Bachelor's degree	67.9%	53.7%
Education: Master's degree	25.9%	17.3%
Top country: United Kingdom	19.8%	13.1%
India	16.1%	8.7%
Canada	13.6%	10.4%
Indonesia	12.4%	10.1%
Top sectors: Water / Oil & Gas / Mining (combined)	71.6%	40.9%

The commissioning subsample was predominantly male (75.3%), site-based (96.3%), and employed on a contractor or consultant basis (64.2%). The age profile skews older than the full sample: while 14.0% of all respondents were aged 18–24, only 6.2% of commissioning engineers fell in this bracket, with the largest group (34.6%) aged 35–44. This profile is consistent with commissioning as an experienced practitioner's role. Water, oil and gas, and mining and resources were the dominant sectors, collectively representing 71.6% of the commissioning subsample, whereas in the full sample (n=335), those sectors accounted for only 40.9%.

4. Results

4.1 Commissioning-specific workplace pressures

All 81 commissioning engineers completed the 14-item commissioning-specific pressure module. Figure 2 presents the full distribution ordered by the proportion reporting often or very often; Table 2 provides the complete numerical breakdown.

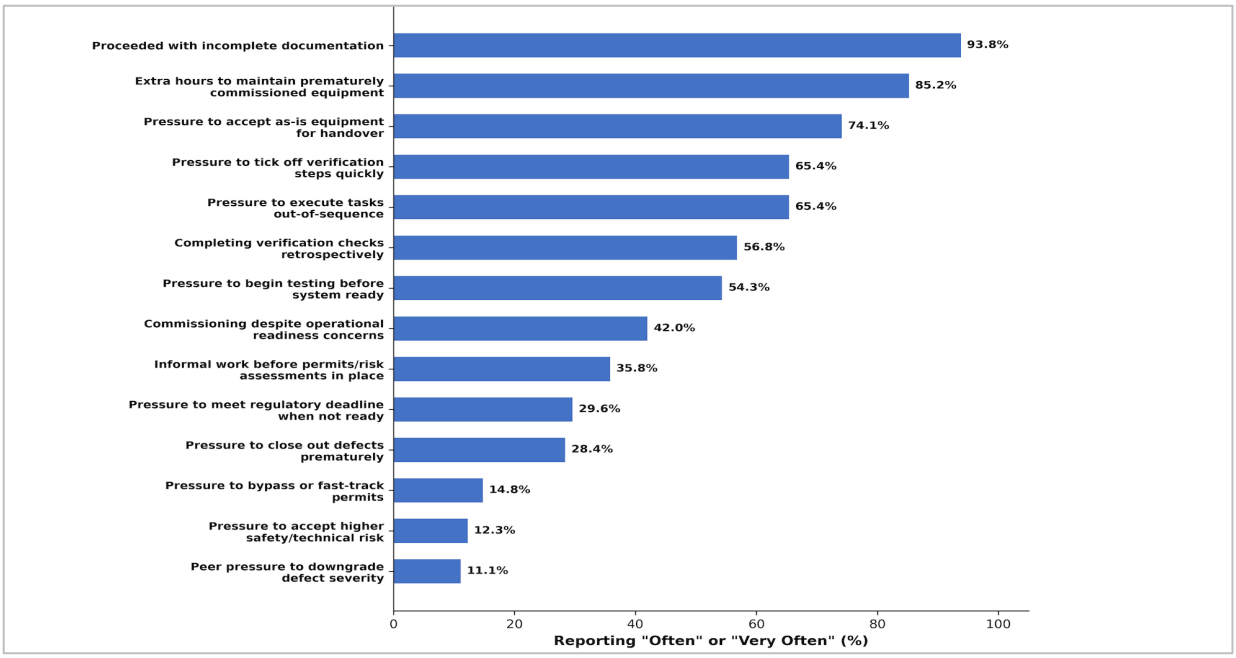


Figure 2. Commissioning-specific workplace pressures: proportion reporting often or very often (n = 81)

Table 2. Frequency of commissioning-specific workplace pressures (n=81), ordered by often/very often response rate.

