



Original Article

## Investigating Supply Chain Management Implementation Challenges in Highway Infra-structure: Evidence from the Sigli–Banda Aceh Toll Road

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**Abstract:** The construction of the Sigli–Banda Aceh Toll Road requires a reliable supply chain management system due to its influence on project cost, quality, schedule, and the presence of significant operational and institutional challenges. This study aims to identify and rank the key challenges associated with implementing supply chain management in the project. A quantitative, questionnaire-based approach was employed, utilizing proportionate stratified random sampling among project stakeholders, which resulted in 49 respondents. The data were analyzed using descriptive statistics, Kendall's coefficient of concordance, and Spearman's rank correlation to assess agreement and relationships among stakeholder groups. The findings indicate that, of the 56 indicators measured, 23 were identified as major challenges, including shortages of skilled labor, limited workforce readiness, restricted quarry availability, and constrained capacity of material processing facilities such as batching plants, crushers, and asphalt mixing plants, as well as uncertainties related to fluctuating material prices. The statistical analysis reveals a high level of agreement and strong rank correlation among the owner, contractors, and supervisory consultants. In conclusion, the results support prioritizing interventions aimed at enhancing workforce competency, developing local suppliers, and increasing the capacity of material production facilities to strengthen the project's supply chain resilience.

**Keywords:** Supply Chain Management; Sigli–Banda Aceh Toll Road; Skilled Labor; Material Availability; Stakeholder Agreement.



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### 1. Introduction

The construction of toll roads constitutes a large-scale infrastructure activity that directly contributes to regional connectivity, the efficiency of goods and services distribution, and the acceleration of local economic development. In megaprojects, the role of supply chain management is particularly critical, as it

ensures the availability of materials, equipment, and labor at the right time and location, thereby affecting project cost, quality, and timely completion. Recent literature emphasizes that supply chains in megaprojects are multi-layered and highly complex, and supply chain decisions exert substantial influence on overall project performance. These insights underscore the need for research that focuses specifically on the challenges associated with implementing supply chain management within the context of construction megaprojects (Stefano et al., 2023).

Although the benefits of supply chain integration in construction are widely acknowledged, including improved time and cost control as well as enhanced coordination among stakeholders, practical implementation often encounters substantial challenges. Survey-based studies and empirical investigations in construction projects reveal common issues, including weak procurement strategies, delays in material delivery, fragmented information among project participants, and low adoption of automation and digitalization in supply chain processes. In many developing countries, these problems are further exacerbated by the limited capacity of local suppliers and subcontractors' inability to meet the technical standards and volume requirements of large-scale projects. Such empirical findings highlight the operational and institutional barriers that must be thoroughly understood before managerial interventions can be effectively implemented (Ogundipe et al., 2024).

In the practical implementation of toll road projects in regions with limited supporting infrastructure, distinct challenges arise related to the scarcity of raw material resources and the lack of material processing facilities. Constraints in the number and capacity of quarries, batching plants, crushers, and asphalt mixing plants in certain areas increase haul distances, fleet waiting times, logistics costs, and the risk of fluctuating material quality. In addition, uncertainty in global and national material prices, along with supply chain disruptions caused by external events (such as logistical disturbances or geopolitical shocks), further heightens the volatility that project managers must address. Cross-disciplinary literature emphasizes that external disruptions and supply chain leadership can significantly influence a system's capacity to respond to and mitigate these impacts (Huang & Li, 2024).

The research gap motivating this study stems from the limited empirical work that specifically examines the challenges of implementing supply chain management in toll road projects within the Indonesian context, particularly in regions with geographical characteristics and industrial capacities that differ from those of national construction centers. Much of the international literature discusses general principles of supply chain management in megaprojects or procurement integration practices in international EPC projects, yet few studies map the specific challenge indicators based on the perceptions of stakeholders involved in toll road projects located in areas with constrained material production facilities. Against this backdrop, this article focuses on identifying and ranking the challenges associated with implementing supply chain management in the construction of the Sigli–Banda Aceh Toll Road, based on the perceptions of project stakeholders. The key findings reveal that, of the 56 indicators assessed, 23 are categorized as major challenges by project stakeholders. These results provide essential empirical insight into the operational and institutional vulnerabilities present within the project's supply chain in this region.

This study is significant for both academics and practitioners as it provides field-based evidence specific to toll road projects in Aceh Province, thereby complementing the literature, which is often general in nature, on supply chain management in megaprojects. Furthermore, the article highlights several hypotheses and debates relevant to a multidisciplinary readership, such as whether megaproject supply chains should be designed as permanent structures relying on national suppliers or as temporary networks that prioritize the use of local capacity, and the controversy surrounding the trade-off between cost efficiency through centralized procurement versus resilience benefits through diversification of local suppliers. By mapping the concrete challenges in the Sigli–Banda Aceh Toll Road project, this article aims to provide an empirical foundation for discussions on procurement policy, the role of local governments, and priorities for future research in construction supply chain management.

## 2. Literature Review

Research on supply chain management (SCM) in the context of construction projects suggests that project success is significantly influenced by the effective management of material flow, information flow, coordination, and collaboration among stakeholders. Previous studies emphasize that the inherent complexity of construction projects renders SCM a strategic element that influences not only operational efficiency but also project outcomes, timely completion, and the minimization of resource waste. Oktaviani (2019) initiated this discourse by demonstrating that low effectiveness in supply chain performance in construction projects primarily stems from insufficient coordination among project participants and the absence of mutually agreed-upon performance evaluation standards. Such conditions create information fragmentation, which slows decision-making processes and leads to misalignment between field requirements and the capacity of suppliers or subcontractors to meet material demands.

Meanwhile, studies focusing on the implementation of green supply chain management (GSCM) demonstrate that challenges in SCM are not solely operational but also related to the knowledge and awareness of construction practitioners. Handayani et al. (2021) found that the low number of suppliers adopting environmentally friendly practices and the limited understanding of the environmental impacts of construction activities constitute significant barriers to GSCM adoption in Indonesia. These findings highlight the pivotal role of human resource quality in facilitating the transition from traditional practices to a more sustainable supply chain model. Knowledge- and capacity-related barriers align with the findings of Kim and Nguyen (2022), who reported that ineffective leadership, limited competencies, inadequate understanding of SCM concepts, and organizational resistance are major factors hindering SCM implementation in Vietnam. Such resistance is typically manifested in an organization's reluctance to adopt new technologies, unwillingness to change hierarchical communication patterns, and inability to foster a culture of transparent information sharing.

