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Enhancing Construction Project Quality Management: A Six Sigma Implementation

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Abstract

This research investigates the effectiveness of Six Sigma methodology in enhancing quality management within the Post-Disaster Courthouse Construction Project in the Regional Court of Banda Aceh. Grounded in quality management and project management principles, particularly the Define, Measure, Analyze, Improve, Control (DMAIC) approach. The study aims to identify implementation processes and assess Six Sigma's efficacy. Utilizing a structured questionnaire administered to contractors involved in the project, data analysis included factor analysis, descriptive analysis, and DMAIC approach assessment. Findings reveal considerable focus on quality planning and management, with identified areas for quality control enhancement. Actionable insights from the DMAIC approach highlight opportunities for refining quality management processes. This study underscores the significance of effective quality management in construction projects, offering practical recommendations for stakeholders and emphasizing continuous training and collaboration to optimize quality outcomes. By applying Six Sigma to construction buildings, this research contributes to advancing quality management practices in similar contexts, with implications for project success and client satisfaction.

Keywords: *Quality management, Construction project, Six sigma, DMAIC*

Abstrak

Penelitian ini menyelidiki efektivitas metodologi Six Sigma dalam meningkatkan manajemen kualitas pada Proyek Konstruksi Pengadilan Pascabencana di Pengadilan Negeri Banda Aceh. Berdasarkan prinsip manajemen kualitas dan manajemen proyek, khususnya pendekatan Define, Measure, Analyze, Improve, Control (DMAIC). Tujuan penelitian untuk mengidentifikasi proses implementasi dan menilai efektivitas Six Sigma. Menggunakan kuesioner terstruktur yang diberikan kepada kontraktor yang terlibat dalam proyek, analisis data mencakup analisis faktor, analisis deskriptif, dan penilaian pendekatan DMAIC. Temuan menunjukkan fokus yang signifikan pada perencanaan dan manajemen kualitas, dengan area yang teridentifikasi untuk peningkatan pengendalian kualitas. Wawasan yang dapat ditindaklanjuti dari pendekatan DMAIC menyoroti peluang untuk memperbaiki proses manajemen kualitas. Penelitian ini menekankan pentingnya manajemen kualitas yang efektif dalam proyek konstruksi, memberikan rekomendasi praktis bagi pemangku kepentingan, dan menekankan pentingnya pelatihan berkelanjutan serta kolaborasi untuk mengoptimalkan hasil kualitas. Dengan menerapkan Six Sigma pada pembangunan gedung, penelitian ini memberikan kontribusi untuk memajukan praktik manajemen kualitas dalam konteks serupa, dengan implikasi terhadap keberhasilan proyek dan kepuasan klien.

Kata kunci: *Manajemen mutu, Proyek konstruksi, Six sigma, DMAIC*

Introduction

Construction projects in Indonesia frequently encounter challenges associated with construction failures, defined by Government Regulation Number 29 of 2000 on Construction Services as deviations from specified requirements in construction work Peraturan Pemerintah Nomor 29, 2000). These failures often stem from technical factors, underscoring the need for robust quality management during project execution (Alawag *et al.*, 2023a). Research by Abdullah *et al.* (2019) reveals that inadequate quality planning, deficient communication of quality requirements, and a lack of awareness regarding the benefits of quality management pose significant obstacles to its effective implementation.

Critical processes within quality management, aligned with established standards, play a pivotal role in ensuring successful construction project execution. These processes include quality planning, quality management, and quality control, as recognized by Project Management Institute (Project Management Institute (2017).

Effendi *et al.* (2021) delve into various quality management methods relevant to construction projects, such as Continuous Improvement (CI), Statistical Process Control (SPC), Total Quality Management (TQM), Kaizen, and the increasingly prominent Six Sigma. Total Quality Management (TQM), as an alternative quality management system, has seen widespread implementation across various sectors (Othman *et al.*, 2021). Despite its global adoption, there exists a common misconception within companies, particularly in the construction industry, wherein ISO 9001 certification is often equated with the deployment of TQM (Budayan and Okudan, 2022).

Studies by Zuhri *et al.* (2018); Ferdian *et al.* (2018) underscore that ISO 9001-certified companies may not automatically initiate TQM implementation due to a lack of awareness regarding the continuous improvement element. Acknowledged as a structured and comprehensive methodology for quality improvement and implementation, Six Sigma has gained traction in the construction industry (Ramasamy *et al.*, 2021). The DMAIC methodology (define, measure, analyze, improve, control) is highlighted as a structured approach within Six Sigma (Muraleedharan *et al.*, 2022).