Pressure item	Often / Very often %	At least sometimes %
Proceeded with incomplete documentation	93.8%	98.8%
Extra hours to maintain prematurely commissioned equipment	85.2%	96.3%
Pressure to accept as-is equipment for handover	74.1%	96.3%
Pressure to tick off verification steps quickly	65.4%	98.8%
Pressure to execute tasks out-of-sequence	65.4%	95.1%
Completing verification checks retrospectively	56.8%	93.8%
Pressure to begin testing before system ready	54.3%	96.3%
Commissioning despite operational readiness concerns	42.0%	81.5%
Informal work before permits/risk assessments in place	35.8%	81.5%
Pressure to meet regulatory deadline when not ready	29.6%	75.3%
Pressure to close out defects prematurely	28.4%	80.2%
Pressure to bypass or fast-track permits	14.8%	55.6%
Pressure to accept higher safety/technical risk	12.3%	61.7%
Peer pressure to downgrade defect severity	11.1%	46.9%

Pressure was near-universal across documentation, schedule, and sequencing domains, with all items in this cluster reported by more than 90% of respondents at least sometimes (Table 2, Figure 2). The pattern suggests these conditions are not exceptional events in commissioning practice but structural features of the role. Safety-critical bypass behaviours formed a distinct second cluster — permit bypassing, risk acceptance, and defect downgrading were broadly experienced but carried substantially lower often/very often rates than documentation and schedule items — indicating that while these pressures exist within commissioning environments, they were less frequently reported as routine. The downstream consequence of premature commissioning was captured by the additional hours item, which produced the highest often/very often rate in the module (85.2%), suggesting that schedule-driven pressure does not disappear at handover but is absorbed as extended labour by the commissioning workforce.

4.2 Recognition and organisational safety alignment

Table 3. Management recognition and safety process alignment for commissioning engineers (n=81).

Item	Response	n	%
Management recognition	Never	13	16.0%
	Rarely	22	27.2%
	Sometimes	31	38.3%
	Often	11	13.6%
	Very often	4	4.9%
Commissioning recognised as high-risk phase	Not recognised	18	22.2%
	Minimally recognised	28	34.6%
	Somewhat recognised	33	40.7%
	Well recognised	1	1.2%
Safety processes reflect commissioning realities	Not at all / Slightly	25	30.9%
	Moderately	50	61.7%
	Mostly	6	7.4%

Table 3 presents data on management recognition and safety alignment. Recognition was low across both dimensions: 43.2% of commissioning engineers reported being never or rarely recognised by their management team, and a further 38.3% reported being recognised only sometimes. Only one respondent (1.2%) considered commissioning well recognised as a distinct high-risk phase in their organisation's safety approach; 56.8% described it as not recognised or minimally recognised.

4.3 Working hours, work-life balance, and retention

Figure 3 illustrates the distribution of working hours for commissioning engineers compared with the full sample. Table 4 presents the full retention and satisfaction data.