In addition to knowledge gaps and organizational resistance, challenges in construction SCM become increasingly complex when digital technology adoption is involved. Onyla et al. (2024) provide an in-depth perspective on the challenges of digitalizing construction supply chains in Nigeria, which include limited government support, high initial costs of technology implementation, insufficient workforce training, a shortage of skilled personnel, poor communication channels among stakeholders, and a lack of standardized data formats. While digitalization is intended to accelerate monitoring, coordination, and reporting processes, it can become a new obstacle when supporting infrastructure and organizational readiness are inadequate. This phenomenon suggests that digital transformation in SCM necessitates a systemic approach that incorporates government policy, targeted financing, and ongoing improvement of human resource capacity.

In the context of developing countries facing various challenges in infrastructure projects, Ogunidipe et al. (2024) demonstrated that SCM issues are strongly influenced by weaknesses in project governance. Weak procurement strategies, unclear project specifications, limited scheduling flexibility, poor construction design, and delays in material delivery are critical factors that hinder SCM performance in construction projects in South Africa. Unclear specifications and inadequate planning serve as the root causes of many infrastructure development problems, as these conditions create uncertainty for suppliers, increase the risk of technical errors, and elevate costs due to repeated revisions. If procurement strategies and planning are not strengthened from the early project phases, SCM implementation on-site will continue to encounter significant inefficiencies.

Although various challenges have been identified in previous studies, some research also offers concrete strategies to enhance SCM effectiveness in construction projects. Stefano et al. (2023) concluded, through a systematic literature review, that supply chain management in megaprojects requires seven key strategies: cross-organizational collaboration, strong governance, risk and uncertainty management, information management, capability development, process standardization, and sustainability. These seven strategies demonstrate that SCM is not merely a technical process, but a socio-technical system that necessitates integration among technology, stakeholder relationships, and organizational policies. Large-scale construction projects, including toll roads, dams, and transportation infrastructure, can achieve maximum efficiency only when there is alignment between internal and external parties, and leadership plays an active role in guiding such synergy.

In line with studies on megaproject strategies, several studies on infrastructure development in Indonesia have frequently employed SWOT analysis to identify internal and external factors affecting project success. Benzaghta et al. (2021), Hidayat et al. (2022), and Fachrurrazi et al. (2022) consistently found that the W-O strategy (minimizing internal weaknesses while maximizing external opportunities) is the most appropriate approach in the Indonesian infrastructure context. This finding suggests that many infrastructure projects still face internal weaknesses, such as limited human resource capacity, insufficient inter-agency coordination, and inadequate technological support, whereas external opportunities, including government policies, community needs, and strategic environmental support, are substantial. Conversely, Fitriadi et al. (2022) showed that the W-T strategy (minimizing weaknesses to avoid threats) is the preferred approach in the development of bicycle lanes in Banda Aceh, particularly when projects encounter external threats such as limited urban space, public resistance, or unfavorable policy changes.

The previous findings provide a comprehensive overview indicating that supply chain management in construction projects is strongly influenced by the complex interaction between internal and external factors. Internally, coordination, human resource competencies, organizational culture, planning quality, and technological readiness are fundamental aspects. Externally, government policies, supplier market conditions, technological developments, and economic environmental dynamics significantly influence the success of SCM implementation. The integration of these factors is crucial for formulating effective SCM strategies, thereby minimizing project risks and enhancing operational efficiency.

This study also highlights a significant research gap in SCM studies for infrastructure projects, particularly in the context of toll road projects in Indonesia. Although numerous studies have addressed

SCM challenges at both national and international levels, no research has specifically examined SCM in the Sigli–Banda Aceh Toll Road project. This project is a nationally strategic initiative with unique geographical, cultural, and logistical characteristics. Limited material access, the geographical conditions of Aceh, local social dynamics, and the involvement of multiple contractors and subcontractors create SCM challenges that differ significantly from those in other infrastructure projects. Therefore, investigating SCM challenges in this toll road project is essential to fill this research gap and provide more contextual insights for the development of SCM practices in Indonesia.

Furthermore, very few previous studies have combined quantitative analytical approaches, such as Kendall’s coefficient of concordance and Spearman’s rank correlation, to determine the priority of SCM challenges, followed by SWOT analysis to formulate corresponding mitigation strategies. Such a combined approach has the potential to yield more robust findings, as it can objectively identify the main challenges based on respondent rankings and levels of agreement, and subsequently develop strategies that are most relevant considering the interaction between internal and external factors. This approach also makes a significant methodological contribution to SCM literature by integrating statistical measurement with strategic, management-oriented analysis. Therefore, research on SCM in the Sigli–Banda Aceh Toll Road project is not only practically relevant but also academically valuable in enriching SCM studies within the Indonesian construction sector.

Thus, the literature indicates that SCM implementation in construction projects continues to face various challenges, stemming from both internal factors such as coordination, human resource competencies, and organizational governance, and external factors, including supplier market conditions, policy support, and technological developments. Although previous studies have proposed various strategies, their application still requires adaptation to the local context of each project. Therefore, research on SCM challenges and strategies in the Sigli–Banda Aceh Toll Road project is essential to provide more specific and contextually relevant empirical insights, while also contributing to the development of more effective SCM policies and practices in Indonesia.

### 3. Materials and Methods

This study employs a quantitative approach using a questionnaire survey. The questionnaire data were utilized to assess challenge indicators in the implementation of supply chain management for the Sigli–Banda Aceh Toll Road Construction Project, based on experiences from 2019 to 2025. Data collection was conducted by visiting respondents in person and administering the questionnaire directly to them.

