



## DETERMINANT FACTORS INFLUENCING THE QUALITY OF RIGID PAVEMENT PROJECT EXECUTION IN SUNGAI PENUH CITY

Deri Zalmi<sup>1)</sup>, Eva Rita<sup>2)</sup>, Rini Mulyani<sup>3)</sup>

<sup>1,2,3)</sup> Program Studi Magister Teknik Sipil, Fakultas Teknik Sipil dan Perencanaan, Universitas Bung Hatta

Corresponding Author E-Mail: [dheryalkrienciehie@gmail.com](mailto:dheryalkrienciehie@gmail.com)

### ABSTRAK

Kualitas proyek konstruksi jalan merupakan penentu kritis bagi kinerja dan keberlanjutan infrastruktur. Namun, di Kota Sungai Penuh, beberapa proyek perkerasan kaku menghadapi masalah kualitas pelaksanaan yang rendah, sehingga berdampak pada berkurangnya daya tahan jalan dan meningkatnya biaya pemeliharaan. Penelitian ini dilakukan dengan tiga tujuan utama: (1) mengidentifikasi faktor-faktor yang berkontribusi terhadap rendahnya kualitas konstruksi, (2) menentukan faktor dominan yang memengaruhi hasil proyek, dan (3) merumuskan solusi praktis untuk perbaikan. Pendekatan mixed methods digunakan dengan menggabungkan analisis kuantitatif melalui survei dengan wawasan kualitatif dari studi literatur dan wawancara pakar. Sebanyak 64 kuesioner disebarakan sehingga memungkinkan analisis statistik secara komprehensif. Hasil penelitian mengungkapkan sembilan faktor utama yang memengaruhi kualitas konstruksi, yaitu desain, metode kerja, material, peralatan, tenaga kerja, aspek manajerial, pengawasan, sumber daya keuangan, serta kondisi lingkungan. Analisis faktor menunjukkan bahwa permasalahan terkait material merupakan faktor dominan dengan kontribusi sebesar 33,907% terhadap variabilitas. Masalah utama meliputi ketidaksesuaian mutu material dengan spesifikasi teknis, pengujian material yang tidak memadai, keterlambatan pengadaan, serta ketidakefisienan logistik. PDCA (Plan–Do–Check–Action) digunakan sebagai solusi terstruktur, yang menekankan pentingnya perencanaan sistematis, implementasi yang efektif, inspeksi mutu, serta langkah korektif. Temuan penelitian ini menunjukkan bahwa peningkatan manajemen material melalui PDCA tidak hanya memperkuat kesesuaian dengan standar teknis, tetapi juga membangun kerangka kerja perbaikan mutu berkelanjutan dalam proyek konstruksi jalan. Studi ini memberikan kontribusi secara teoretis dengan memvalidasi faktor-faktor kritis dalam kualitas konstruksi, serta secara praktis dengan menawarkan strategi aplikatif bagi para pemangku kepentingan untuk memastikan pembangunan infrastruktur berkelanjutan di Kota Sungai Penuh.

Kata kunci : kualitas konstruksi jalan, analisis faktor, PDCA, manajemen material, Kota Sungai Penuh

### ABSTRACT

*The quality of road construction projects is a critical determinant of infrastructure performance and sustainability. However, in Sungai Penuh City, several rigid pavement projects have faced issues of poor execution quality, leading to reduced durability and increased maintenance costs. This study was conducted with three main objectives: (1) to identify the factors contributing to low construction quality, (2) to determine the dominant factors influencing project outcomes, and (3) to propose practical solutions for improvement. A mixed-methods approach was adopted, combining quantitative analysis through surveys with qualitative insights from literature reviews and expert interviews. A total of 64 questionnaires were distributed, allowing comprehensive statistical analysis. The results revealed nine major factors influencing construction quality: design, work methods, materials, equipment, workforce, managerial aspects, supervision, financial resources, and environmental conditions. Factor analysis highlighted that material-related issues were the most dominant, accounting for 33.907% of the variance. Key problems included non-compliance of materials with technical specifications, inadequate material testing, procurement delays, and logistical inefficiencies. To address these challenges, a PDCA (Plan–Do–Check–Action) framework was applied as a structured solution, emphasizing systematic planning, effective implementation, quality inspection, and corrective measures. The findings demonstrate that improving material management through PDCA not only enhances compliance with technical standards but also establishes a framework for continuous quality improvement in road construction projects. This study contributes both*



*theoretically by validating critical factors in construction quality and practically by offering actionable strategies for stakeholders to ensure sustainable infrastructure development in Sungai Penuh City.*

