MEASURING THE IMPACT OF EXTERNAL RISK FACTORS ON COSTS FOR DRAINAGE CONSTRUCTION PROJECT IN ACEH-INDONESIA

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Abstract: Infrastructure projects are always faced with uncertainty and risks, both from within and outside the project, including drainage projects. An understanding of the sources and impacts of risks is required for construction implementers to minimize the negative effects of these risks. One of the impacts commonly experienced by construction companies is the emergence of cost overruns, which can potentially lead to project failure. This study aimed to analyze the impact of risk on cost for external factors in the implementation of drainage projects in Aceh Province in 2021. Employing a mixed-method approach, primary data were gathered through the distribution of questionnaires to 52 respondents actively engaged in project implementation. The questionnaire was designed to collect information on the impact of risk on costs for 3 external factors, namely social (2 variables), government policy (2 variables), and disaster (4 variables). The impact of risks was assessed using the severity index (SI) analysis. The findings revealed eight external risk variables exerting an influence on the cost of implementing drainage projects in Aceh Province in 2021. The most substantial impact on cost was categorized as "moderate" and manifested in two variables: uncertain weather conditions (SI = 0.400) and flooding (SI = 0.388). Understanding the potential impact of risks on project costs, especially those originating from external factors, will make it easier for contractors to plan risk mitigation and ensure the project is completed on target.

Keywords: risk impact; external factors; drainage project; cost; Aceh

Abstrak: Drainase merupakan salah satu proyek infrastruktur yang tidak lepas dari risiko-risiko yang dapat memengaruhi tujuan proyek. Risiko pada proyek dapat berasal dari faktor eksternal yang berasal dari luar dan tidak berhubungan dengan kegiatan proyek, namun dapat berdampak pada pencapaian tujuan proyek. Penerapan manajemen risiko perlu diaplikasikan, utamanya berkenaan dengan pemahaman terhadap potensi risiko yang dihadapi dan dampak yang ditimbulkan. Pembengkakan biaya merupakan bentuk risiko yang sering terjadi dan dapat berakhir pada kondisi terburuk berupa kegagalan proyek. Tujuan penelitian ini adalah menganalisis dampak risiko terhadap biaya pelaksanaan proyek dari faktor-faktor risiko eksternal. Objek penelitian ini difokuskan pada proyek drainase di Provinsi Aceh yang dilaksanakan pada tahun 2021. Data penelitian ini diperoleh melalui penyebaran kuesioner kepada 52 responden yang terlibat dan berperan langsung dalam pelaksanaan proyek. Kuesioner disusun untuk

mengumpulkan informasi dampak dari 3 faktor eksternal, yaitu faktor sosial (2 variabel), faktor kebijakan pemerintah (2 variabel) dan faktor bencana (4 variabel). Dampak risiko terhadap biaya diukur dengan analisis *severity index* (SI). Dari 8 variabel yang dianalisis, dampak risiko tertinggi yang ditemukan muncul pada 2 variabel dengan level dampak "sedang." Variabel-variabel tersebut adalah kondisi cuaca yang tidak menentu (SI = 0,400) dan banjir (SI = 0,388). Dengan mengenali potensi dampak risiko terhadap biaya, khususnya pada faktor-faktor eksternal, kontraktor dapat lebih awal bersiap dan merencanakan mitigasi risiko untuk memastikan proyek dapat diselesaikan sesuai dengan sasaran.

Kata kunci: dampak risiko; faktor eksternal; proyek drainase; biaya; Aceh

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Introduction

Drainage is one of the infrastructures that serves to drain or control excess water on the surface of an area. The drainage infrastructure is a strategic utility required for public uses, particularly in managing rainwater run-off and waste-water to mitigate flood risks. This system serves to protect the city's physical assets from structural degradation due to water exposure and erosion. Furthermore, drainage functions a integral part in environmental sanitation, preventing the spread of water-borne diseases, and supporting ecosystem sustainability through groundwater reserve management and aquatic biota conservation (Chapman & Hall, 2022). Drainage system construction is highly complex, making it vulnerable to various technical and non-technical risks. Failure to anticipate these uncertainties has the potential to trigger schedule delays and other operational challenges. Therefore, implementing inclusive risk management is an absolute prerequisite to ensure target achievement and effective project implementation on the ground (Buba et al., 2020; Marasabessy et al., 2020; Weinbren et al., 2021).