#### 3.1. Population and Sample

The population targeted in this study comprised project stakeholders, including the owner, contractors, and supervisory consultants, who were involved in supply chain management for the Sigli–Banda Aceh Toll Road Construction Project from 2019 to 2025. According to data from PT. Hutama Karya (Persero) had a total of 56 stakeholders. In this study, the sample size was determined using the Krejcie and Morgan formula by Morgan (1970), as shown in Equation (1).

$$n = \frac{d^2(N - 1) + X^2P(1 - P)}{X^2NP(1 - P)} = \frac{3,841 \times 56 \times 0,5 \times (1 - 0,5)}{0,052 \times (56 - 1) + 3,881 \times 0,5 \times (1 - 0,5)} = 48,986 \approx 49 \quad (1)$$

Where, S = Sample size,  $X^2$  = Chi-square value with  $df = 1$  at 95% confidence level  $\approx 3.841$ , N = Total population, P = Population proportion = 0.5, d = Margin of error = 0.05

The sampling technique employed in this study was proportionate stratified random sampling, which is used when the population consists of non-homogeneous members and is stratified proportionally (Tubel Agusven et al., 2023). This technique was applied to select respondents based on the proportion of personnel from each stakeholder group involved in supply chain management for the Sigli–Banda Aceh Toll Road Construction Project. The population and sample proportions of stakeholder personnel are presented in Table 1.

**Table 1.** Summary of Population and Sampling proportion

| No.Stakeholder Group     | Population | Sample                   |
|--------------------------|------------|--------------------------|
| 1 Owner                  | 12         | $(12/56) \times 49 = 10$ |
| 2 Contractor             | 35         | $(35/56) \times 49 = 31$ |
| 3 Supervisory Consultant | 9          | $(9/56) \times 49 = 8$   |
| Total                    | 56         | 49                       |

### 3.2. Data Analysis

The analysis of questionnaire data on challenges in implementing supply chain management employed several statistical techniques, as described below:

#### 3.2.1. Descriptive Analysis

Quantitative descriptive analysis is the process of analyzing data to describe or summarize the characteristics of a dataset numerically (Creswell & Creswell, 2017). In this study, quantitative descriptive analysis was employed to illustrate the characteristics and perceptions of respondents regarding the challenges of implementing supply chain management in the Sigli-Banda Aceh Toll Road Construction Project. The steps for quantitative descriptive analysis are as follows:

##### Respondent Characteristics

1. Calculating the frequency and percentage of responses for indicators of respondent characteristics.
2. Presenting the frequency and percentage data for these indicators in tables.

##### Description of Respondent Perceptions

Respondent perceptions were described both individually (partially) by stakeholder groups, including owners, contractors, and supervisory consultants, and collectively (simultaneously). The steps for describing respondent perceptions are as follows:

1. Calculating the mean value of each indicator by summing the Likert scale scores for that indicator and dividing by the number of respondents.
2. Ranking the indicators based on their mean values.

Kendall's coefficient is an analysis used to measure the level of agreement among respondents within a group regarding the ranking of indicators (Kim & Nguyen, 2022). In this study, Kendall's coefficient of concordance was employed to assess the level of agreement among stakeholder groups on the ranking of challenges in implementing supply chain management for the Sigli-Banda Aceh Toll Road Construction Project. The steps for calculating Kendall's coefficient of concordance using SPSS are as follows:

- a. Formulating Hypotheses:
  - Null hypothesis ( $H_0$ ): There is no significant agreement among raters regarding the ranking of challenges in implementing supply chain management.
  - Alternative hypothesis ( $H_a$ ): There is significant agreement among raters regarding the ranking of challenges in implementing supply chain management.
- b. Calculating the Kendall's coefficient of concordance ( $W$ ) and the significance value ( $Sig$ ).
- c. Interpreting the  $W$  value based on the classification presented in Table 2.

**Table 2.** Interpretation of Kendall's W Coefficient

| No. | W Coefficient | Level of Agreement  |
|-----|---------------|---------------------|
| 1   | 0.00 – 0.19   | Very low agreement  |
| 2   | 0.20 – 0.39   | Low agreement       |
| 3   | 0.40 – 0.59   | Moderate agreement  |
| 4   | 0.60 – 0.79   | High agreement      |
| 5   | 0.80 – 1.00   | Very high agreement |

##### Hypothesis Decision:

1. If  $Sig. P < 0.05$ , indicating significant agreement among raters regarding the ranking of challenges in implementing supply chain management; therefore,  $H_0$  is rejected and  $H_a$  is accepted.
2. If  $Sig. > 0.05$ , indicating no significant agreement among raters regarding the ranking of challenges in implementing supply chain management; therefore,  $H_0$  is accepted and  $H_a$  is rejected.

#### 3.2.2. Spearman Rank Correlation

Spearman rank correlation ( $r_s$ ) is an analysis used to measure the degree of association (correlation) between the rankings of indicators provided by different respondent groups (Kim & Nguyen, 2022). In this study, Spearman rank correlation was employed to determine whether two respondent groups have significantly similar perceptions regarding the ranking of challenges in implementing supply chain management for the Sigli-Banda Aceh Toll Road Construction Project. The steps for performing Spearman rank correlation using SPSS are as follows:

- a. Formulating Hypotheses:
  1. Null hypothesis ( $H_0$ ): There is no significant relationship or similarity in perceptions between the two respondent groups regarding the ranking of challenges in implementing supply chain management.
  2. Alternative hypothesis ( $H_a$ ): There is a significant relationship or similarity in perceptions between the two respondent groups regarding the ranking of challenges in implementing supply chain management.
- b. Calculating the Spearman rank correlation coefficient ( $r_s$ ) and the significance value (Sig).
- c. Interpreting the  $r_s$  coefficient based on the classification presented in Table 3.

**Table 3.** Interpretation of Spearman’s  $r_s$  Coefficient

| No. | Range Correlation Coefficient | Level of Correlation |
|-----|-------------------------------|----------------------|
| 1   | 0.000 – 0.199                 | Very weak            |
| 2   | 0.200 – 0.399                 | Weak                 |
| 3   | 0.400 – 0.599                 | Moderate             |
| 4   | 0.600 – 0.799                 | Strong               |
| 5   | 0.800 – 1.000                 | Very strong          |

**Hypothesis Decision:**

1. If Sig. < 0.05, indicating a significant relationship or similarity in perceptions between the two respondent groups regarding the ranking of challenges in implementing supply chain management; therefore,  $H_0$  is rejected and  $H_a$  is accepted.
2. If Sig. > 0.05, indicating no significant relationship or similarity in perceptions between the two respondent groups regarding the ranking of challenges in implementing supply chain management; therefore,  $H_0$  is accepted and  $H_a$  is rejected.