*Keyword : road construction quality, factor analysis, PDCA, material management, Sungai Penuh City*

## 1. INTRODUCTION

Road infrastructure plays a fundamental role in enhancing regional connectivity, supporting logistics distribution, and promoting equitable economic development. Among various pavement types, rigid pavement is widely implemented in high-capacity road projects due to its superior durability under heavy traffic loads and its relatively long service life [1]. Nevertheless, the quality of rigid pavement construction across many regions in Indonesia, including Sungai Penuh City, often falls short of the required technical standards. The Audit Board of Indonesia (BPK) reported that during 2022–2024, a significant portion of financial losses in Sungai Penuh's road projects were caused by nonconformities between the delivered concrete quality and the design specifications [2]. Such findings indicate that quality deficiencies are not merely a matter of construction errors but also reflect managerial and technical weaknesses across the project cycle.

Sungai Penuh City faces unique challenges that exacerbate these issues. The region's hilly topography, humid climate, and limited access to construction materials from outside areas complicate both material control and project execution. While many previous studies have explored rigid pavement performance from a purely technical perspective—such as slab thickness, jointing, subgrade condition, and concrete mix design [4], [5], [6]—few have examined the combined influence of managerial practices, local logistical constraints, and environmental conditions on construction quality in small municipalities. Similarly, although risk-based inspection frameworks and quality management systems have been introduced in highway projects [7], their localized adaptation to resource-constrained environments such as Sungai Penuh remains limited.

This research seeks to address these gaps by systematically identifying the factors

influencing rigid pavement construction quality in Sungai Penuh, determining the most dominant factors through statistical and field validation, and formulating a context-sensitive quality-improvement strategy based on the PDCA (Plan–Do–Check–Act) cycle [3], [8]. By integrating both quantitative and qualitative approaches, the study aims to generate practical recommendations for local government agencies, contractors, and supervisory consultants, ultimately strengthening the quality management framework of road infrastructure projects in regions with dynamic geographical and climatic conditions.

## 2. LITERATURE REVIEW

Rigid pavement is a type of pavement structure that relies primarily on the flexural strength of concrete slabs to distribute loads. Compared to flexible pavement, rigid pavement offers higher durability and lower maintenance requirements, particularly for roads with high traffic volumes and heavy loads [1], [4]. The performance of rigid pavement depends on several technical factors, including slab thickness, joint design, subbase quality, and the strength of concrete materials [5]. Studies have shown that initial roughness and early-age cracking of concrete slabs are strongly influenced by construction quality, environmental conditions, and material variability [6].

In the Indonesian context, the application of rigid pavement follows the national standards established in SNI 2847:2019 for concrete structures and SNI 1732:2017 for pavement design [1], [9]. However, various audit reports and empirical studies have highlighted challenges in ensuring compliance with these standards, particularly in regions with complex geography and limited infrastructure support [2]. For instance, inconsistent quality control during batching, mixing, and curing often results in compressive strength values that fall



below design requirements, leading to premature deterioration [10].

From the managerial perspective, project quality is not only determined by technical specifications but also by the effectiveness of contractors, supervisory consultants, and owner agencies in implementing quality assurance (QA) and quality control (QC) processes [7]. Research on road construction quality management emphasizes that delays, cost overruns, and quality failures are frequently associated with weaknesses in supervision, contractor competence, and ineffective monitoring mechanisms [11]. In this regard, international practices such as those recommended by the Federal Highway Administration (FHWA) advocate the use of risk-based inspection systems and systematic documentation to reduce nonconformance risks in rigid pavement construction [4], [7].

Quality management frameworks such as the PDCA (Plan-Do-Check-Act) cycle have also been widely applied in the construction sector as a continuous-improvement methodology [3], [8]. PDCA provides a systematic approach by integrating planning, implementation, evaluation, and corrective actions in a feedback loop. Several studies show that the PDCA cycle can improve construction performance by reducing defects, enhancing contractor awareness, and increasing accountability in supervision [8], [12]. However, most applications of PDCA in construction quality management are reported in large-scale projects or developed-country contexts, whereas localized studies in small municipalities with resource constraints remain limited.

Therefore, while the existing literature provides comprehensive insights into the technical and managerial determinants of rigid pavement quality, a research gap persists in the integration of these two perspectives within the local context of Indonesian municipalities. This study contributes to filling that gap by analyzing both technical and managerial factors affecting rigid pavement quality in Sungai Penuh City and proposing a PDCA-based improvement framework tailored to its specific challenges.

