(p-issn: 2089-8630) (e-issn: 2962 5696)
Jurnal Sains dan Teknologi Tadulako

DOI: https://doi.org/10.22487/jstt.v12i2.1095

CONSTRUCTION SUPPLY CHAIN RISK ANALYSIS OF SEDIMENT CONTROL PROJECT (SABODAM) IN SIGI REGENCY USING A MONTE CARLO SIMULATION MODEL

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Abstract
Natural disasters such as earthquakes, liquefaction, and flash floods are natural phenomena; the events of September 28, 2018 and in 2019 in Central Sulawesi Province resulted in increased sedimentation in the Palu River Basin and caused infrastructure damage in Sigi Regency. These events formed the basis for the Infrastructure Reconstruction Sector Loan (IRSL) Program as an effort to control sediment (sabodam) in Namo Village and Bolapapu Village. The supply chain for project implementation is prone to risks that will impact the timeline, cost, and quality of the work. This study aims to analyze the construction supply chain risk in the Sediment Control Project (Sabodam) in Sigi Regency using the Monte Carlo Simulation model. Risk identification is carried out based on the supply chain cycle which includes specifications, procurement, transportation, and fabrication. The research data was obtained from questionnaires filled out by ten respondents representing the managerial and operational functions of the project. The results showed that there were five main risks that significantly affected project implementation, namely changes in material prices, material scarcity, materials without permits (IUP), vendors not registered in the system, and transportation disruptions due to field conditions such as landslides. A Monte Carlo simulation run for 20,000 iterations estimated that the project faced a 6.23% risk of delay from the planned duration, a 6.11% risk of quality decline, and a 6.08% risk of cost increase from the total project budget. This study concludes that effective risk mitigation strategies include supplier diversification, improved vendor verification mechanisms, optimized logistics management, and the use of material monitoring technology.

Keywords: *Natural disasters, Supply Chain Risk, Monte Carlo Simulation, Construction Project*

1. Introduction

Natural disasters are events caused by natural phenomena, such as earthquakes, tsunamis, soil liquefaction, volcanic eruptions, floods, droughts, cyclones, and landslides. On September 28, 2018, in Central Sulawesi Province, an earthquake triggered landslides at several points along the hills of the Palu River Basin (DAS). This resulted in flash floods with high sedimentation levels, accompanied by heavy rainfall of high intensity lasting 6 to 8 hours per day (Work Framework, 2022). In 2019, flooding occurred again in several areas of Central Sulawesi Province, damaging agricultural land and residential areas and causing damage to public infrastructure, particularly in Sigi Regency, including in Namo Village (Namo River) and Bolapapu Village (Magila and Tamurai Rivers).

A series of natural disasters, specifically floods, that occurred in the area led to the creation of the Infrastructure Reconstruction Sector Loan (IRSL) program, initiated by the Japan International

Received June 5, 2026; Revised August 15, 2026; Accepted for publication August 19, 2026

Cooperation Agency (JICA), with the aim of rebuilding damaged infrastructure in various regions affected by natural disasters in Central Sulawesi. The program was implemented through the "Sediment Control (Sabodam) in Sigi Regency" project. The project is being implemented by PT. AK at two locations: Namo Village (Namo River) and Bolapapu Village (Magila River and Tamurai River). in Sigi Regency. PT. AK developed an activity plan based on work phases (a systematic sequence of work stages). Some materials and equipment were sourced from Palu City and even from outside Palu City, which could lead to various issues such as material shortages, fluctuations in material prices, distribution logistics, and on-site construction challenges—all of which significantly impact schedule, cost, and quality.

In implementing this package, risks will arise; these risks can be analyzed, and there is a need for construction supply chain risk management as an approach that prioritizes the most critical issues in complex and high-risk projects and selects appropriate and efficient measures. According to (Muh Nur Shole, 2020), weak supply chain management can lead to delays and cost overruns in the construction industry. The importance of supply chain management in the construction industry lies in improving construction performance at various levels (strategic, tactical, and operational) and enhancing mutual relationships among parties; supply chain risk management can be an effective key to reducing costs and delays in construction projects.

(Ahmed Hani, 2017) found in his study that changes in the construction supply chain affect the time and cost of construction projects in Canada. He used a Monte Carlo simulation model, which provides project managers with automated reports, thereby helping to optimize costs and schedules.