**4. Results**

**4.1. Respondent Characteristics**

A total of 49 stakeholders participated as respondents in this study. The identified characteristics of respondents include gender, age, highest level of education, stakeholder group, and experience in managing supply chains. The detailed characteristics of respondents are presented in Table 4.

**Table 4.** Respondent Characteristics

| Demography                          | Response               | Frequency | Percentage |
|-------------------------------------|------------------------|-----------|------------|
| Gender                              | Male                   | 49        | 100        |
|                                     | 21–30 years            | 5         | 10.2       |
| Age                                 | 31–40 years            | 13        | 26.53      |
|                                     | 41–50 years            | 11        | 22.45      |
|                                     | > 50 years             | 20        | 40.82      |
| Highest Education Level             | Diploma (D3)           | 1         | 2.04       |
|                                     | Bachelor (S1)          | 42        | 85.71      |
|                                     | Master (S2)            | 6         | 12.24      |
| Stakeholder Group                   | Owner                  | 10        | 20.41      |
|                                     | Contractor             | 31        | 63.27      |
|                                     | Supervisory Consultant | 8         | 16.33      |
| Experience in Managing Supply Chain | 0–4 years              | 8         | 16.33      |
|                                     | 5–9 years              | 7         | 14.29      |
|                                     | 10–19 years            | 16        | 32.65      |
|                                     | > 20 years             | 18        | 36.73      |

Table 4 presents the demographic characteristics of the 49 stakeholders who participated in this study. All respondents were male, reflecting the male-dominated composition of the workforce in the project context. In terms of age distribution, the largest group of respondents was over 50 years old (40.82%), followed by those aged 31–40 years (26.53%), 41–50 years (22.45%), and 21–30 years (10.2%). Regarding educational qualifications, the majority held a bachelor’s degree (S1, 85.71%), while six

respondents had a master’s degree (S2, 12.24%) and only one respondent had a diploma (D3, 2.04%). Analysis by stakeholder group shows that most respondents were contractors (63.27%), followed by owners (20.41%) and supervisory consultants (16.33%). Regarding experience in managing supply chains, 36.73% of respondents had over 20 years of experience, 32.65% had 10–19 years, 16.33% had 0–4 years, and 14.29% had 5–9 years. Overall, these characteristics suggest that the study gathered insights from a highly experienced, predominantly male, and technically qualified group of stakeholders, with strong representation from contractors, who play a central role in supply chain management for the Sigli–Banda Aceh Toll Road project.

#### 4.2. Ranking of Challenges in the Implementation of Supply Chain Management

The ranking of challenge indicators in the implementation of supply chain management (SCM) in the Sigli–Banda Aceh Toll Road Project was compiled based on respondent group perceptions, expressed as mean values from the Likert scale used. A comparison of the challenge rankings, both partially (by stakeholder group) and simultaneously (across all stakeholders), is presented in Table 5.

**Table 5.** Comparison of SCM Challenge Rankings

| No. | Indicators   | Partially |            |            | Simultaneously Stakeholders |
|-----|--|-----------|------------|------------|-----------------------------|
|     |  | Owner     | Contractor | Consultant |                             |
| 1   | Lack of environmentally friendly suppliers                             | 6         | 5          | 8          | 14                          |
| 2   | Tight and inflexible stakeholder deadlines                             | 8         | 11         | 9          | 28                          |
| 3   | Insufficient stakeholder engagement/collaboration                      | 10        | 11         | 9          | 31                          |
| 4   | High implementation costs of green practices                           | 10        | 11         | 8          | 30                          |
| 5   | Limited knowledge and awareness of green practices and their benefits  | 6         | 5          | 8          | 14                          |
| 6   | Limited understanding of supply chain management concepts              | 10        | 10         | 9          | 27                          |
| 7   | Passive behavior of subcontractors and suppliers                       | 8         | 8          | 8          | 17                          |
| 8   | Inappropriate tendering methods  | 10        | 12         | 10         | 32                          |
| 9   | Organizational structures that do not support supply chain management  | 10        | 10         | 10         | 28                          |
| 10  | Poor communication and information exchange                            | 9         | 9          | 9          | 24                          |
| 11  | Reluctance to share risks and benefits, and prioritizing self-interest | 8         | 12         | 8          | 31                          |
| 12  | Insufficient training in supply chain management                       | 8         | 10         | 7          | 25                          |
| 13  | Organizational resistance to SCM implementation                        | 8         | 10         | 7          | 25                          |
| 14  | Non-utilization of Information Technology (IT) systems                 | 10        | 9          | 11         | 26                          |
| 15  | Lack of trust among parties in the supply chain                        | 5         | 2          | 4          | 8                           |
| 16  | Lack of commitment to supply chain management                          | 5         | 2          | 4          | 8                           |
| 17  | Absence of shared goals among supply chain parties                     | 5         | 2          | 5          | 9                           |
| 18  | Limited competencies of parties involved in supply chain management    | 7         | 10         | 6          | 23                          |
| 19  | Lack of effective leadership   | 7         | 10         | 7          | 24                          |
| 20  | Ineffective problem-solving mechanisms                                 | 7         | 10         | 7          | 24                          |
| 21  | Unclear reward or incentive systems                                    | 5         | 3          | 4          | 11                          |