### 3. METHOD

This study adopts a mixed-methods approach by combining quantitative and qualitative techniques. The quantitative approach is applied to identify the dominant factors affecting the low quality of rigid pavement projects in Sungai Penuh City, while the qualitative approach is employed through literature review and expert interviews. Literature sources include journal articles, technical guidelines, and previous studies on road construction quality factors in both domestic and international contexts. Previous research shows that road construction quality is influenced by factors such as equipment and materials [13], financial and managerial capacity [14], environmental and natural conditions [15], and contractor competence [16]. These findings are consistent with other studies that highlight planning, financial management, and supervision as critical determinants of road project performance [17]–[19].

Based on the literature review, nine variables were identified as potential determinants of quality performance: design, work methods, materials, equipment, labor, managerial competence, supervision, finance, and environmental conditions. According to Sugiyono [20], variables in a study are categorized into dependent variables (the observed quality outcomes) and independent variables (the predictors, such as managerial or technical factors). These variables were operationalized into measurable indicators and translated into questionnaire items using a Likert scale from 1 to 5 [21]. Respondents, consisting of contractors, supervisory consultants, and government officials from the Public Works and Housing Agency (Dinas PUPR) of Sungai Penuh City, were selected as the sample population. The total population involved in rigid pavement projects between 2022 and 2024 was 64 individuals, drawn from eight project packages audited by the Audit Board of Indonesia (BPK). Sampling was conducted using a purposive method to ensure that respondents had direct involvement in project execution.

To achieve the first research objective, descriptive analysis was used to identify the perceived importance of each factor. Data



validity and reliability tests were conducted using SPSS. The Kaiser-Meyer-Olkin (KMO) and Bartlett's tests were applied to assess sampling adequacy and correlation among variables, with thresholds of KMO > 0.5 and significance < 0.05 [22]. Validity was assessed through factor loading, with items considered valid if the loading value exceeded 0.5 [23], while reliability was tested using Cronbach's Alpha, where values greater than 0.6 indicated acceptable consistency.

For the second research objective, factor analysis was conducted to identify dominant variables contributing to low-quality outcomes. Communalities tests ensured that extracted factors explained at least 50% of the variance, while eigenvalues greater than 1 determined the number of retained factors. Rotation methods were employed to clarify factor loading distributions, and naming of factor groups was based on the commonality of variables. Confirmatory Factor Analysis (CFA) was applied to validate the model structure and ensure robustness of the identified factors.

Finally, to formulate improvement strategies (the third research objective), the results of statistical analysis were combined with qualitative insights from expert interviews. Three experts were purposively selected based on criteria of minimum 10 years of project management experience, at least a bachelor's degree in civil engineering, and senior managerial roles [24]. The experts were asked to validate the findings, suggest feasible solutions, and provide recommendations for applying the PDCA (Plan-Do-Check-Act) cycle to strengthen quality assurance systems in rigid pavement projects. The triangulation of literature, statistical results, and expert opinion ensured that the proposed solutions are both evidence-based and contextually relevant.

#### 4. Results and Discussion

The respondents of this study consisted of individuals directly involved in the road construction projects in Sungai Penuh City. A total of 64 questionnaires were distributed, and all 64 were returned, resulting in a 100% response rate. This complete return enabled the continuation of the advanced data analysis process.

##### 4.1 Identify the factors influencing rigid pavement construction quality

The first research objective was to identify the variables that contribute to the low quality of road construction in Sungai Penuh City. Several statistical tests were conducted to ensure the validity and reliability of the research instruments.

###### a. KMO and Bartlett's Test

The results showed that the sampling adequacy and correlation among variables met the requirements, with a Kaiser-Meyer-Olkin (KMO) value greater than 0.5 and a significance value below 0.005. This indicates that the data were suitable for further factor analysis.

###### b. Validity Test

The validity test results confirmed that all statement items were valid. Each item demonstrated a calculated correlation coefficient ( $r$ ) higher than the critical table value ( $r$  table). This means that every variable statement could be used for the next stage of analysis.

###### c. Reliability Test

Reliability analysis revealed that all variables had Cronbach's Alpha values greater than 0.60, confirming internal consistency and reliability. This implies that the instruments used were stable and dependable for measuring the constructs of low-quality roadwork factors.