2. Method

This study began by identifying and formulating the research questions, determining the research objectives, and collecting primary data through interviews and secondary data from project information, as outlined in the methodology flowchart

This study was conducted by compiling a list of risks associated with projects located in Namo Village (Namo River) and Bolapapu Village (Magila River and Tamurai River) in Sigi Regency, identifying the supply chain cycle, grouping supply chain risks, assessing risk probability, evaluating the severity of risk impacts, analyzing and evaluating probability and severity levels through Monte Carlo simulation, and implementing risk mitigation. The data used in this study was collected through interviews with the following respondents: Project Manager, Project Procurement Manager, Project Construction Manager, Project Commercial Manager, Project QHSE Manager, Procurement Officer, Expeditor Officer, Supervisor, Quality Control, and Project Risk Officer. The data from the interviews was then used to calculate risk values, minimum, most likely, and maximum values, after which the data was input into the Crystal Ball software with 20,000 iterations.

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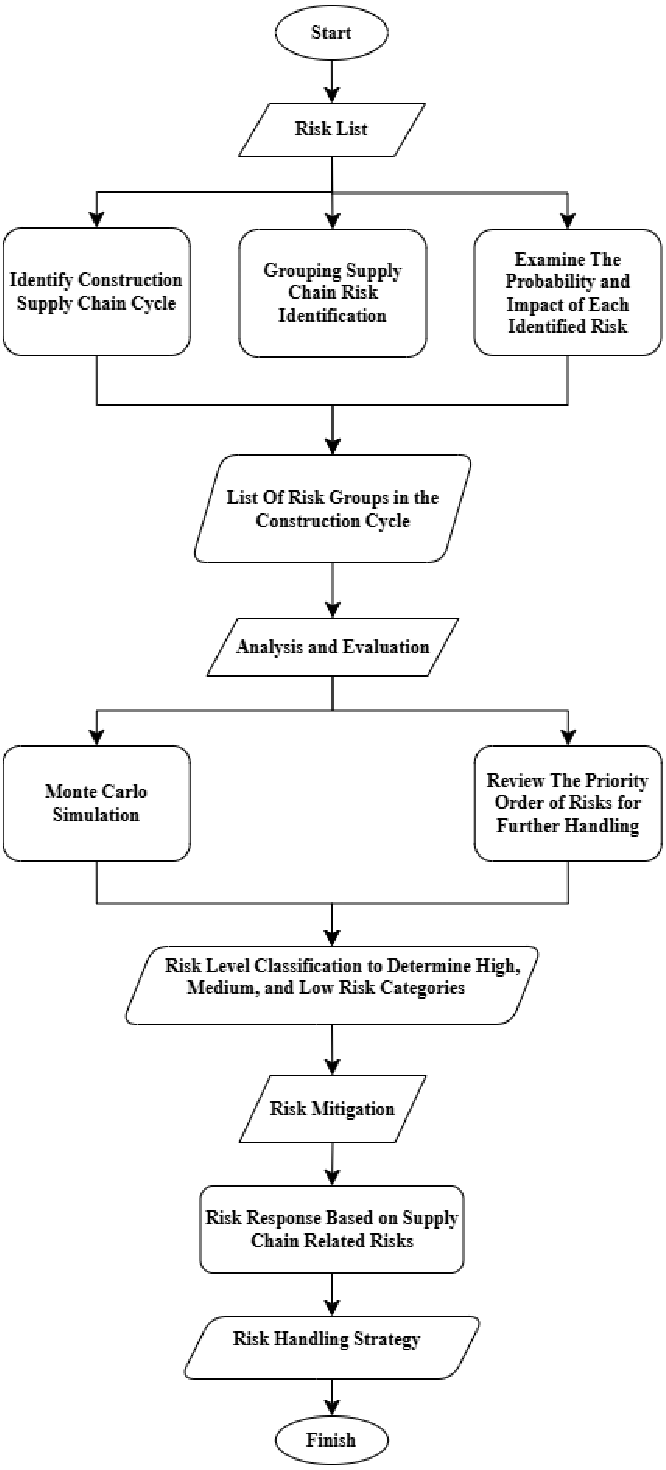