| No. | Indicators  | Partially |            |            | Simultaneously Stakeholders |
|-----|---|-----------|------------|------------|-----------------------------|
|     |   | Owner     | Contractor | Consultant |                             |
| 22  | Complex and cumbersome supply chain processes   | 9         | 8          | 12         | 20                          |
| 23  | Temporary or short-term supply chain networks   | 5         | 2          | 5          | 9                           |
| 24  | Limited understanding of customer requirements  | 6         | 6          | 6          | 14                          |
| 25  | Fragmented characteristics of the construction industry                                       | 8         | 8          | 13         | 19                          |
| 26  | Minimal or no support from the government   | 10        | 11         | 9          | 31                          |
| 27  | Inadequate internet and digital infrastructure  | 10        | 11         | 13         | 33                          |
| 28  | Interoperability issues (incompatibility between systems)                                     | 10        | 12         | 14         | 34                          |
| 29  | Perceived complexity (view that the system is too complicated)                                | 3         | 1          | 2          | 2                           |
| 30  | Lack of skilled labor   | 1         | 1          | 1          | 1                           |
| 31  | Inaccuracy and unreliability of data  | 8         | 6          | 14         | 18                          |
| 32  | Weak procurement strategies   | 7         | 12         | 9          | 29                          |
| 33  | Unclear project specifications  | 10        | 12         | 15         | 35                          |
| 34  | Poor construction design  | 10        | 12         | 15         | 35                          |
| 35  | Delays in material delivery   | 3         | 7          | 4          | 13                          |
| 36  | Poor budget management  | 4         | 8          | 3          | 15                          |
| 37  | Extreme weather conditions  | 2         | 3          | 2          | 7                           |
| 38  | Inability to develop effective alliance-based monitoring methods                              | 6         | 9          | 6          | 22                          |
| 39  | Lack of integration of automation processes in supply chain management                        | 9         | 9          | 9          | 24                          |
| 40  | Inadequate project planning prior to project commencement                                     | 3         | 4          | 3          | 10                          |
| 41  | Subcontractors do not understand the concept of supply chain management                       | 6         | 8          | 6          | 16                          |
| 42  | Inaccurate material cost estimates  | 10        | 8          | 14         | 21                          |
| 43  | Design changes during project implementation  | 4         | 4          | 2          | 10                          |
| 44  | Changes in work scope to meet testing requirements  | 4         | 4          | 4          | 12                          |
| 45  | Use of inappropriate construction methods   | 3         | 4          | 2          | 9                           |
| 46  | Low capability of local suppliers to meet required material quality and quantity standards    | 1         | 2          | 1          | 2                           |
| 47  | Limited readiness and suboptimal capacity of the project workforce                            | 1         | 1          | 1          | 1                           |
| 48  | Limited availability of raw materials (quarries) in Aceh Province as a significant constraint | 1         | 1          | 1          | 1                           |
| 49  | Limited capacity of batching plants   | 2         | 2          | 2          | 4                           |
| 50  | Limited capacity of crushers  | 2         | 2          | 2          | 4                           |
| 51  | Limited capacity of Asphalt Mixing Plants (AMP)   | 2         | 2          | 2          | 4                           |

| No. | Indicators   | Partially |            |            | Simultaneously |
|-----|--|-----------|------------|------------|----------------|
|     |  | Owner     | Contractor | Consultant | Stakeholders   |
| 52  | Fluctuating material prices  | 2         | 1          | 4          | 3              |
| 53  | Work contracts based on the design-and-build concept                     | 4         | 1          | 5          | 6              |
| 54  | Timeliness in the payment system   | 1         | 3          | 1          | 5              |
| 55  | Work sites located far from industrial or manufacturing material centers | 3         | 3          | 3          | 8              |
| 56  | Local customs and community culture in the work environment              | 1         | 3          | 1          | 5              |

Table 5 shows that, on a partial basis, the perceptions of the owners influence the ranking up to the 10th position, contractors up to the 12th position, and supervisory consultants up to the 15th position. When all stakeholder perceptions are combined simultaneously, the ranking extends to the 35th position.

### 4.3. Level of Agreement Among Respondent Groups

The level of agreement among respondent groups regarding the ranking of challenges in implementing supply chain management on the Sigli-Banda Aceh Toll Road Construction Project was analyzed using Kendall's coefficient of concordance. The results of this analysis are presented in Table 6.

**Table 6.** Results of Kendall's Coefficient of Concordance Analysis

| Respondent Group       | Sample Size | Kendall's W | Level of Agreement | Sig.  | Conclusion  |
|------------------------|-------------|-------------|--------------------|-------|-------------|
| Owner                  | 10          | 0.791       | High               | 0.000 | Significant |
| Contractor             | 31          | 0.689       | High               | 0.000 | Significant |
| Supervisory Consultant | 8           | 0.732       | High               | 0.000 | Significant |
| Stakeholders           | 49          | 0.638       | High               | 0.000 | Significant |

Table 6 presents the results of the Kendall's coefficient of concordance analysis, which was conducted to evaluate the level of agreement among different respondent groups regarding the ranking of challenges in implementing supply chain management on the Sigli-Banda Aceh Toll Road Project. The findings indicate consistently high levels of agreement across all groups. The owner group, comprising 10 respondents, recorded the highest coefficient ( $W = 0.791$ ), indicating a strong and cohesive perception of the relative importance of the identified challenges. Similarly, the supervisory consultant group, although smaller in size with 8 respondents, showed a high level of concordance ( $W = 0.732$ ), indicating that their assessments were also closely aligned. The contractor group, which formed the largest respondent segment with 31 participants, produced a slightly lower but still strong agreement level ( $W = 0.689$ ), reflecting consistent perceptions despite the group's larger and more heterogeneous composition. When all 49 respondents were analyzed collectively as a single stakeholder group, the coefficient remained high ( $W = 0.638$ ), suggesting robust consensus among all parties involved in the project. Importantly, all significance values were below 0.05 ( $Sig. = 0.000$ ), confirming that the observed agreements are statistically significant. These results collectively affirm that the respondent groups share a coherent and mutually aligned understanding of the key challenges affecting the implementation of supply chain management on the project. Therefore, the null hypothesis ( $H_0$ ), which states that there is no significant agreement among raters on the ranking of SCM challenges, is rejected. Conversely, the alternative hypothesis ( $H_a$ ), which states that there is a significant agreement among raters, is accepted.

### 4.4. Level of Rank Correlation Among Respondent Groups

The level of correlation in the ranking of challenges in the implementation of supply chain management (SCM) for the Sigli-Banda Aceh Toll Road Project among different respondent groups was analyzed using Spearman's rank correlation. The detailed results are presented in Table 7.