##### 4.2 Identify the dominant factors influencing rigid pavement construction quality

The second objective was to identify the dominant factors contributing to the low quality of road construction projects in Sungai Penuh City. Several advanced tests were conducted as follows:

###### a. Measures of Sampling Adequacy (MSA)

The MSA results revealed that one variable had an MSA value below 0.5, which did not meet the eligibility criteria. Consequently, this variable was excluded from further analysis. A total of 39 variables remained and were included in subsequent tests.

###### b. Communalities Test



The communalities results indicated that all variables met the requirements, with extraction values greater than 0.50. This demonstrates that each variable had sufficient correlation with others, allowing them to be predicted and analyzed further.

c. Factor Extraction

Factor extraction was carried out using eigenvalue criteria. Nine factors were extracted, each with eigenvalues greater than 1, explaining a cumulative variance of 73.030%. This indicates that these nine factors collectively explained 73.03% of the variation in road construction quality in Sungai Penuh City. Factor 1 contributed the most, accounting for 33.907% of the total variance.

d. Factor Loading

For the sample size of 64, the minimum acceptable factor loading was 0.50. The rotated component matrix demonstrated the distribution of variables across the nine factors, where variables with factor loadings above 0.50 were considered significant contributors. These results provide a clearer grouping of the dominant factors influencing road construction quality.

The findings confirm that the low quality of road construction in Sungai Penuh City is influenced by multiple interrelated factors. The identification of nine dominant factors aligns with previous studies, which highlighted financial, managerial, environmental, material, and human resource variables as critical determinants of project performance [13]–[19]. In particular, Factor 1, which explained the largest proportion of variance (33.907%), emphasizes the strong influence of managerial and planning aspects, echoing the findings of Ferdian et al. [14] and Yenri et al. [17].

The cumulative variance of 73.03% suggests that these nine factors collectively provide a comprehensive understanding of the quality issues in road construction. This percentage is relatively high, indicating that the variables chosen through literature review and expert validation were appropriate and reflective of the field conditions.

The exclusion of one variable due to a low MSA value indicates that not all initially assumed indicators are equally relevant in the local context of Sungai Penuh City. This reinforces the importance of context-specific analysis in construction project studies, as factors can vary across regions depending on governance, environmental conditions, and resource availability.

These results underscore the necessity of adopting integrated approaches that address not only technical aspects (such as material and equipment) but also managerial, financial, and human resource dimensions. Furthermore, the dominance of managerial and planning-related variables suggests that capacity-building programs for project managers and supervisors could significantly improve roadwork quality.

Based on the results of factor analysis, the variables were grouped into nine main factors that contribute to the quality of rigid pavement construction projects in Sungai Penuh City. The grouping is presented in Table 1.

**Table 1.** Factor Grouping Based on Factor Analysis

Factor	Factor Name	Description
1	Material	Conformity of material quality and physical condition with technical specifications; contractors' testing of materials used in the project; mismatches between material ordering and implementation schedules; optimization of material logistics to the work site.
2	Design and Work Method	Comprehensive and structured technical planning; completeness and clarity of technical specifications and work requirements (RKS); application of appropriate construction methods; design information and criteria adapted to field conditions; equipment



		operation methods; feasibility of equipment used.
3	Finance and Equipment	Budgeting that accounts for inflation and material price escalation; contingency funds for risks and unforeseen conditions; timely and sustainable project funding; optimization of work volumes through periodic project needs evaluations. Flexible design and work adjustments based on field needs; adequacy of manpower deployed on site;
4	Planning and Resources	accuracy of cost estimation according to actual conditions; traffic control and occupational safety management within project areas. Differences between actual site conditions and planning documents; planning and optimization of site access; equipment productivity under environmental constraints.
5	Environmental Conditions	Supervision during material fabrication; quality of human resources and project organization; contribution of on-site supervisory experts; performance of subcontractors used.
6	Supervision	Monitoring subcontractor performance; adjustment of work methods according to field conditions. Adjustment of construction methods to weather conditions; readiness and mitigation strategies for natural disaster risks; adequacy of material availability during the construction process.
7	Subcontractor Management	Contractor technical staff availability for quality control; procedures and systems of quality management applied.
8	Natural Conditions and Material Availability	
9	Quality Management	

The factor analysis results grouped the observed variables into nine dominant categories: Material, Design and Work Method, Finance and Equipment, Planning and Resources, Environmental Conditions, Supervision, Subcontractor Management, Natural Conditions and Material Availability, and Quality Management. These factors collectively represent the multidimensional challenges influencing the quality of rigid pavement road construction in Sungai Penuh City.