Figure 1 Methodology Flowchart

3. Results and Discussion

Based on the results of a questionnaire administered to 10 respondents from PT. AK regarding the sediment control project (sabodam) in Sigi Regency, a number of risk variables were identified, stemming from the stages of material procurement, distribution, and on-site construction, which were categorized into specifications, procurement, transportation, and fabrication. The results of the risk

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assessment questionnaire for the sediment control project (sabodam) in Sigi Regency evaluated the impact of risks on quality, time, and cost, which were then subjected to a Monte Carlo simulation using Crystal Ball software. The results of the Monte Carlo simulation indicate that the risk of material price fluctuations has an average impact of 25.1%, indicating a high level of risk, caused by the project's reliance on materials from outside the region due to market conditions and distribution policies.

Table 1 Risk Rating for the Entire Supply Chain

NO	Risk	Risk Code	Risk Rangking	Point (%)
1	Changes in material prices may affect material procurement in construction projects	R2	I	25.1%
2	The main impact of material scarcity on construction projects	R3	II	16.8%
3	Materials without a mining business permit (IUP) may affect the progress of construction	R5	III	10.3%
4	Vendors not yet registered in the company's partner system may affect project continuity	R9	IV	8.6%
5	Landslides in several areas may affect the availability of materials for construction projects	R10	V	6.2%

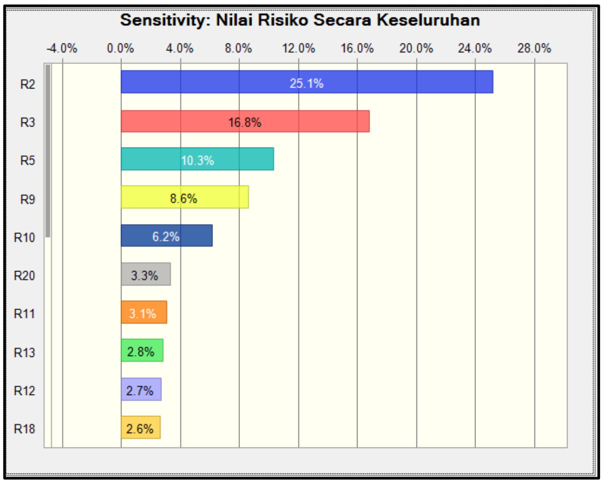

Figure 2. Risk Score Percentage

The quantitative analysis of the construction supply chain reveals that material scarcity constitutes a primary vulnerability, manifesting a significant severity impact of 16.8%. This material deficit invariably triggers cascading project disruptions, specifically inducing procurement bottlenecks, escalating acquisition expenditures, and precipitating critical schedule overruns during on-site execution. Furthermore, regulatory compliance and administrative governance introduce substantial project uncertainties; reliance on uncertified materials lacking a valid Mining Business License (IUP) (10.3%) and the engagement of unregistered vendor partners (8.6%) frequently result in bureaucratic impediments and mandated temporary work suspensions. Compounding these operational risks are

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geotechnical hazards, notably localized landslides, which impose a 6.2% impact severity by obstructing logistical distribution routes. Such physical disruptions directly induce material delivery delays, inflate baseline operational costs, and necessitate the mobilization of supplementary logistical resources. Ultimately, this discourse underscores that the institutionalization of rigorous risk assessment protocols is fundamental to preserving project management integrity. The strong congruence between the empirical research findings and the contractor's internal evaluations validates the efficacy of their existing mechanisms for identifying and preempting operational bottlenecks. Consequently, the project's strategic framework is robustly fortified to navigate inherent uncertainties, thereby substantially elevating the overarching probability of successful infrastructure delivery.

4. Conclusion

This study provides an overview of supply chain risks in sediment control projects (Sabodam) in Sigi and Bobot districts, as well as the sensitivity of these risks based on Monte Carlo simulation results. The Monte Carlo simulation identifies the certainty by showing that the project has an average potential delay of 6.23%, quality issues of up to 5.94%, and cost overruns of approximately 6.08%. Risk mitigation strategies to reduce these dominant risks in the sediment control (Sabodam) project in Sigi Regency include ensuring accuracy and commitment to timely payments to subcontractors, thorough planning regarding material procurement from suppliers, and planning material management in accordance with field requirements

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Received June 5, 2026; Revised August 15, 2026; Accepted for publication August 19, 2026