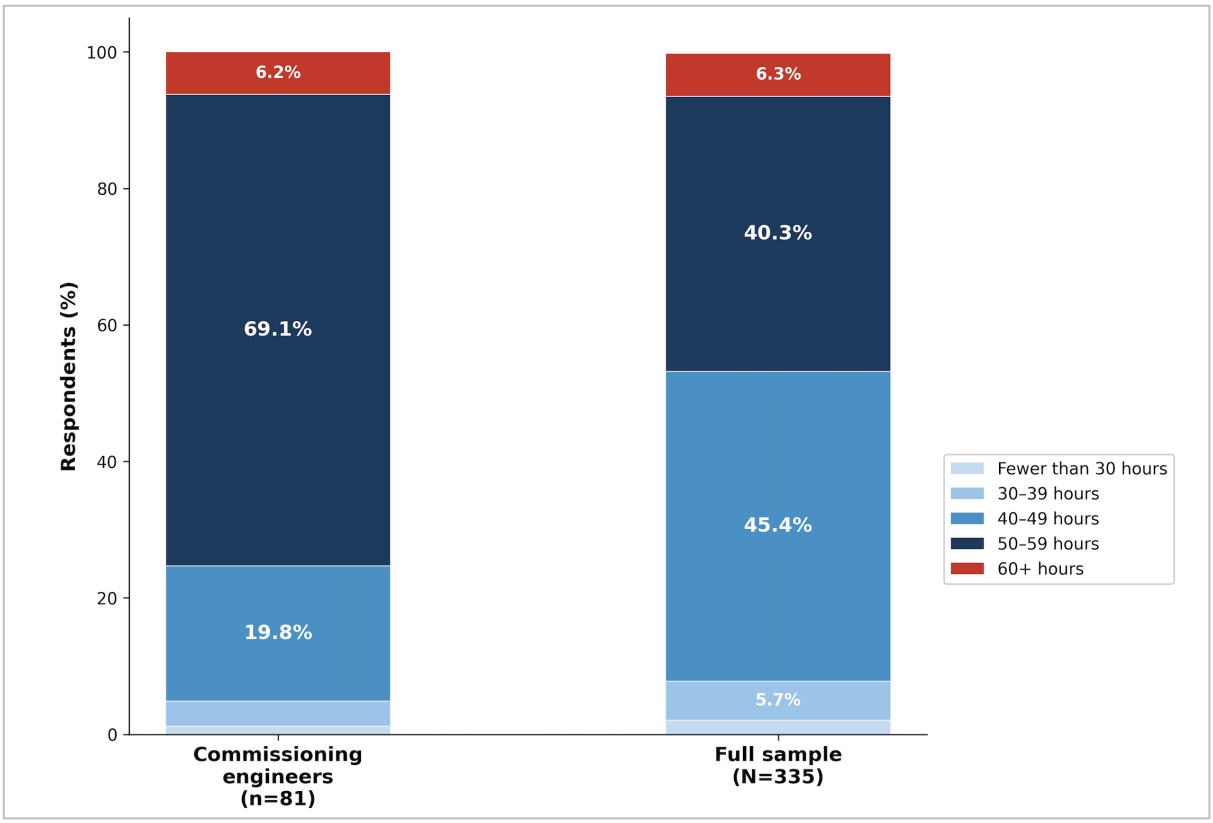


Figure 3. Working hours distribution: commissioning engineers vs full sample (N = 335).

Table 4. Working hours, work-life balance, satisfaction, and retention: commissioning engineers vs full sample.

Measure	Commissioning (n=81)	Full Sample (N=335)
Working 50+ hours per week	75.3%	46.6%
Work-life balance: Good or Very good	86.4%	74.3%
Job satisfaction: Satisfied or Very satisfied	93.8%	83.0%
Considering leaving current organisation	11.1%	23.6%
Considering leaving engineering profession	6.2%	14.6%

Three-quarters of commissioning engineers (75.3%) worked 50 or more hours per week, compared with 46.6% of the full sample. Despite this, 93.8% reported being satisfied or very satisfied with their job, and 86.4% rated their work-life balance as good or very good — both higher than full-sample rates. Commissioning engineers reported markedly lower intention to leave their organisation (11.1% vs 23.6%) and the profession (6.2% vs 14.6%). Despite higher structural pressure, commissioning engineers scored significantly higher on job satisfaction than other roles ($U = 7{,}772$, $p < .001$, $r = .25$). However, within the commissioning subsample, SPI scores correlated negatively with satisfaction ($r = -.363$ $p = .001$), indicating that structural pressure does erode satisfaction within the group even as baseline satisfaction remains elevated (Bakker and Demerouti, 2007; Karasek, 1979). The coexistence of high satisfaction with high structural pressure is discussed in Section 5.

A four-item Structural Pressure Index (SPI) was constructed from items measuring unrealistic expectations, role expansion, extended working hours, and harsh treatment of mistakes ($\alpha = .748$, Nunnally and Bernstein, 1994). A three-item variant excluding the mistakes item demonstrated equivalent reliability ($\alpha = .741$), confirming robustness to alternative

specification.
Commissioning engineers scored significantly higher on the SPI than all other roles (Mdn = 3.75, M = 3.75, SD = 0.57; U = 7,206, p < .001, r = .30). SPI analyses used complete cases (n = 329); six respondents were excluded due to incomplete item responses (1.8%).

Within the commissioning subsample, SPI scores were negatively correlated with job satisfaction (ρ = −.363, p = .001), indicating that higher structural pressure was associated with lower satisfaction even within this high-satisfaction group. SPI scores were also positively correlated with frequency of incomplete documentation (ρ = .329, p = .003), providing convergent validity against the commissioning-specific module.