The Material factor emerged as a fundamental determinant of quality, emphasizing conformity of materials with technical specifications and the importance of proper material testing. Similar findings were reported by Rauzana et al. [15], who highlighted material quality as a critical influence on project outcomes. The Design and Work Method factor further reinforces the need for technical clarity and construction methods tailored to site-specific conditions, consistent with Sembiring et al. [16], who emphasized the risks of poor design and inadequate work methods.

The grouping also identified Finance and Equipment as a distinct factor, underscoring the importance of timely funding and adequate equipment in ensuring project continuity. This resonates with findings from Yenri et al. [17] and Ali et al. [18], where financial planning and equipment availability were shown to be decisive in project quality. Similarly, the Planning and Resources factor, which includes manpower adequacy and occupational safety, supports Ferdian et al. [14], who highlighted human resources and managerial planning as integral to successful road projects.

Environmental challenges were represented by the Environmental Conditions and Natural Conditions and Material Availability factors, which align with Kausari et al. [25], who noted that natural conditions and material scarcity significantly influenced construction performance in rural Indonesia. The Supervision factor and Subcontractor Management factor emphasize the importance of consistent oversight, supervisory expertise, and subcontractor reliability, consistent with Alau et al. [19], who noted that weak



supervision and subcontractor mismanagement reduce quality outcomes.

Finally, the Quality Management factor highlights the role of systematic quality control procedures and availability of skilled technical staff in ensuring compliance with standards, reinforcing the necessity of structured quality management systems as suggested by Hwang et al. [19].

Overall, the nine grouped factors demonstrate that rigid pavement construction quality issues are not only technical but also managerial and environmental in nature. This multidimensional perspective confirms the relevance of applying systemic frameworks, such as the PDCA cycle, to address interrelated challenges and improve construction quality in dynamic geographical and climatic contexts.

#### **4.3 Solutions for Improving Road Construction Quality**

In line with the third research objective, which sought to propose practical solutions to enhance the quality of road construction in Sungai Penuh City according to established standards, the analysis identified material factors as the most dominant contributor to poor construction outcomes, accounting for 33.907% of the issue. Four critical variables were highlighted: compliance of material quality and physical condition with technical specifications, the contractor's responsibility to conduct material testing for project use, inaccuracy between procurement schedules and project implementation timelines, and the optimization of logistics from procurement to delivery at the construction site. To address these challenges, a systematic improvement framework was developed using the PDCA (Plan-Do-Check-Action) approach.

At the planning stage, emphasis is placed on aligning material needs with technical specifications, establishing clear quality standards, synchronizing procurement schedules with project progress, and preparing testing and logistics plans at the outset of the project. The implementation stage requires the application of proper technical procedures, including material storage to prevent damage, laboratory testing, and phased delivery, supported by the involvement of competent

personnel and effective coordination among stakeholders. The checking stage focuses on evaluating compliance with technical requirements through physical inspections, laboratory results, and delivery timeliness, while also ensuring systematic documentation and reporting for quality control. Finally, the action stage involves corrective measures, such as updating standard operating procedures (SOPs), retraining technical staff, reviewing supply chains, adjusting work schedules, and identifying alternative routes for material mobilization.

The integration of PDCA across these variables demonstrates that structured and collaborative material management is critical to achieving quality standards in road construction. This approach not only reduces risks associated with poor material practices but also establishes a continuous improvement mechanism that supports sustainable infrastructure development in regions with complex geographical and logistical challenges such as Sungai Penuh City.

#### **5 CONCLUSION**

This study set out to achieve three main objectives related to the quality of rigid pavement construction projects in Sungai Penuh City. First, the research successfully identified the key factors affecting project quality through statistical testing, including managerial, financial, human resource, environmental, design, supervision, subcontractor, and equipment-related aspects. Second, factor analysis was conducted to determine the dominant variables, and the findings revealed that material-related issues were the primary contributors, accounting for 33.907% of the variance. These issues included non-compliance of material quality with technical specifications, lack of proper material testing, inaccuracies in procurement scheduling, and logistical inefficiencies. Third, solutions were formulated through expert validation and further analysis using the PDCA (Plan-Do-Check-Action) framework. The proposed strategy emphasizes structured planning, effective implementation, systematic inspection, and corrective actions to improve



material management and ensure compliance with quality standards.

Overall, the study demonstrates that the application of PDCA as a continuous improvement tool can address the root causes of poor construction quality, particularly those related to material management, and contribute to the development of sustainable and reliable road infrastructure in Sungai Penuh City. The results provide both practical recommendations for contractors, supervisors, and project owners, as well as strategic insights for policymakers to strengthen quality assurance systems in road construction projects.

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