**Table 7.** Results of Spearman Rank Correlation Analysis

| No. | Respondent Groups    | Coefficient (Rs) | Level       | Sig.  | Decision    |
|-----|----------------------|------------------|-------------|-------|-------------|
| 1   | Owner and Contractor | 0.847            | Very Strong | 0.000 | Significant |

| No. | Respondent Groups                     | Coefficient (Rs) | Level       | Sig.  | Decision    |
|-----|---------------------------------------|------------------|-------------|-------|-------------|
| 2   | Owner and Supervisory Consultant      | 0.943            | Very Strong | 0.000 | Significant |
| 3   | Contractor and Supervisory Consultant | 0.786            | Strong      | 0.000 | Significant |

Table 7 presents a comprehensive analysis of the Spearman rank correlation between different respondent groups regarding the ranking of challenges in implementing supply chain management (SCM) for the Sigli–Banda Aceh Toll Road Project. The results indicate a very strong and significant correlation between the rankings of the owner and contractor, with an rs coefficient of 0.847 and a significance value of 0.000. This suggests that both parties share highly aligned perceptions of the main SCM challenges, likely due to their routine interactions through project coordination meetings, claims processes, and performance evaluations. Similarly, the correlation between the owner and the supervisory consultant is even stronger, with an rs value of 0.943 and a significance of 0.000. This high level of agreement can be attributed to the supervisory consultant’s role as the owner’s representative on-site, resulting in nearly identical perceptions regarding SCM challenges. Meanwhile, the correlation between the contractor and the supervisory consultant is also significant and strong, with an rs coefficient of 0.786 and a significance of 0.000. Both groups are directly involved in day-to-day operational activities, which enables them to observe and evaluate similar challenges in SCM implementation.

Thus, the rank correlation between the owner and contractor, as well as between the owner and the supervisory consultant, regarding SCM challenges is very strong and significant. Meanwhile, the rank correlation between the contractor and the supervisory consultant is strong and significant. The null hypothesis (H0), which stated that there is no significant correlation between the two respondent groups regarding the ranking of SCM challenges, is rejected. Conversely, the alternative hypothesis (Ha), which posits that there is a significant correlation between the two respondent groups, is accepted. Overall, these findings confirm that all pairwise correlations among the key stakeholder groups are statistically significant, highlighting a shared understanding of SCM challenges across different roles in the project.

#### 4.5. Challenges in Implementing SCM

Based on an empirical study, a total of 56 indicators of challenges in implementing supply chain management (SCM) were identified. To determine the primary challenges in SCM implementation for the Sigli–Banda Aceh Toll Road Project, these 56 indicators were subsequently ranked. The ranking was conducted using the mean values obtained from quantitative descriptive analysis, reflecting the perceptions of respondent groups both partially (by stakeholder group) and simultaneously (combined stakeholders). To assess the level of agreement among respondent groups regarding the ranking of SCM challenges, Kendall’s coefficient of concordance was employed. The results can be discussed as follows:

##### 4.5.1. Primary Challenges According to Owners:

Based on the perceptions of 10 owners, 20 indicators were identified as highly critical challenges, ranked up to the 4th position. These primary challenges are detailed in Table 8.

**Table 8.** Primary Challenge Indicators According to Owners

| No. | Indicators  | Mean  | Ranking |
|-----|---|-------|---------|
| 1   | Lack of skilled labor.  | 4,800 | 1       |
| 2   | Limited capacity of local suppliers to meet the required quality and quantity standards of materials. |       |         |
| 3   | The project workforce readiness remains limited and suboptimal.                                       |       |         |
| 4   | Availability of quarries in Aceh Province is a significant limiting factor.                           |       |         |
| 5   | Accuracy and timeliness in the payment system.  |       |         |
| 6   | Local customs and community cultural practices at the worksite.                                       |       |         |
| 7   | Extreme weather conditions.   | 4,700 | 2       |
| 8   | Limited capacity of batching plants.  |       |         |
| 9   | Limited capacity of crushers.   |       |         |
| 10  | Limited capacity of Asphalt Mixing Plants (AMP).  |       |         |
| 11  | Fluctuating material prices are creating uncertainty.   |       |         |
| 12  | Perceived complexity of SCM processes (viewed as overly complicated).                                 | 4,600 | 3       |
| 13  | Delays in material delivery.  |       |         |

| No. | Indicators  | Mean  | Ranking |
|-----|---|-------|---------|
| 14  | Inadequate project planning before project commencement.                    |       |         |
| 15  | Use of inappropriate construction methods.                                  |       |         |
| 16  | Worksite location is far from industrial or manufacturing material centers. |       |         |
| 17  | Poor budget management.   | 4,500 | 4       |
| 18  | Design changes during project execution.                                    |       |         |
| 19  | Scope changes are required to meet testing needs.                           |       |         |
| 20  | Contract type based on the design-build concept.                            |       |         |

The ranking presented in Table 8 indicates a high and statistically significant level of agreement among the owner personnel, with a Kendall's W coefficient of 0.791 and a p-value of 0.000.

#### 4.5.2. Primary Challenges According to Contractors:

Based on the perceptions of 31 contractors, 23 indicators were identified as highly critical challenges, ranked up to the 4th position. These primary challenges are summarized in Table 9.

**Table 9.** Primary Challenge Indicators According to Contractors

| No. | Indicators   | Mean  | Ranking |
|-----|--|-------|---------|
| 1   | Perceived complexity of the system (viewed as overly complicated).                           | 4.839 | 1       |
| 2   | Lack of skilled labor.   |       |         |
| 3   | Project workforce readiness is still limited and suboptimal.                                 |       |         |
| 4   | Availability of quarries in Aceh Province is a significant limiting factor.                  |       |         |
| 5   | Fluctuating material prices are causing uncertainty.   |       |         |
| 6   | Contract type based on the design-build concept.   |       |         |
| 7   | Lack of trust among parties in the supply chain.   | 4.742 | 2       |
| 8   | Lack of commitment to supply chain management.   |       |         |
| 9   | Absence of shared objectives among supply chain parties.                                     |       |         |
| 10  | Supply chain networks that are temporary or short-term in nature.                            |       |         |
| 11  | Limited capacity of local suppliers to meet the quality and quantity standards of materials. |       |         |
| 12  | Limited capacity of batching plants.   |       |         |
| 13  | Limited capacity of crushers.  |       |         |
| 14  | Limited capacity of Asphalt Mixing Plants (AMP).   |       |         |
| 15  | Unclear reward or incentive systems.   | 4.645 | 3       |
| 16  | Extreme weather conditions.  |       |         |
| 17  | Accuracy and timeliness in the payment system.   |       |         |
| 18  | Worksite location is far from industrial or manufacturing material centers.                  |       |         |
| 19  | Local customs and community cultural practices at the worksite.                              |       |         |
| 20  | Inadequate project planning prior to project commencement.                                   | 4.581 | 4       |
| 21  | Design changes during project execution.   |       |         |
| 22  | Scope changes are required to meet testing requirements.                                     |       |         |
| 23  | Use of inappropriate construction methods.   |       |         |

The ranking presented in Table 9 indicates a high and statistically significant level of agreement among the contractor personnel, with Kendall's W coefficient of 0.689 and a p-value of 0.000.