Risks defined as an uncertain event that negatively impacts project objectives (Siraj & Fayek, 2019; Sharma & Kumar Gupta, 2020). Some previous studies have concluded that risks occurring in a project can cause disruptions to the achievement of cost targets (Amani & Safarzadeh, 2022; Agus et al., 2024; Afana et al., 2024), completion time (Karamoozia et al., 2019; Banihashemi & Khalilzadeh, 2022; Ariska et al., 2024), and project quality (Husin et al., 2019[b]; Buba et al., 2020; Tian et al., 2025). Most projects have risks, because project activities are unique and the level of uncertainty is varied (PMI, 2017). The uniqueness of a project is determined by its fundamental characteristics, such as the type of project, its value, and its implementation time. These project characteristics directly impact the potential risks and the magnitude of the impacts that may be felt by the parties involved (Fathoni, 2020; Kaufmann & Kock, 2022; Jahan et al., 2022). A low risk level is

directly proportional to budget optimization and project smoothness. Given that large-scale projects have broader risk exposure and the risk of delaying work schedules, prioritizing significant risks is essential. Focusing on these key risks is crucial for all parties involved to protect profit margins and ensure timely completion.

Mastering risk management directly contributes to increasing a project's chances of success while minimizing potential adverse impacts. This capability is rooted in the ability to identify risk sources, analyze their severity, and formulate mitigation or elimination strategies during the construction phase (Husin et al., 2019[a]; Fathoni, 2020). Implementing risk management not only increases awareness of project threats but also provides a robust database for strategic and efficient decision-making (Buba et al., 2020; Jahan et al., 2022).

PMI (2017) classifies risks from two main sources, namely from internal projects and from external projects. Internal risk factors are consequences of the project operational process that are triggered by the actions or policies of parties within the project's organizational structure itself (Husin et al., 2019[b]; Siraj & Fayek, 2019; Ariska et al., 2024; Agus et al., 2024). External factors involve various uncertainties that arise outside the project environment and cannot be directly handled by the project team. Although not under the project team's control, these risks still require close monitoring because they have the potential in affecting the project's success (Mubarak et al., 2016; Mubarak et al., 2017). Regarding external risk factors, the first external risk factor includes: socio-political risk factors, originating from social and political events that have the potential to change or even fail the project. Second, government policy factors, generally related to regulations issued by the government with specific objectives related to the public interests. Third, disaster factors related to natural events that have a significant impact on the human population. Fourth, monetary factors, which relate to controlling macroeconomic conditions through regulating the money supply to stabilize prices and inflation (Mubarak et al., 2016; Mubarak et al.,2017; Husin et al., 2019[b]).

The project implementation situation in infrastructure sector has deteriorated due to the pandemic that has struck Indonesia, especially Aceh Province (Azhari et al., 2021). During the pandemic, risk continues to increase, and the projects implementation cannot run normally, efficiently, and finally affected quality, completion time, and cost disbursed. Project implementation during the pandemic requires additional funding and at the same time has an impact on reducing the profit of construction companies. Calculation of all potential risks must be carefully calculated to avoid failure to achieve project targets (Olanrewaju et al., 2021).

During project implementation, cost overruns are one of the risks contractors' encounters, and they can directly impact the amount of money they receive at the end of the project. This type of risk should be a primary consideration, as it has the potential to cause project failure (Risandi, et al., 2017; Afana, et al., 2024; Sovacool & Ryu, 2025). The limited availability of project budgets demands the most

efficient control measures possible to ensure adequate overall performance targets are achieved. Cost allocation planning must be carefully and accurately calculated according to implementation needs, ensuring there are no significant discrepancies between planning and implementation (Khodeir & El Ghandour, 2019; Sugiyanto & Kosbiamtoro, 2022). Project costs must also be planned, taking into account the potential and impact of potential risks, while ensuring the availability of a sufficient budget to complete all project work. In project management, a budget is not simply a static figure used to pay for resources, but rather a risk management tool. Project failures often occur not because of technical difficulties, but because of overly optimistic cost estimates that do not account for uncertainty (Plebankiewicz & Wieczorek, 2020; Babaei et al., 2022).