Project quality management in the construction industry is an integrated technical management system that unifies the stages of construction into a cohesive whole (Wahyu *et al.*, 2021). It involves processes aligning organizational quality policies, including planning, management, control, and quality requirements, to meet stakeholder objectives (Project Management Institute, 2017).

Four identified quality management policies include detailed engineering designs, compliance with quality management system procedures, achieving satisfactory performance, and fulfilling specified project requirements (Riaz *et al.*, 2023). Quality planning involves identifying quality requirements and documenting how the project will demonstrate compliance with these requirements (Project Management Institute, 2017). Managing quality translates the quality management plan into execution activities that integrate organizational quality policies into the project (Mardikaningsih and Darmawan, 2020). Control quality monitors and records the results of quality management activities, ensuring project results are complete, accurate, and meet customer expectations (Alawag *et al.*, 2023b).

In developing countries, challenges hindering quality management implementation include the absence of top management commitment, inadequate expertise, low bidding contract award concept, undervalued education and training, lack of worker involvement and empowerment, rigorous attitudes and behaviors, and a rigid executive approach towards the quality management system (Alawag *et al.*, 2023b). Implementation challenges in the construction sector include an unproductive quality system, excessive paperwork, inadequate knowledge of process requirements, and high implementation costs (Riaz *et al.*, 2023a).

Effective implementation of project quality management in construction optimizes project management and control towards predefined objectives (Uluskan *et al.*, 2021). Othman et al. (2021) identify three main factors influencing the implementation of quality management: teamwork, related employees, and organizational culture. Constructive efforts by construction companies in quality management ensure project execution quality. Areas for improvement include the utilization of the latest technology, facilitating information technology for workers, open leadership feedback, sufficient time for job completion, and leadership guidance and workforce training (Alawag *et al.*, 2023c).

Six Sigma is a comprehensive system for achieving, sustaining, and maximizing results, serving as a statistical method for quality implementation (Muraleedharan *et al.*, 2022). Executed through the DMAIC approach, it involves defining, measuring, analyzing, improving, and controlling processes for gradual improvements (Effendi *et al.*, 2021).

The term "Sigma" in Six Sigma denotes a scale of quality measurement, with Six Sigma equating to 3.4 defects per million opportunities (Timans *et al.*, 2021). Popular methods for continuously enhancing production and quality in manufacturing companies include lean, six-sigma (Sunder and Antony, 2020; Zhang *et al.*, 2022; Kumar *et al.*, 2020b), and lean six-sigma (Abbes *et al.*, 2022; Sunder & Antony, 2020; Yadav *et al.*, 2021). This advancement is possible by combining the Six Sigma technique of reducing process variance with the Lean methodology of eliminating non-added value (Kumar *et al*., 2020b). Quality, process efficiency, responsiveness, and cost are all measured using Lean Six Sigma (Timans *et al*., 2021). This approach is frequently employed by manufacturing companies across the globe. The latter resulted in a decrease in the raised sigma level from 4.36 sigma to 3.74 and a 27% reduction in changeover time in the manufacturing line (Kumar *et al*., 2021). The DMAIC methodology is recognized as a problem-solving tool, complemented by the preventative methodology known as Design for Six Sigma (DFSS), consisting of DMADV (Antony *et al*., 2022). A notable ongoing project in Banda Aceh is the Post-Disaster Courthouse Construction Project, initiated on September 9, 2022, under the auspices of the Supreme Court and funded by the National Budget (APBN). Conceived in response to the 2004 tsunami disaster, this phased project aims to enhance the courthouse's quality. Consequently, effective implementation of quality management is imperative during its execution.

This research specifically addresses the implementation of quality management and evaluates the efficacy of applying the Six Sigma methodology in the Post-Disaster Courthouse Construction Project in Banda Aceh. The study seeks to identify and analyze the key processes of quality management implementation, emphasizing the application of the Six Sigma method. To gather insights, the study employs a questionnaire distributed among contractor personnel engaged in the construction of the Post-Disaster Courthouse in Banda Aceh, with 18 respondents participating in discussions on quality management processes and the utilization of Six Sigma methodology. The sampling technique adopted is saturation sampling, with Six Sigma serving as the chosen method for quality management implementation in this research. The post-disaster construction context presents high uncertainty, complex coordination, and urgent timelines, which often lead to quality deviations and rework. Such a context is particularly relevant for assessing the applicability of Six Sigma, as its structured and data-driven DMAIC approach can minimize variability and enhance consistency under high-pressure conditions (Antony *et al*., 2022; Ramasamy *et al*., 2021).