4.4 Comparison with the broader engineering workforce

Figure 4 presents the key dissociation finding: commissioning engineers report significantly greater structural pressure than other roles, yet no greater psychological distress (Deci and Ryan, 2000). Table 5 provides the full statistical results.

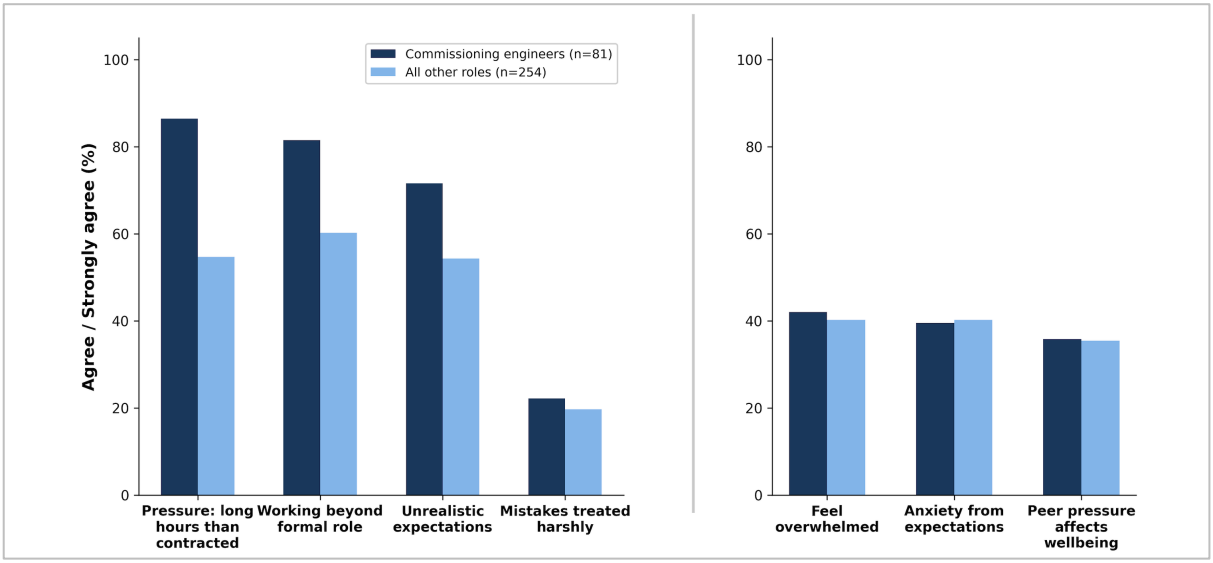


Figure 4. Structural pressure versus psychological outcomes: commissioning engineers vs all other roles.

Table 5. Mann-Whitney U comparisons: commissioning engineers vs all other roles on shared pressure and wellbeing items.

Item	Comm %	Other %	U	p	r
STRUCTURAL PRESSURE ITEMS					
Pressure to work longer hours than contracted	86.4%	54.7%	5,961	< .001	.42
Working beyond formal role	81.5%	60.2%	7,307	< .001	.29
Unrealistic expectations	71.6%	54.3%	8,146	.002	.21
Mistakes treated harshly	22.2%	19.7%	8,243	.004	.20
PSYCHOLOGICAL OUTCOME ITEMS					
Often feel overwhelmed	42.0%	40.2%	9,760	.460	.05
Anxiety related to team expectations	39.5%	40.2%	9,760	.464	.05
Peer pressure negatively affected wellbeing	35.8%	35.4%	9,041	.086	.12

Commissioning engineers reported significantly higher pressure on all four structural items, with the largest effect for extended hours (r = .42). No significant differences emerged on any of the three psychological outcome items, producing the structural-psychological dissociation discussed in Section 5. As reported in Section 4.3, the composite SPI confirmed this pattern: commissioning engineers scored significantly higher than all other roles (Mdn = 3.75 vs 3.25; U = 7,206, p < .001, r = .30).

A sensitivity analysis restricting the comparison group to site-based respondents from other roles (n = 89) confirmed that extended working hours (p < .001, r = .25) and communication transparency (p = .006, r = .20) remained significantly elevated for commissioning engineers within the site-based population (Field, 2013). General structural pressure items showed attenuated effects in this restricted comparison, suggesting that some workload pressure is shared across site-based roles, while labour intensification and communication isolation are more specific to commissioning. It is acknowledged that the commissioning subsample also differs from the broader sample in its employment model, age profile, and sectoral composition; multivariate modelling would be needed to isolate the relative contribution of the lifecycle phase from the employment ecology.