#### 4.5.3. Primary Challenges According to Supervisory Consultants:

Based on the perceptions of 8 supervisory consultants, 25 indicators were identified as highly critical challenges, ranking up to the 5th position. These primary challenges are summarized in Table 10.

**Table 10.** Primary Challenge Indicators According to Supervisory Consultants

| No. | Indicators             | Mean  | Ranking |
|-----|------------------------|-------|---------|
| 1   | Lack of skilled labor. | 5.000 | 1       |

| No. | Indicators   | Mean  | Ranking |
|-----|--|-------|---------|
| 2   | Limited capacity of local suppliers to meet required quality and quantity standards for materials. |       |         |
| 3   | Project workforce readiness is still limited and suboptimal.                                       |       |         |
| 4   | Availability of quarries in Aceh Province as a significant limiting factor.                        |       |         |
| 5   | Accuracy and timeliness in the payment system.   |       |         |
| 6   | Local customs and community cultural practices at the worksite.                                    |       |         |
| 7   | Perceived complexity of the system (viewed as overly complicated).                                 | 4.875 | 2       |
| 8   | Extreme weather conditions.  |       |         |
| 9   | Design changes during project execution.   |       |         |
| 10  | Use of inappropriate construction methods.   |       |         |
| 11  | Limited capacity of batching plants.   |       |         |
| 12  | Limited capacity of crushers.  |       |         |
| 13  | Limited capacity of Asphalt Mixing Plants (AMP).   |       |         |
| 14  | Poor budget management.  | 4.750 | 3       |
| 15  | Inadequate project planning prior to project commencement.   |       |         |
| 16  | Worksite location far from industrial or manufacturing material centers.                           |       |         |
| 17  | Lack of trust among parties in the supply chain.   | 4.625 | 4       |
| 18  | Lack of commitment to supply chain management.   |       |         |
| 19  | Unclear reward or incentive systems.   |       |         |
| 20  | Delays in material delivery.   |       |         |
| 21  | Changes in the scope of work to meet testing requirements.   |       |         |
| 22  | Fluctuating material prices causing uncertainty.   |       |         |
| 23  | Absence of shared objectives among parties in the supply chain.                                    | 4.500 | 5       |
| 24  | Supply chain networks that are temporary or short-term in nature.                                  |       |         |
| 25  | Contract type based on the design and build concept.   |       |         |

The ranking presented in Table 10 reflects a high and statistically significant level of agreement among the supervisory consultant personnel, with a Kendall's W coefficient of 0.732 and a p-value of 0.000.

#### 4.5.4. Primary Challenges According to Stakeholders:

Based on the perceptions of 49 stakeholders (simultaneously), 23 indicators were identified as highly critical challenges, ranked up to the 12th position. These primary challenges are summarized in Table 11.

**Table 11.** Primary Challenge Indicators According to Stakeholders

| No. | Indicators   | Mean  | Ranking |
|-----|--|-------|---------|
| 1   | Lack of skilled labor.   | 4.875 | 1       |
| 2   | Limited readiness and suboptimal condition of the project workforce.                               |       |         |
| 3   | Availability of quarries in Aceh Province as a significant limiting factor.                        |       |         |
| 4   | Perceived complexity of the system (viewed as overly complicated).                                 | 4.796 | 2       |
| 5   | Limited capacity of local suppliers to meet required quality and quantity standards for materials. |       |         |
| 6   | Fluctuating material prices causing uncertainty.   | 4.776 | 3       |
| 7   | Limited capacity of batching plants.   | 4.755 | 4       |
| 8   | Limited capacity of crushers.  |       |         |
| 9   | Limited capacity of Asphalt Mixing Plants (AMP).   |       |         |
| 10  | Accuracy and timeliness in the payment system.   | 4.735 | 5       |
| 11  | Local customs and community cultural practices at the worksite.                                    |       |         |
| 12  | Contract type based on the design and build concept.   | 4.714 | 6       |
| 13  | Extreme weather conditions.  | 4.694 | 7       |
| 14  | Lack of trust among parties in the supply chain.   | 4.653 | 8       |
| 15  | Lack of commitment to supply chain management.   |       |         |
| 16  | Worksite location far from industrial or manufacturing material centers.                           |       |         |

| No. | Indicators  | Mean  | Ranking |
|-----|---|-------|---------|
| 17  | Absence of shared objectives among parties in the supply chain.   | 4.633 | 9       |
| 18  | Supply chain networks that are temporary or short-term in nature. |       |         |
| 19  | Use of inappropriate construction methods.                        |       |         |
| 20  | Inadequate project planning prior to project commencement.        | 4.612 | 10      |
| 21  | Design changes during project execution.                          |       |         |
| 22  | Unclear reward or incentive systems.                              | 4.592 | 11      |
| 23  | Changes in the scope of work to meet testing requirements.        | 4.571 | 12      |

Table 11 illustrates that the ranking of challenges in the implementation of supply chain management (SCM) exhibits a high and significant level of agreement among the owner, contractor, and supervisory consultant groups, with a Kendall's coefficient of concordance (W) of 0.638 and a significance value of 0.000. To further examine the alignment of perceptions among the respondent groups, a Spearman rank correlation analysis was conducted. The results indicate that the rank correlation between the owner and contractor is very strong and significant, with a correlation coefficient (rs) of 0.847 and a p-value of 0.000. This reflects the routine interactions between the two parties through project coordination meetings, claims processes, and performance evaluations, which align their perceptions regarding the level of SCM challenges. Furthermore, the rank correlation between the owner and the supervisory consultant is also very strong and significant, with an rs value of 0.943 and a significance of 0.000. This is understandable, as the supervisory consultant acts as the owner's extension on-site, resulting in nearly identical perceptions of SCM challenges. Meanwhile, the correlation between the contractor and the supervisory consultant is strong and significant, with an rs value of 0.786 and a significance of 0.000, reflecting that both parties are directly involved in daily operational activities on-site and therefore face similar challenges in SCM implementation.