Methodology

This research employs a quantitative approach using a structured questionnaire to evaluate the implementation of Six Sigma in the Post-Disaster Courthouse Construction Project in the Regional Court of Banda Aceh. The post-disaster reconstruction context is particularly relevant for studying Six Sigma because such projects require strict quality control, rapid execution, and minimal tolerance for errors. Previous studies (Abbes *et al*., 2022; Muraleedharan *et al*., 2022) highlight that Six Sigma is effective in environments where variability must be minimized, conditions typically found in post-disaster reconstruction projects where safety, structural reliability, and compliance are critical.

Population and sample

The sampling technique follows the definition by (Rani & Arlianti, 2024), in which the sample is selected based on the characteristics required for the research. The population consists of all personnel directly involved in the Post-Disaster Courthouse Construction Project. A total of 18 personnel participated, representing the entire population Although the sample size is relatively small, it is methodologically acceptable because: 1) it reflects the full target population, not a subset, 2) Factor analysis is used exploratively, 3) according to Hair *et al*. (2019), sample sizes below 50 are still acceptable when communalities exceed 0.5 and factor loadings are strong,and 4) the objective is to understand internal relationships within indicators, not to infer to a larger population.

Research variables and data collection method

Research variables consist of three components: quality planning, quality management, and quality control. Each variable contains specific indicators as presented in Table 1. Data were collected using a structured questionnaire distributed directly to all personnel involved in the project. The questionnaire used a five-point Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Validation of respondent understanding

To ensure data validity, respondents were provided with: 1) a brief explanation of Six Sigma and DMAIC prior to answering the questionnaire, 2) clarification for each indicator to ensure consistent interpretation, and 3) an additional filter question verifying familiarity with Six Sigma concepts. Only respondents who confirmed adequate understanding were included in the analysis.

Use of perception-based data

This study utilizes perception-based survey data due to the unavailability of complete objective project quality performance records such as defect logs, rework rates, and quality deviation data.

Table 1. Research variables and indicators

No.	Variable	Indicator
1	Quality planning (X1)	Identification of quality requirements. Determining quality standards. Setting quality targets. Formation of a quality team.
2	Quality management (X2)	Implementation of the quality plan. Quality performance monitoring. Implementation of quality audits. Evaluation and quality improvement.
3	Quality control (X3)	Construction quality measurement. Construction quality verification. Identification of deficiencies and non-conformities in construction quality. Controlling changes in construction quality.

Table 2. Stages and action in DMAIC

No.	Six Sigma Stages	Action
1	Define stage	Define the problem to be solved on the construction project and set the goals to be achieved.
2	Measure stage	Collect data about the process to be improved, which is used to measure the performance of the ongoing process.
3	Analyze stage	Analyzing data that has been collected at the measure stage, which is used to identify factors that influence process performance.
4	Improve stage	Determine the solution according to the results of data analysis at the analyze stage.
5	Control stage	Ensure that the solutions that have been implemented run well.

This limitation is common in construction projects without a formal digital quality assurance system (Othman *et al*., 2021). Perception-based data remain valuable for evaluating management processes, personnel practices, and organizational readiness for Six Sigma implementation.

Data processing and analysis

All questionnaire responses were processed using IBM SPSS Statistics version 24. To ensure measurement accuracy: 1) validity was tested using Pearson's correlation for each indicator and 2) reliability was tested using Cronbach's Alpha, with a minimum threshold of 0.70 considered acceptable (Creswell & Creswell, 2021). Indicators that did not meet validity criteria were excluded from further analysis. Factor analysis was used to identify: 1) the Kaiser-Meyer-Olkin (KMO) value obtained was 0.506, which is considered acceptable for exploratory purposes. According to Rani & Arlianti (2024), KMO values between 0.50-0.59 are categorized as miserable but acceptable for exploratory analysis, especially with small samples, 2) Bartlett's Test of Sphericity was used to confirm correlations among indicators, and 3) communalities greater than 0.5 supported the adequacy of factor extraction.