4.5 Organisational culture and communication

Figure 5 presents the organisational culture comparison; Table 6 provides full statistical results. Commissioning engineers reported substantially less favourable organisational environments than other roles across all four culture dimensions.

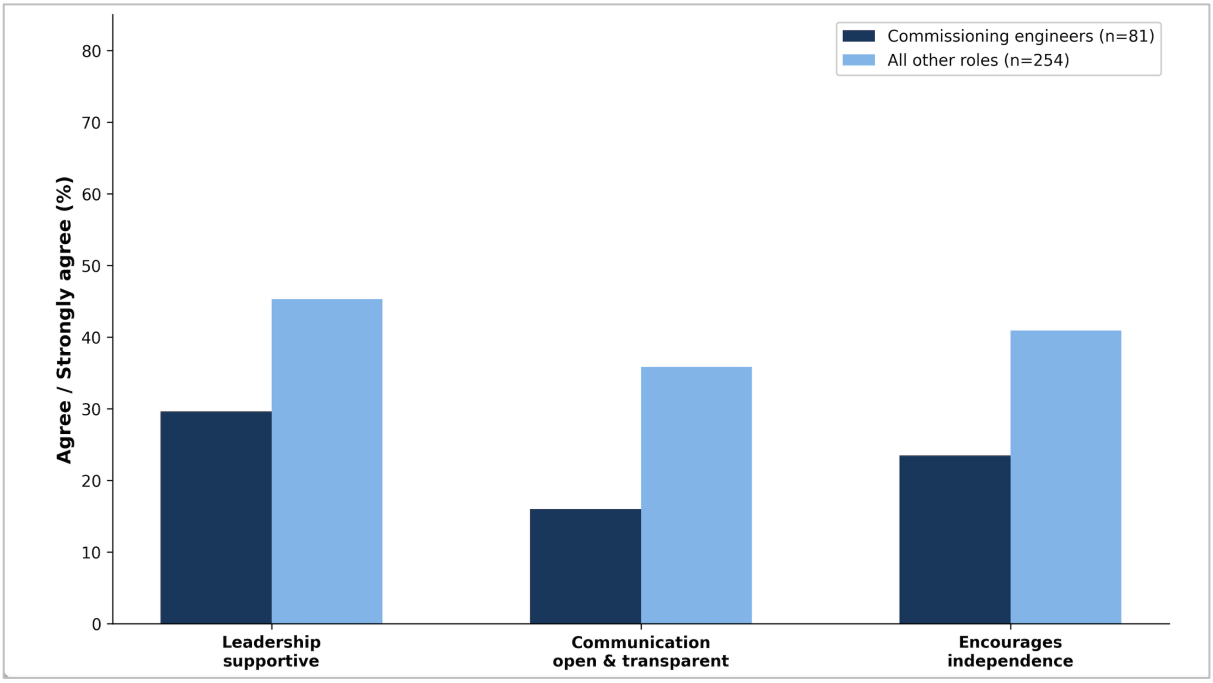


Figure 5. Organisational culture: commissioning engineers vs all other roles (all differences p < .001).

Table 6. Organisational culture comparisons: commissioning engineers vs all other roles.

Item	Comm %	Other %	U	p	r
Leadership in my organisation is supportive	29.6%	45.3%	13,698	< .001	.33

Communication is open and transparent	16.0%	35.8%	14,756	< .001	.43
Organisation encourages independence and initiative	23.5%	40.9%	13,232	< .001	.29
Mistakes treated as learning opportunities	39.5%	46.1%	12,510	.002	.22

Only 16.0% of commissioning engineers agreed that communication in their organisation is open and transparent, compared with 35.8% of other roles (r = .43, large effect). Similarly, only 29.6% reported supportive leadership (vs 45.3%, r = .33) and only 23.5% felt the organisation encouraged independence (vs 40.9%, r = .29). These findings indicate that commissioning engineers do not merely experience greater workload than their peers; they do so within organisational environments they perceive as significantly less communicative, less supportive, and less empowering (Zohar and Luria, 2005).

