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Quality Culture for Preventing Technical Risk in Building Apartment Construction Project

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ABSTRACT: Apartment construction projects in Batam frequently encountered technical risks, such as cost overruns and schedule delays, which were exacerbated by a predominantly young workforce and stringent SLF (Certificate of Functionality) regulations. This study examined the impact of quality culture, leadership, communication, QMS, and Six Sigma on the perception of technical risk in these projects. A quantitative methodology was employed, disseminating structured online surveys to building professionals in Batam. The participants were predominantly young employees (ages 18–25) with fewer than three years of experience. Data were analyzed using descriptive statistics (percentages) and validity and reliability assessments, employing Microsoft Excel and SPSS. Most respondents (95%) agreed that a robust quality culture substantially mitigated technical risks. This favorable perception highlighted that integrating a quality culture into daily operations, including discipline and compliance with standards, was highly effective in preventing errors. Nonetheless, attitudes regarding the effectiveness of QMS, Six Sigma, and SLF were predominantly neutral, indicating a need for more consistent socialization and implementation. Technical risks originated from both physical factors and managerial procedures. A strong quality culture emerged as the key factor in reducing technical risks in apartment development projects in Batam. The construction industry needed to strengthen its quality culture, supported by modern management systems and effective communication, to ensure compliance with regulatory standards (SLF) and enhance overall project performance.

KEYWORDS: Quality culture; technical risk; construction project; QMS; six sigma.

1. Introduction

Technical hazards in construction projects stemmed from several project-specific factors, such as design choices, material selection, quality control measures, equipment maintenance, work conditions, and safety protocols [1, 2]. Issues within these components often resulted in disturbances in project costs, funding, and timelines, with cost overruns and delays consistently being prevalent problems in apartment construction projects [2]. To reduce these hazards, effective construction management, adherence to safety regulations, and regular maintenance were essential, as demonstrated in numerous large apartment buildings in China [3]. These preventive measures strengthened structures and improved stability over time [4].

Numerous studies demonstrated that a robust quality culture and effective leadership created the foundation for exceptional construction performance, largely due to their influence on organizational discipline in maintaining quality standards [5, 6]. The application of quality management frameworks and variation-reduction approaches, such as Six Sigma, was advantageous in reducing process deviations, improving workflow stability, and lowering the likelihood of rework [7, 8]. These findings highlighted the need for a planned and coordinated approach to address quality issues in building projects [9]. Accordingly, project success required strategic planning, appropriate material selection, the use of modern construction technology, and strict compliance with safety and quality standards [10]. Neglecting these factors often resulted in prolonged delays, inflated budgets, and frustrated stakeholders, thereby amplifying technical risks [11]. Conversely, projects supported by rigorous management practices produced structures that were more reliable, requiring less maintenance over time [12]. Ultimately, the construction sector benefited significantly from the adoption of strict quality standards that enhanced overall performance and reliability [13, 14].

While valuable, much of the existing literature was based on developed economies or broad international trends, which often did not translate to the specific nuances of the Indonesian construction sector [15]. There remained a noticeable gap in empirical data regarding how leadership, communication, QMS, and Six Sigma interacted to mitigate technical risks within Indonesian projects—particularly in a unique hub such as Batam [16]. The operational landscape in Batam presented distinct challenges that generalized global studies could not capture. Delays in obtaining Certificates of Occupancy (Sertifikat Laik Fungsi/SLF) for several apartment buildings reflected difficulties in coordination among contractors, consultants, and regulators [17]. Beyond management practices, the heavy reliance on a young and relatively inexperienced workforce significantly increased the margin for error and the likelihood of costly rework [18, 19]. This situation underscored a critical reality in Batam: technical hazards were not solely engineering-related but were deeply intertwined with managerial gaps and local regulatory dynamics [20]. Consequently, international findings could not simply be transplanted to the local context, making it vital to examine quality culture through Batam's unique operational environment [21].