Analysis method

Descriptive analysis was used to obtain minimum, maximum, and mean values for each indicator. These statistical results were used to identify strengths and weaknesses in the construction project's quality management. Six Sigma implementation was evaluated using the DMAIC framework. The percentage score for each DMAIC stage was calculated using:

$$\text{Percentage} = \left(\frac{\text{Mean Score}}{5}\right) \times 100\% \quad (1)$$

Where 5 is the maximum Likert scale value. This method allows the transformation of Likert responses into standardized performance values for each DMAIC stage. The DMAIC stages used follow the standard Six Sigma framework (Table 2).

Results and Discussion

Respondent characteristics

The respondents in this study consist of 18 contractor personnel involved in the Post-Disaster Courthouse Construction Project in the Regional Court of Banda Aceh. Respondent characteristics are summarized in Table 3.

Table 3. Respondent characteristics

Category	Sub category	Frequency	
		n	(%)
Gender	Male	16	88.89
	Female	2	11.11
Age (year)	20–35	12	66.67
	36–45	4	22.22
	>45	2	11.11
Education Level	Diploma 3	1	5.56
	Bachelor	13	72.22
	Master	4	22.22
Position	Project manager	1	5.56
	Quality engineer	4	22.22
	Quantity engineer	3	16.67
	Site manager	3	16.67
	Inspector	2	11.11
	Supervisor	2	11.11
	Surveyor	3	16.66
Years of Experience	< 5 years	5	27.77
	5–10 years	10	55.56
	>10 years	3	16.67

Factor analysis

Factor analysis was conducted to examine the suitability of the indicators used in measuring the three research variables: quality planning (X1), quality management (X2), and quality control (X3). Prior to extracting the factors, two preliminary statistical tests were carried out: the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity.

Table 4. KMO and Barlett's test of sphericity

KMO and Barlett's test		
Kaiser-Meyer-Olkin measure of sampling adequacy		0.506
Barlett's test of sphericity	Approx. Chi-Square	118.532
	Df	66
	Sig.	0.000

The Kaiser–Meyer–Olkin (KMO) value obtained was 0.506, indicating marginal but acceptable sampling adequacy for exploratory factor analysis. According to Rani & Arlianti (2024), a KMO value above 0.50 is considered the minimum acceptable threshold for proceeding with factor extraction, particularly in exploratory studies. This interpretation is reinforced by Hair *et al.* (2019), who state that exploratory factor analysis remains appropriate for small sample sizes when communalities are sufficiently high.

Bartlett's Test of Sphericity yielded a significance value of $p < 0.001$, demonstrating that the correlation matrix is not an identity matrix. This result confirms that there are statistically significant relationships among the indicators, making the dataset suitable for factor extraction.

Communalities for all indicators were found to be above 0.50, indicating that each indicator contributes adequately to explaining the underlying construct. High communality values suggest that the extracted factor structure represents the dataset well and that the individual indicators share sufficient variance with their respective latent variables.

The results of the KMO, Bartlett's test, and communalities demonstrate that the dataset fulfills the assumptions required for exploratory factor analysis. Therefore, factor analysis was deemed appropriate for identifying the underlying structure of the quality planning, quality management, and quality control variables examined in this study. To further assess indicator suitability for factor extraction, communalities were examined. The extraction values for all indicators are presented in Figure 1.

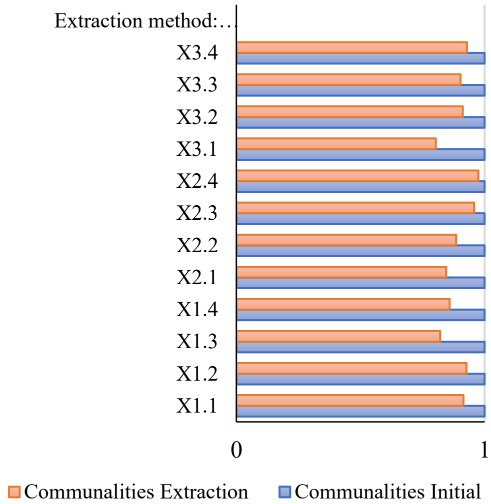

Figure 1. Communalities tests results

All indicators exhibit communalities above 0.50, indicating that each item contributes sufficiently to explaining the variance of its underlying factor. These results demonstrate that all indicators meet the minimum criteria for inclusion in factor extraction, thereby supporting the suitability of the dataset for exploratory factor analysis.