4.6 Peer pressure cross-validation

Two universal peer-pressure items provided independent cross-validation of the commissioning module's findings. Table 7 presents the results.

Table 7. Peer pressure items: commissioning engineers vs all other roles.

Item	Comm %	Other %	U	p	r
Peer pressure to execute tasks out of sequence	66.7%	21.2%	3,857	< .001	.60
Peer pressure to shorten testing/commissioning/verification	51.9%	13.4%	2,805	< .001	.59
Peer pressure to rely on workarounds	72.8%	24.8%	4,192	< .001	.57
Hesitate to challenge decisions due to peer reactions	15.2%	34.2%	13,438	< .001	.31

Commissioning engineers reported peer pressure to execute tasks out of sequence at more than three times the rate of other roles (66.7% vs 21.2%, r = .60), and peer pressure to shorten testing and verification at nearly four times the rate (51.9% vs 13.4%, r = .59). Both represent large effects by conventional thresholds (r > .50); it is noted that these items used a binary response format, which may influence effect size magnitude relative to Likert-scaled items. These independently measured items corroborate the pervasive sequencing and verification pressures reported in the commissioning-specific module (Vaughan, 2016).

5. Discussion

This study set out to examine the specific workplace pressures facing commissioning engineers and to determine whether these pressures differed meaningfully from those of the broader engineering workforce. The results provide consistent empirical evidence on both questions.

The most striking finding is the near universality of incomplete documentation as a working condition: 93.8% of commissioning engineers report this often or very often, positioning it as the de facto norm rather than an occasional deviation. When combined with the 85.2% who work additional hours to maintain prematurely commissioned equipment, the data describe a systematic pattern of downstream absorption — where the consequences of upstream decisions are reconciled through unplanned labour and elevated risk exposure (Turner and Pidgeon, 1997). That only 1 of 81 respondents considered commissioning well recognised as

a high-risk phase suggests this gap is bridged primarily by the engineers themselves (Reason, 2016).

The comparison with the broader engineering workforce confirms that commissioning engineers report significantly greater structural pressure — particularly around hours, role boundaries, and expectations — but not significantly worse psychological outcomes. The coexistence of high satisfaction (93.8%) with 75.3% working 50+ hours per week may reflect role-specific recalibration of expectations within commissioning communities: where extended hours are normative and shared across peers, work–life balance assessments are likely calibrated against community norms rather than absolute thresholds. This interpretation is consistent with professional identity research suggesting that high-demand roles with strong technical engagement can sustain positive self-assessment even under an objectively elevated workload. The very low intention to leave the profession (6.2%) is consistent with a group that derives genuine meaning from technically demanding work, even when that work is structurally unsupported (Fouad et al., 2017; Shan et al., 2017)

5.1 Interpreting commissioning pressure within lifecycle governance

The results indicate that commissioning engineers report a systematically elevated structural pressure profile relative to other engineering roles. The largest cross-role difference emerged for working beyond contracted hours (86.4% vs 54.7%, r = .42), followed by working beyond formal role boundaries (81.5% vs 60.2%, r = .29) and unrealistic expectations (71.6% vs 54.3%, r = .21). Commissioning is therefore not merely experiencing "more of the same" pressure, but a distinct configuration of workload intensification and role expansion.

The commissioning-specific module provides operational depth to this pattern. As Table 2 demonstrates, documentation incompleteness, out-of-sequence execution, retrospective verification, and premature testing were all reported by more than 90% of respondents at least sometimes. Labour absorption appears to be the mechanism through which commissioning teams reconcile upstream variance during activation, with adaptive labour input substituting for structural readiness (Davies and Mackenzie, 2014). Table 8 summarises effect sizes across all key comparative items.

Table 8. Effect size summary: commissioning engineers vs all other roles.