The city's rapid push toward vertical housing frequently collided with strict labor issues and mandatory SLF requirements. When young, untrained workers handled these projects, operational friction often arose, ranging from minor misunderstandings to major delays in critical SLF documentation [22]. Unlike many global case studies, the Batam context required strict adherence to safety, structural integrity, and accessibility checks conducted by certified professionals. Failing to secure an SLF carried significant legal consequences and could render a building unusable. These localized regulatory pressures created a risk profile that differed sharply from general international trends, demonstrating that a strong quality culture and steadfast leadership were essential for project success [23]. Riau, Akadira, and Diana (2023) asserted that the SLF procedure enhanced public confidence and ensured compliance with legal standards prior to project implementation [26].

Consequently, technical risks arose not only from physical or engineering issues but also from managerial practices within construction firms [27]. Deficient leadership, insufficient communication, and inconsistent oversight elevated the likelihood of errors, delays, and misinterpretations during project execution [28]. Inadequate documentation, ambiguous role assignments, and discrepancies between design and field implementation increased technical

risks by disrupting the continuity of planning, execution, and quality assurance [29]. Strengthening management discipline was shown to reduce errors, improve safety performance, and enhance overall construction quality [30], indicating that managerial competence was as critical as technical expertise in mitigating risk escalation [31].

This study examined the influence of quality culture, leadership, communication, quality management systems, and Six Sigma on the perception of technical hazards in residential complexes in Batam. A literature review revealed that prior research on quality culture, leadership, and advanced quality management systems focused primarily on industrialized nations or major international initiatives [32]. These environments contrasted markedly with Batam, where projects relied on younger labor forces and were subject to stringent SLF regulatory mandates. Such circumstances produced specific technical-risk patterns, including rework and delays caused by miscommunication and permit processing difficulties [33]. Thus, a research gap existed due to the scarcity of empirical studies linking quality culture and quality management systems to technical risk mitigation within the local Batam context [34]. This study aimed to fill this gap by providing empirical evidence that enhances the current literature and offers practical insights for the Indonesian construction sector.

2. Materials and Methods

2.1. Research design.

This study employed a quantitative, cross-sectional survey design to examine the influence of quality culture and related managerial factors on the perception of technical risk in apartment construction projects in Batam. A survey-based approach was appropriate for capturing practitioners' perceptions regarding organizational culture and risk management practices, as widely applied in construction quality and Total Quality Management (TQM) studies [35].

2.2. Study area and respondents.

The study focused on Batam City within Indonesia's Riau Islands Province, an urban center experiencing a surge in high-rise residential projects under stringent SLF (Sertifikat Laik Fungsi) requirements. To obtain an accurate representation of the industry, the research engaged a diverse group of practitioners directly involved in these apartment developments. This cohort included project managers, site managers, field supervisors, administrative staff, and workers. By selecting participants with hands-on experience, the study ensured that the collected insights were grounded in the practical realities of the local construction sector.

2.3. Research variables and measurement indicators.

The questionnaire comprised five main constructs derived from the literature. Quality Culture was defined as shared organizational values and norms that emphasized discipline, compliance with standards, continuous improvement, and error prevention [5, 13]. This construct was measured using five items adapted from prior construction quality culture studies, such as "Quality standards are consistently prioritised in daily work activities." Quality Practices referred to routine on-site practices related to quality control, inspection, and corrective actions during construction execution [9, 12]. Four specific metrics were used to evaluate this construct, including the frequency and consistency of quality inspections performed throughout the building phase. In tandem, the Leadership and Communication component was assessed

based on how effectively management provided guidance and maintained a seamless flow of information across the team [6, 23]. This was measured through factors such as whether project leaders actively communicated quality and safety benchmarks to their staff. Furthermore, the study integrated QMS, Six Sigma, and SLF Practices to represent the combination of formal management frameworks, tools for minimizing process variation, and essential legal requirements for regulatory compliance [16, 35]. This construct included four items, such as "QMS or Six Sigma principles are practically applied in this project." Technical Risk Reduction was defined as the perceived reduction of errors, rework, delays, and technical failures during project execution [1, 27]. This variable was measured using three items, for example, "Quality practices in this project help prevent technical errors and rework." All items were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

2.4. Questionnaire development and data collection.

The questionnaire was developed based on established instruments in the construction quality and risk management literature [35, 37]. To refine the instrument's clarity and ensure content validity, a pilot review was first conducted with academic supervisors, following established pre-testing protocols [38]. After the survey was finalized, it was deployed via Google Forms. The distribution was targeted specifically to construction professionals in Batam to ensure the integrity and relevance of the data. This digital approach was chosen not only for convenience but also for its efficiency and accessibility, making it suitable for this type of fieldwork, as supported by prior methodological studies [36].