## 5. Discussion

The findings of this study are consistent with those of Kim and Nguyen (2022), which reported that the ranking of challenges in implementing supply chain management in construction projects in Vietnam demonstrated a very strong and significant level of concordance among owners, contractors, and supervisory consultants. This similarity suggests that, despite differences in project contexts and national environments, stakeholders tend to form aligned perceptions due to comparable operational roles, communication channels, and performance expectations. Therefore, project management teams and policymakers should prioritize collaborative protocols and integrated training initiatives to strengthen alignment and enhance responsiveness to SCM-related challenges. Oktaviani (2019) indicated that one of the critical factors contributing to poor supply chain performance is the lack of coordination among project actors and the absence of mutually agreed-upon performance evaluation standards. These findings, however, do not align with the conditions observed in the Sigli-Banda Aceh Toll Road Construction Project. In this project, the key indicators contributing to the low performance of supply chain management are the shortage of skilled labor, the limited readiness of the project workforce, and the restricted availability of raw materials (quarry).

In addition, Handayani et al. (2021) found that there are two significant barriers to implementing green supply chain management in construction projects in Indonesia: the shortage of suppliers adopting green supply chain practices in the construction sector and the lack of knowledge and awareness regarding the environmental impacts of construction activities. These findings, however, are not consistent with the conditions of the Sigli-Banda Aceh Toll Road Construction Project. Both indicators were indeed identified, but they did not emerge as significant barriers; instead, they appeared only as part of the broader list of challenges. The shortage of environmentally friendly suppliers and the lack of environmental awareness were both ranked 14th in the priority list of challenges.

Besides that, Kim and Nguyen (2022) indicated that the five most significant barriers to the implementation of supply chain management in construction projects in Vietnam are the lack of effective leadership, insufficient competence among actors within the supply chain, limited understanding of supply chain concepts, passive subcontractors and suppliers, and organizational resistance to supply chain management. However, these findings are not aligned with the conditions of the Sigli-Banda Aceh Toll Road Construction Project. Although all five indicators appear in the list of challenges identified in this study, none of them emerged as significant barriers. Specifically, the lack of effective leadership was ranked 24th, insufficient competence among supply chain actors ranked 23rd, limited understanding of supply chain concepts ranked 27th, passive subcontractors and suppliers ranked 17th, and organizational resistance to SCM ranked 25th.

Onyla et al. (2024) identified six major challenges related to the adoption of digital technologies in construction supply chain management in Nigeria, namely the lack of government support, inadequate workforce training, high initial installation costs, shortages of skilled personnel, poor communication channels among stakeholders, and insufficient standardization of data formats (Onyla et al., 2024). These findings are not fully consistent with the conditions observed in the Sigli–Banda Aceh Toll Road Construction Project. Of the six indicators, only one emerged as a major challenge, three were included in the list of general challenges, and the remaining two were not relevant to this study. Specifically, the shortage of skilled personnel ranked first as the most critical challenge. The lack of government support ranked 31st, while the high cost of implementing environmentally friendly practices ranked 30th. Poor communication channels among stakeholders ranked 24th. Meanwhile, inadequate workforce training did not appear in the assessment, and insufficient standardization of data formats was deemed invalid and therefore excluded from the evaluation.

Also, Ogundipe et al. (2024) identified five major challenges that influence supply chain management in the delivery of construction projects in South Africa, namely weak procurement strategies, unclear project specifications, difficulties in achieving scheduling flexibility, poor construction design, and delays in material delivery. These findings do not align with the conditions observed in the Sigli–Banda Aceh Toll Road Construction Project. None of the five indicators emerged as primary challenges in this study, although four of them appeared in the list of identified challenges. Specifically, weak procurement strategies ranked 29th, unclear project specifications ranked 35th, and poor construction design also ranked 35th. Material delivery delays, although not a primary challenge, ranked 13th. Meanwhile, scheduling flexibility issues did not appear in the assessment.

## 6. Conclusions

This study successfully addressed its primary objective of identifying the key indicators of challenges in implementing supply chain management on the Sigli–Banda Aceh Toll Road Project. The stakeholder perception analysis revealed a set of systemic and operational barriers that were consistently rated as significant by the owner, contractors, and supervisory consultants. These findings reinforce the initial hypothesis that limitations in local capacity and resource readiness are critical determinants of supply chain management effectiveness. The results underscore the need for multidimensional interventions encompassing human resource development, material infrastructure support, and improvements in contractual mechanisms. This summary is grounded in the outcomes derived from the data analysis.

The practical implications of this study highlight several policy priorities and managerial actions required from project stakeholders. First, training programs to enhance workforce skills and strengthen the capabilities of local suppliers should be prioritized to reduce dependence on external sources. Second, improving the capacity of material production facilities and diversifying supply sources can help mitigate risks associated with material shortages and long transport distances. Third, refining payment mechanisms, harmonizing contractual arrangements, and enhancing coordination among project parties will strengthen trust and commitment throughout the supply chain. Fourth, the integration of information technology to improve data transparency and monitoring holds potential to accelerate the mitigation of operational constraints.

For future research, it is recommended to conduct evaluations of applied interventions and longitudinal studies to assess the effectiveness of the proposed improvement measures. Further studies may examine workforce training programs, incentive models for local suppliers, and the impact of procurement process digitalization on supply chain management performance in similar projects. Additionally, comparative analyses across toll road projects in different regions would help generalize the findings and inform more targeted policy development. Finally, future research should incorporate advanced quantitative approaches and cost–benefit analyses to support more precise and evidence-based policy recommendations.

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