Descriptive analysis

In this study, there are three variables examined: quality planning (X1), quality management (X2), and quality control (X3). The results of the descriptive analysis can be seen in Figure 2. Based on the descriptive analysis, the highest mean values were observed in indicators X1.1 (identification of quality requirements), X1.2 (determination of quality standards), and X2.1 (implementation of the quality plan), each achieving a mean score of 4.39. These results indicate that respondents strongly perceive quality planning and the execution of quality plans as well-implemented within the project. In contrast, indicator X3.4 (controlling changes in construction quality) recorded the lowest mean value of 3.50, suggesting that change control within the quality control process is perceived as less effective compared to other quality management components.

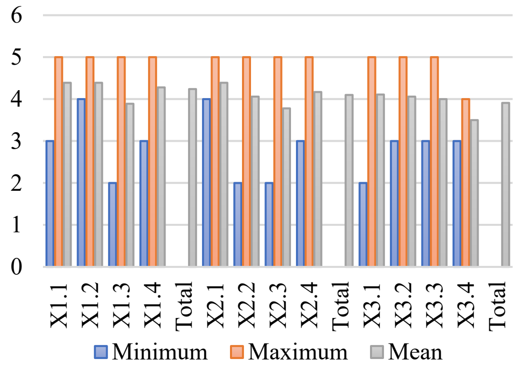

Figure 2. Results of descriptive analysis

DMAIC percentage analysis

The implementation of Six Sigma within the project was further evaluated by mapping each indicator to its corresponding DMAIC stage. The percentage values used in this section were derived by converting the mean Likert-scale scores into percentage achievement levels using the calculation procedure described in the Methodology section. This conversion allows for a clearer interpretation of how strongly each indicator reflects the perceived implementation of the Define, Measure, Analyze, Improve, and Control stages. The results for all DMAIC indicators are presented in Table 5.

Interpretation of Six Sigma Effectiveness

The DMAIC percentage results suggest that respondents perceive Six Sigma principles as being implemented to a moderate degree within the project, with stronger emphasis on planning and measurement activities. However, it is important to emphasize that these interpretations are based solely on perception, not on objective performance outcomes. Because objective indicators such as defect rates, rework frequency, cycle-time reduction, or sigma-level calculations were not available for this project, the results do not provide evidence of actual performance improvement. Instead, the findings should be understood as a reflection of project personnels perceived effectiveness of Six Sigma implementation.

Table 5. Percentage of DMAIC actions

No	Six Sigma Stages	Var.	Indicator	%
1	Define stage	X1	Setting quality targets.	22.95
2	Measure stage	X2	Implementation of the quality plan.	26.78
			Quality performance monitoring.	24.75
			Implementation of quality audits.	23.05
			Evaluation and quality improvement.	25.42
3	Analyze stage	X2	Implementation of quality audits.	23.05
4	Control stage	X3	Construction quality measurement.	26.24
			Construction quality verification.	25.89
			Identification of deficiencies and non-conformities in construction quality.	25.53
			Controlling changes in construction quality.	22.34

Conclusion

This study examined the implementation of Six Sigma in the Post-Disaster Courthouse Construction Project of the Regional Court of Banda Aceh using the DMAIC framework. The exploratory factor analysis and descriptive findings indicate that quality planning (X1) and quality management (X2) are perceived as being implemented effectively, particularly in the identification of quality requirements, the determination of quality standards, and the execution of quality plans. In contrast, the quality control variable (X3) shows relatively lower performance, especially in controlling changes in construction quality, highlighting the need to strengthen monitoring systems, documentation procedures, and audit practices.

It is important to emphasize that the conclusions of this study are based solely on the perceptions of project personnel. Due to the absence of objective performance data, such as defect rates, rework frequency, cycle-time reductions, or sigma-level calculations, this study does not provide evidence of actual Six Sigma performance improvement.

Therefore, the results should be interpreted as an assessment of perceived effectiveness rather than a measurement of operational impact.