2.5 Data analysis techniques.

The collected data were coded and analyzed using Microsoft Excel and SPSS. Descriptive statistics, including percentages, means, and standard deviations, were used to summarize respondent characteristics and perception patterns. Reliability was assessed using Cronbach's alpha, with a threshold value of 0.70 considered acceptable for internal consistency [40]. Construct validity was verified by examining item-total correlations to ensure each measure functioned as intended. For the main analysis, Pearson correlation was employed to examine the relationships among quality culture, management practices, and perceptions of technical risk. This method was chosen over more complex models, such as SEM or regression, because the study was primarily exploratory. Given the focused sample size and the interest in understanding perceptions rather than establishing direct causality, a correlational approach was the most appropriate. Although advanced modeling was beyond the scope of this study, it is recommended as a key avenue for future research [41, 42].

3. Results and Discussion

3.1. Respondent profile.

The demographic profile indicated that the respondent group was dominated by young construction practitioners aged 18–25 years (74.2%), followed by those aged 26–35 years (22.6%). Most respondents had less than three years of work experience, reflecting the labor structure commonly found in Batam's construction industry. This demographic characteristic was important, as younger and less experienced workers were more susceptible to technical

errors and required stronger organizational guidance [18, 19]. Detailed respondent characteristics are presented in Figure 1.

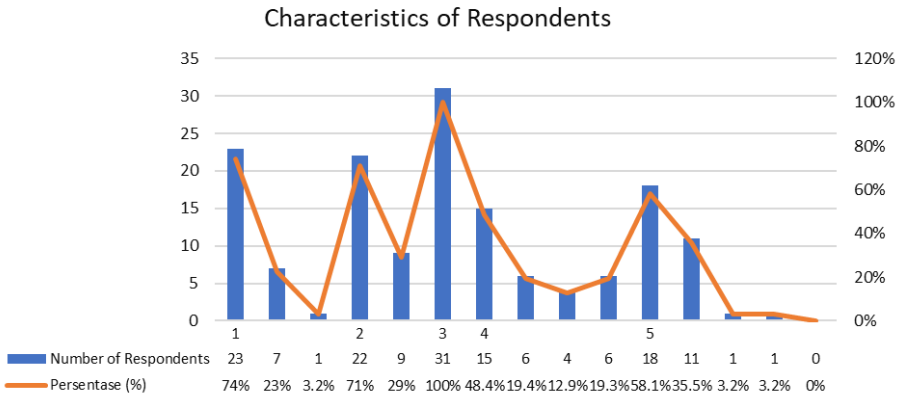

Figure 1. Characteristics of respondents.

3.2. Perceptions of Quality Culture and Quality Practices

Results showed a strong positive perception of organizational quality culture, with 87.1% of respondents selecting “agree” or “strongly agree” (Figure 2). These findings aligned with earlier research suggesting that a robust quality culture acts as a backbone for discipline, effectively reducing deviations while ensuring construction standards were met [5, 14]. A similar pattern was observed for quality practices, with many respondents emphasizing that routine inspections and proactive corrections were indispensable (Figure 3). Beyond organizational routines, recent literature suggests that a quality culture serves as a fundamental behavioral anchor, particularly in the Batam context, where projects rely on a younger, less experienced workforce. These internalized norms and routines helped bridge the expertise gap that technical training alone might not cover [23, 35].

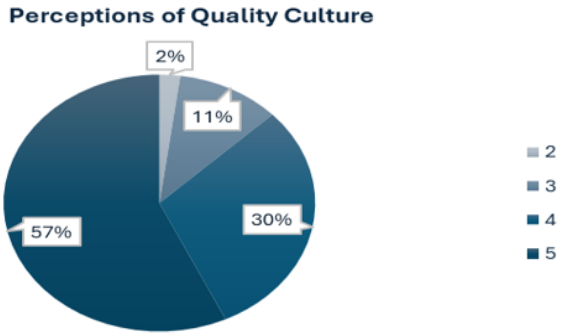

Figure 2. Perceptions of quality culture.