Item	Commissioning Mdn (IQR)	Other roles Mdn (IQR)	U	p	r	Effect size
Structural Pressure Index (SPI, 4-item composite)	3.75 (3.50–4.25)	3.25 (2.75–3.75)	7,206	< .001	.30	Medium
Unrealistic expectations	4.00 (3–4)	4.00 (3–4)	8,146	= .002	.21	Small
Beyond contracted hours	4.00 (4–5)	4.00 (3–4)	5,961	< .001	.42	Medium
Beyond role boundaries	4.00 (4–5)	4.00 (2–4)	7,307	< .001	.29	Small
Mistakes treated harshly	3.00 (2–3)	2.00 (2–3)	8,243	= .004	.20	Small
Leadership support	3.00 (2–4)	4.00 (3–4)	13,698	< .001	.33	Small
Communication transparency	2.00 (2–3)	3.00 (2–4)	14,756	< .001	.43	Medium

Note. Mdn = median; IQR = interquartile range; r = rank-biserial correlation. Effect size benchmarks: small r = .10, medium r = .30, large r = .50 (Cohen, 2013). All comparisons: commissioning engineers (n = 81) vs all other roles (n = 248–254, varying by item missingness). Higher scores on structural pressure items indicate greater pressure; higher scores on leadership support and communication transparency indicate more favourable organisational environments. SPI = mean of four structural pressure items; complete cases n = 329.

Peer-pressure findings reinforce this interpretation. Commissioning engineers reported peer pressure to execute tasks out of sequence at more than three times the rate of other roles (66.7% vs 21.2%, r = .60), and pressure to shorten testing or verification at nearly four times the rate (51.9% vs 13.4%, r = .59). The magnitude of these effects, coupled with the internal

consistency of the commissioning module, reduces the likelihood that the observed pattern reflects measurement artefact or isolated organisational cultures (Vaughan, 2016). Instead, the convergence of structural, behavioural and peer-level indicators suggests that commissioning occupies a patterned site of delivery compression. These findings indicate behavioural normalisation patterns but do not constitute ethnographic evidence of deviance normalisation in the strict sociological sense.

Notably, elevated structural pressure did not correspond with elevated psychological distress. No significant cross-role differences were observed for feeling overwhelmed, anxiety related to expectations, or peer pressure negatively affecting well-being. At the same time, commissioning engineers reported significantly lower perceptions of leadership support (29.6% vs 45.3%, r = .33) and communication transparency (16.0% vs 35.8%, r = .43). This combination indicates that commissioning pressure may be normalised within role expectations rather than experienced as episodic dysfunction (Hollnagel, 2018). From a governance perspective, such normalisation has implications for organisational visibility: delivery performance may be sustained through labour intensification even where integration conditions remain structurally strained (Whyte et al., 2016b).

While causal inference is not possible within a cross-sectional design, the magnitude and coherence of these findings are consistent with lifecycle governance accounts in which decision latitude narrows as projects progress and commitments harden (Winch, 2010). Commissioning, as the activation and verification phase, may function as an interface through which accumulated variance is operationally managed (Turner and Pidgeon, 1997). The data are consistent with commissioning being a structurally exposed integration phase within construction and engineering delivery systems.

5.2 Implications for project governance and lifecycle management

The empirical pattern observed carries implications for how commissioning is conceptualised within construction governance frameworks.

First, the near-universal reporting of documentation incompleteness at activation raises questions regarding the alignment between documentation maturity and milestone progression (ISO 9001, 2015). If activation routinely proceeds in the presence of incomplete information, stage-gate controls may not be fully capturing readiness conditions.

Second, the consistent differences in extended working hours and role expansion indicate that commissioning performance may depend materially on discretionary labour input. While such absorption can stabilise short-term schedule performance, sustained reliance on labour intensification may obscure systemic coordination deficits across earlier lifecycle phases (Hanna et al., 2005). Monitoring commissioning workload patterns may therefore provide a practical indicator of lifecycle compression.

Third, the significantly lower perceptions of leadership support and communication transparency suggest that commissioning risk exposure may be insufficiently visible within organisational oversight structures (Zohar and Luria, 2005). If commissioning is framed primarily as a procedural close-out rather than as a high-risk integration phase, governance attention may remain concentrated upstream even as operational complexity converges downstream.

For construction management research, these findings support conceptualising commissioning as a consequential integration phase rather than as an administrative endpoint. Empirical attention to documentation maturity, sequencing dependency and labour absorption offers a basis for modelling how delivery pressure is redistributed across lifecycle phases rather than eliminated. Recognising commissioning as structurally exposed may enhance understanding of how projects sustain apparent schedule performance while shifting variance toward late-stage integration work (Flyvbjerg, 2014).