The conversion of indicator scores into DMAIC percentage values reflects the respondents' perceptions of how strongly each DMAIC stage has been applied within the project. These values should not be interpreted as absolute measures of Six Sigma performance but as indicative assessments of perceived process implementation. The findings highlight that Six Sigma principles are generally recognized and applied within the planning and management phases of this post-disaster construction project. However, quality control functions require further reinforcement. Future studies should incorporate objective performance indicators to determine whether perceived improvements translate into measurable enhancements in construction quality outcomes.

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References

Abbes, N., Sejri, N., Xu, J. & Cheikhrouhou, M. (2022). New lean six sigma readiness assessment model using Fuzzy Logic: Case study within clothing industry. *Alexandria Engineering Journal*, *61*(11), 9079–9094. https://www.sciencedirect.com /science/article/pii/S1110016822001429

Abdullah, U., Bustani, S. A., Hassan, A. & Rotimi, F. E. (2019). Assessing quality management practice in Nigerian construction industry. *Journal of Construction Business and Management*, *3*(2), 17–25. https://doi.org/10.15641/jcbm.3.2.569

Alawag, A. M., Alaloul, W. S. & Liew, M. S. (2023a). Critical technical factors influencing construction failure in industrialized building systems: A case study in Malaysia. *Ain Shams Engineering Journal, 14*(3), 101798. https://doi.org/10.1016/j.asej.2023.101798

Alawag, A. M., Alaloul, W. S., Liew, M. S., Musarat, M. A., Baarimah, A. O., Saad, S. & Ammad, S. (2023b). Critical success factors influencing total quality management in industrialised building system: A case of Malaysian construction industry. *Ain Shams Engineering Journal*, *14*(2). https://doi.org/10.1016/j.asej.2023.101788

Alawag, A. M., Alaloul, W. S. & Liew, M. S. (2023c). Key factors influencing TQM adoption in construction projects: A case from the Malaysian construction industry. *Ain Shams Engineering Journal, 14*(2), 101788. https://doi.org/10.1016/j.asej.2023.101788

Antony, J., Gupta, S. & Kumar, M. (2022). Lean Six Sigma in healthcare: A systematic review of critical success factors, barriers, and enablers. *Total Quality Management & Business Excellence, 33*(5-6), 507–531. https://doi.org/10.1080/14783363.2020.1841237

Budayan, C. & Okudan, O. (2022). Roadmap for the implementation of Total Quality Management (TQM) in ISO 9001-certified construction companies: Evidence from Turkey. *Ain Shams Engineering Journal*, *13*(6). https://doi.org/10.1016/j.asej.2022.101788

Creswell, J. W. & Creswell, J. D. (2021). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (5th ed.). Thousand Oaks, CA: Sage Publications. https://us.sagepub.com/en-us/nam/research-design/book255675

Effendi, A. M., Rahmawati, V. Y., Kiromo, M. Z. H. & Yaqin, M. A., 2021. Pengukuran kinerja manajemen proyek menggunakan six sigma. *Ilkomnika: Journal of Computer Science and Applied Informatics*, *3*(3), 353–366. https://doi.org/10.28926/ilkomnika.v3i3.354

Ferdian, T., Isya, M. & Rani, H. A. (2018). Analisis hubungan dan pengaruh faktor-faktor berkontribusi terhadap kinerja mutu proyek konstruksi jalan di Provinsi Aceh. *Jurnal Arsip Rekayasa Sipil dan Perencanaan*, *1*(4), 174–183. https://jurnal.usk.ac.id/JARSP/article/view/12468

Kumar, V., Antony, J. & Douglas, A. (2020a). Critical success factors for the implementation of Lean Six Sigma in SMEs. *International Journal of Quality & Reliability Management, 37*(5), 757–774. https://doi.org/10.1108/IJQRM-02-2019-0065

Kumar, V., Antony, J. & Garza-Reyes, J. A. (2020b). Enhancing operational excellence through Lean Six Sigma: A systematic literature review. *Total Quality Management & Business Excellence, 31*(9-10), 1075–1097. https://doi.org/10.1080/14783363.2018.1492888

Kumar, M., Antony, J. & Montgomery, D. C. (2021). Lean Six Sigma for higher education institutions (HEIs): Current status and future directions. *International Journal of Productivity and Performance Management, 70*(8), 2031–2053. https://doi.org/10.1108/IJPPM-06-2020-0311

Mardikaningsih, R. & Darmawan, D. (2020). *Sistem Pengendalian Mutu*. Surabaya, Indonesia: Metromedia.