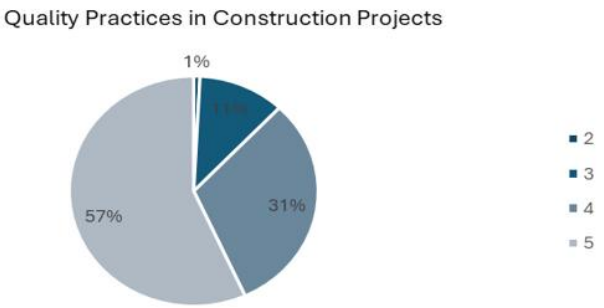

Figure 3. Quality practices in construction projects.

3.3. Management systems (QMS, Six Sigma, SLF) and technical risk.

A different picture emerged for formal frameworks such as QMS, Six Sigma, and SLF protocols, where respondent sentiment was largely neutral (Figure 4). Approximately 52% of respondents selected neutral scores, indicating that these systems had not yet been fully embraced or consistently applied on-site. This reflected Limón-Romero et al.'s [16] observation that in developing economies, a QMS is effective only to the extent that organizational maturity and training support it. The high proportion of neutral responses may also be attributed to the dominance of young workers, who were more exposed to informal practices than to structured management systems [15]. This highlighted a gap between formal quality frameworks and day-to-day implementation in Batam's apartment projects.

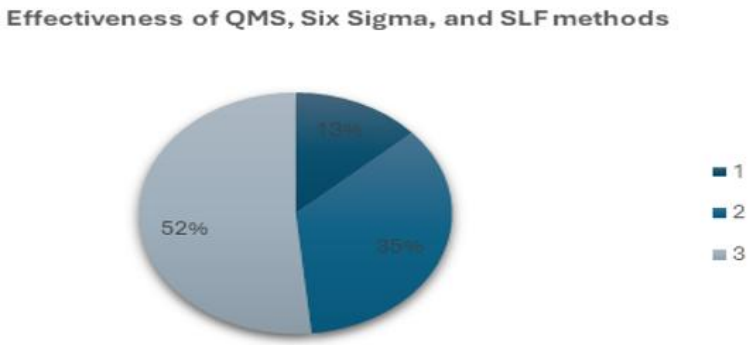

Figure 4. Effectiveness of QMS, six sigma, and SLF.

3.4. Relationship between quality culture and technical risk reduction.

A total of 95% of respondents agreed that a strong quality culture contributed to reducing technical risks (Figure 5). This finding aligned with recent empirical evidence demonstrating that quality culture directly influenced error prevention, rework reduction, and schedule reliability in construction projects [12, 30]. Theoretically, this reinforced TQM, which posits that organizational culture forms the foundation upon which formal management systems operate effectively [35]. In the Batam context, quality culture also supported SLF readiness by ensuring documentation accuracy, inspection preparedness, and compliance discipline [24, 26].

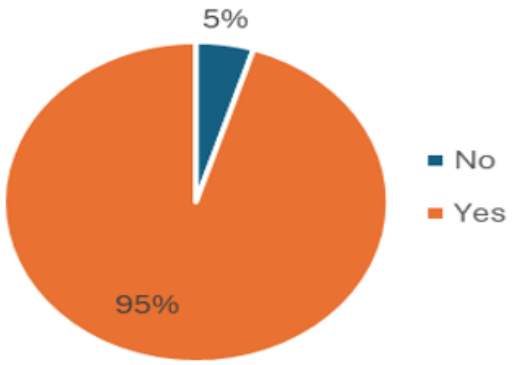

Figure 5. Relationship between quality culture and technical risk.

3.5. Summary of descriptive statistics.

While Figures 2–5 provided a visual overview, Table 1 synthesized the findings, presenting mean values, standard deviations, and overall agreement percentages. This summary allowed

for a nuanced comparison across constructs, illustrating how respondents prioritized different aspects of the study.

Table 1. Descriptive statistics of research variables.