5.3 Limitations and directions for future research

Several limitations should be acknowledged. First, the study is based on cross-sectional, self-reported survey data. While self-report is appropriate for capturing experienced workplace pressure and organisational perception, it does not permit causal inference regarding the relationship between upstream governance decisions and downstream commissioning conditions (Podsakoff et al., 2003). The findings, therefore, identify patterned associations rather than directional effects.

Second, the sample was recruited through professional engineering networks and represents an internationally distributed convenience sample. Although the dataset spans multiple sectors and countries, it may overrepresent practitioners engaged in large, internationally oriented project environments. Replication across additional project types and national contexts would strengthen generalisability. Voluntary participation may also introduce self-selection bias; individuals under greater workplace pressure may be more likely to respond, potentially inflating prevalence estimates (Bethlehem, 2010). The sample is not intended to be statistically representative of all commissioning environments, and findings should be interpreted as indicative rather than population-level estimates.

Third, all variables were measured using self-report instruments within a single survey administration. Common-method variance and professional identity norms may influence reporting patterns (Podsakoff et al., 2003). In particular, the absence of elevated psychological distress among commissioning engineers, despite higher structural pressure, may reflect role expectations or professional normalisation rather than the objective absence of strain (Deci and Ryan, 2000). Future research incorporating mixed methods or organisational performance indicators could provide further insight. It is also noted that the commissioning-specific module is newly developed for this study and has not yet been externally validated as a standalone scale; replication across independent samples would strengthen confidence in the instrument. It is noted, however, that role assignment was based on objective self-classification of primary job function rather than a subjective rating, which partially mitigates common-method concerns for the primary independent variable.

Fourth, the analysis focused on cross-role comparisons rather than multivariate modelling. While the observed differences were statistically significant and of meaningful magnitude, commissioning roles in this sample were also more likely to be site-based and contractor-oriented. Further research employing multivariate controls could examine the relative contribution of lifecycle phase, employment structure and sector (Field, 2013).

Finally, the study examined perceived working conditions rather than direct project performance outcomes. Integrating commissioning workload patterns with schedule variance, rework incidence, or safety data would provide a more comprehensive understanding of how lifecycle compression translates into measurable delivery consequences (Love et al., 2008).

Despite these limitations, the study offers rare large-scale empirical insight into commissioning as a structurally exposed phase within construction delivery systems and establishes a foundation for further lifecycle-sensitive workforce research.

The near-universal experience of incomplete documentation at handover is consistent with Whyte et al.'s (2016a) findings on information asymmetry at project interfaces and extends that work specifically to the commissioning phase. The additional hours burden aligns with Khan and Haddara's (2003) characterisation of premature commissioning as a cost-transfer mechanism — shifting schedule risk onto the operational workforce rather than resolving it upstream.

6. Conclusion

Commissioning is often described as the final procedural step before project handover (CIBSE, 2018). The findings of this study suggest it is something more consequential: a structurally downstream phase in which upstream governance decisions may be operationally reconciled under constraint.

Peer pressure data provided independent cross-validation: commissioning engineers reported peer pressure to execute tasks out of sequence (66.7% vs 21.2%) and to shorten testing and verification steps (51.9% vs 13.4%), at rates far exceeding those of other roles, with large effect sizes. This pattern aligns with established accounts of procedural drift under pressure (Vaughan, 2016).

Taken together, these findings suggest that commissioning may function as a stabilising buffer within project systems (Turner and Pidgeon, 1997). Where milestones are hardened and flexibility exhausted, adaptation appears to occur through labour intensification and procedural compression rather than schedule recalibration (Winch, 2010). Professional commitment enables projects to maintain visible delivery performance but simultaneously obscures structural lifecycle misalignment. High satisfaction and low turnover intent are not evidence that conditions are acceptable (Fouad et al., 2017; Shan et al., 2017). They are evidence that the conditions have been absorbed — and that this absorption renders the problem invisible to governance systems not designed to look for it.

For project management research, the study highlights the need to treat commissioning not as a technical afterthought but as a governance interface. Without lifecycle-aligned delivery models that explicitly account for verification complexity, documentation maturity, and integration dependencies, the data suggest that downstream pressure absorption may become routine rather than exceptional — and the cost of delivery may be carried not by schedules, but by people.

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