Muraleedharan, P., Siddarth, R. & Prakash, R. (2022). Integrating Six Sigma DMAIC methodology with Industry 4.0 tools: A systematic approach. *Journal of Cleaner Production, 351*, 131636. https://doi.org/10.1016/j.jclepro.2022.131636

Othman, I., Ghani, S. N. M. & Choon, S. W. (2021). A review of TQM implementation in the construction industry. *Ain Shams Engineering Journal, 12*(3), 697–704. https://doi.org/10.1016/j.asej.2021.101788

Othman, I., Ghani, S. N. M. & Choon, S. W. (2020). The Total Quality Management (TQM) journey of Malaysian building contractors. *Ain Shams Engineering Journal*, *11*(3),697–704. https://www.sciencedirect.com/science/article/pii/S209044791930156X

Peraturan Pemerintah Nomor 29 Tahun 2000 tentang Penyelenggaraan Jasa Konstruksi**.** Indonesia. https://peraturan.bpk.go.id/Details/ 53213/pp-no-29-tahun-2000

Project Management Institute. (2017). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, Sixth ed. Newtown Square, Pennsylvania, USA. https://www.pmi.org/pmbok-guide-standards

Ramasamy, S., Antony, J. & Kumar, M. (2021). Lean Six Sigma for sustainability: Current status and future directions. *Journal of Cleaner Production, 278*, 123840. https://doi.org/10.1016/j.jclepro.2020.123840

Rani, H. A. & Arlianti, N. (2024). *Dasar-dasar Statistika dan Probabilitas dalam Ilmu Sains*. Yogyakarta, Indonesia: Deepublish. https://books.google.co.id/books/about/Dasar_Dasar_Statistika_Dan_Probabilitas.html?id=GO8uEQAAQBAJ&redir_esc=y

Riaz, H., Khan, K. I. A., Ullah, F., Tahir, M. B., Alqurashi, M. & Alsulami, B. T. (2023a). Key factors for implementation of total quality management in construction sector: A system dynamics approach. *Ain Shams Engineering Journal*, *14*(3). https://www.sciencedirect.com/ science/article/pii/S2090447922002143

Riaz, H., Khan, K. I. A. & Alqurashi, M. (2023b). Framework for enhancing quality assurance in construction management. *Ain Shams Engineering Journal, 14*(3), 101786. https://doi.org/10.1016/j.asej.2023.101786

Sunder, M. V. & Antony, J. (2020). A strategic framework for Lean Six Sigma project management: Insights from stakeholder management perspective. *The TQM Journal, 32*(6), 1239–1260. https://doi.org/10.1108/TQM-07-2019-0188

Timans, W., Antony, J. & Kumar, V. (2021). Lean Six Sigma in small and medium-sized manufacturing enterprises: The Dutch experience. *International Journal of Production Research, 59*(3), 901–917. https://doi.org/10.1080/00207543.2020.1715873

Uluskan, M., Joines, J. A. & Antony, J. (2021). Quality management in global supply chains: A systematic review. *Supply Chain Management: An International Journal, 26*(4), 321–342. https://doi.org/10.1108/SCM-05-2020-0209

Wahyu, A., Suryani, F. & Dinariana, D. (2021). Kemampuan pengelolaan manajemen mutu terhadap hasil kerja diukur dari standar QPASS (Studi kasus: Proyek Arandra Residence). *IKRAITH-Teknologi*, *5*(2), 48–57. https://journals.upi-yai.ac.id/index.php/ikraith-teknologi/article/view/969

Yadav, G., Seth, D. & Desai, T. N. (2021). Application of hybrid Lean Six Sigma framework in manufacturing: An empirical study. *Production Planning & Control, 32*(8), 618–632. https://doi.org/10.1080/09537287.2020.1828756

Zhang, M., Wang, W. & Antony, J. (2022). Comprehensive Lean Six Sigma applications in complex systems: A review. *Production Planning & Control, 33*(10), 901–920. https://doi.org/10.1080/09537287.2021.1957889

Zuhri, Z., Isya, M. & Rani, H. A. (2018). Pengaruh faktor-faktor kualifikasi kontraktor terhadap kualitas proyek konstruksi jalan di Kota Banda Aceh. *Jurnal Arsip Rekayasa Sipil dan Perencanaan*, *1*(3), 113–121. https://jurnal.usk.ac.id/JARSP/article/view/11775