No	Variable / Construct	Number of Items	Mean	Standard Deviation	Percentage Agreement (%)
1	Quality Culture	5	4.32	0.56	87.1
2	Quality Practices	4	4.28	0.59	88
3	Leadership and Communication	4	4.15	0.63	84.5
4	QMS, Six Sigma, and SLF Practices	4	3.41	0.72	48
5	Technical Risk Reduction	3	4.38	0.52	95

3.6. Reliability and validity results.

Reliability analysis confirmed acceptable internal consistency across all constructs, with Cronbach's alpha values exceeding the recommended threshold of 0.70 [40]. Item-total correlations also indicated satisfactory construct validity. Detailed results are provided in Table 2.

Table 2. Reliability and validity test results.

Variable / Construct	Number of Items	Cronbach's Alpha	Item–Total Correlation Range	Validity Status	Reliability Status
Quality Culture	5	0.88	0.61 – 0.74	Valid	Reliable
Quality Practices	4	0.85	0.58 – 0.71	Valid	Reliable
Leadership and Communication	4	0.82	0.55 – 0.69	Valid	Reliable
QMS, Six Sigma, and SLF Practices	4	0.79	0.46 – 0.63	Valid	Reliable
Technical Risk Reduction	3	0.86	0.64 – 0.77	Valid	Reliable

3.7. Managerial versus technical risk perspective.

The findings indicated that technical risks in Batam apartment projects were influenced more strongly by managerial factors such as leadership, communication, and quality culture, than by technical systems alone. The presence of structured tools like QMS and Six Sigma was only part of the solution; their actual impact depended heavily on the commitment of management and the readiness of the workforce to adopt them. In the context of developing economies, this distinction was not a minor technicality but the foundation of the entire project. The ultimate success of a technical intervention in these settings rarely depended solely on the sophistication of the tools in use. Instead, the quality of managerial discipline behind those tools determined the outcome [28, 31].

Conclussion

This study examined the influence of quality culture, leadership, communication, and quality management systems on the perception of technical risk in apartment construction projects in Batam. The findings indicate that quality culture was the most influential factor in reducing perceived technical risks, with respondents emphasizing that embedding values such as discipline, proactive error prevention, and adherence to standards into daily workflows was highly effective in minimizing rework and maintaining schedules. In contrast, formal systems like Six Sigma, QMS, and SLF procedures were viewed neutrally, suggesting that while these

frameworks exist, they have not yet been fully internalized by the workforce. Given the predominance of younger, less experienced staff, informal cultural norms and direct managerial guidance currently play a larger role in risk mitigation than formal procedures. The study highlights that technical risks in Batam's apartment developments are not merely the result of engineering errors or material failures but are strongly shaped by organizational and managerial behavior. For practitioners, fostering a robust quality culture through leadership, communication, and hands-on oversight is essential to anchor the decisions and behaviors of less experienced staff. Integrating QMS, Six Sigma, and SLF practices into routine workflows rather than treating them as end-stage formalities can further reduce delays and enhance reliability. Policy implications include prioritizing leadership development and quality awareness to strengthen the effectiveness of regulatory frameworks. Limitations of the study include reliance on self-reported data, geographic focus on Batam, and the use of descriptive and correlational analysis, which precludes causal inference. Future research should adopt more advanced modeling, expand to other regions, and employ longitudinal designs to assess how quality culture evolves and impacts technical risk over the course of construction projects.

Author Contributions

All authors made substantial and meaningful contributions to this research. Grace Febiola Parura was responsible for developing the research concept, designing the methodology, collecting and organizing the data, conducting the formal analysis, and preparing the initial draft of the manuscript. Mulia Pamadi provided supervision, contributed to validation, and participated in the critical review and editing of the manuscript to ensure analytical accuracy and academic rigor. Indrastuti contributed through supervisory guidance, assisted in the validation process, and supported the refinement of the manuscript through substantive review. All authors read and approved the final version of the manuscript.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. To protect respondent confidentiality and ensure ethical compliance, raw questionnaire responses cannot be made publicly accessible. However, anonymized datasets and summarized analytical outputs may be provided for academic or research purposes upon formal request.

Competing Interest

The authors declare that they have no known financial, professional, or personal conflicts of interest that could have influenced the work reported in this study.

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