Previous research by Mubarak et al. (2017) explained the impacts of risks during construction completion in the Aceh region, especially during the conflict and post-tsunami disaster conditions that prevailed in this region. The study reported that the cost impacts of risks linked to external factors generally remained at a low intensity. High-intensity impacts were observed only in government policy aspects, particularly the variable of rising fuel prices, which persisted throughout the study. In contrast, moderate-intensity impacts were identified in three disaster-related variables and two monetary factors. Over the course of the study, there was little variation in the intensity of these cost impacts.

Referring to the results of previous research, the impact of risk varies greatly according to the factors reviewed and the conditions at the time the project is implemented. Considering the context of factors and conditions during project implementation, this study was aimed to analyze the impact of risks on project implementation costs caused by external risk factors. This study emphases on project of drainage infrastructures in Aceh Province during the fiscal year 2021. The study period was chosen to provide an overview of the risk impact of project implementation in a region during the Covid pandemic with various forms of activity restrictions imposed by the government.

Method

Object of Study

The object studied was an urban drainage project implemented in a number of districts/cities within the Aceh Province region. These projects were all implemented with the Aceh Government budget for fiscal year 2021. All projects have a budget of under IDR 5 billion and were implemented by small qualification contractors.

Data Collection

This study applied a mixed-methods approach, integrating qualitative and quantitative methodologies. Data were collected from primary and secondary sources. Primary data were collected using a questionnaire distributed to target

respondents. Secondary data which provided information on contractor companies involved in drainage projects, were obtained from the Aceh Provincial Procurement Agency (LPSE). The data indicated that there were 105 drainage project packages spread across several districts/cities within the province. The number of project samples was identified using a probability sampling technique with a stratified proportional random sampling method. Number of samples was calculated by using the Slovin equation (Singh, 2006). The number of samples used for this research was 52 projects with proportions and distribution in 17 districts or cities, as shown in Table 1.

Table 1. Distribution of projects sample

Districts/Cities	Number of Projects
Aceh Barat	4
Aceh Barat Daya	4
Aceh Besar	5
Banda Aceh	6
Aceh Jaya	1
Aceh Selatan	3
Subulussalam	5
Aceh Tamiang	2
Aceh Tengah	1
Lhokseumawe	1
Aceh Utara	2
Langsa	1
Bener Meriah	6
Bireun	1
Nagan Raya	7
Pidie	2
Pidie Jaya	1
Total	**52**

Data collection was obtained using a questionnaire instrument that was distributed to targeted respondents. The respondents were managerial personnels that directly responsible for project implementation. They held positions as members of the company's board of directors (president director or deputy director), project managers, or engineers.

The research questionnaire was designed referring to the factors and variables in the previous study (Mubarak et al., 2017). The study observed 12 variables from 4 external risk factors. All variables and factors were re-selected by experts to test their relevance to the context of the object and period of this study. The expert consists of 3 people who have adequate project experience, each from academics, contractor, and construction consultant. This expert opinion resulted in the number of variables used in this research being 8 variables from 3 external risk factors,

namely: social factor (2 variables), government policy factor (2 variables), and disaster factor (4 variables), as shown in Table 2.

The questionnaire was arranged in a close form and divided in 2 (two) parts which consisted of: First part, intended to identify the characteristics of respondent and companies; Second part, intended to record the responses data related to risks impact on cost to all variables that were sourced from the external factors of projects.

Table 2. External Risk Factors

Factors	Code	Variable (Mubarak et al., 2017)
Social Risk (Factor K)	K1	Cultural conditions and customs of the community around the project site
	K2	Social problems (surrounding environment)
Government Policy Risk (Factor L)	L1	Changes/updates in government policy led to project suspension
	L2	Increase in fuel price
Disaster Risk (Factor M)	M1	Uncertain weather conditions
	M2	Pandemic or endemic disease outbreaks
	M3	Flood occurrence
	M4	Earthquake occurrence

The measured scale used for cost assessment was a Likert scale with a score range of 1-5 (Singh, 2006). The interpretation of scales applied to quantify the classification of risk impact on cost, as described in Table 3 (Hollmann, 2011).

Descriptive statistical analysis

The descriptive analysis was applied to describe the object of study through the collected data. The techniques used were frequency distribution analysis, and mean. Frequency distribution analysis was used to determine the percentage of responded given by respondents based on the value of each factor (Eq. 1), while the average (mean) was used to identify the tendency of respondents' answers (Eq. 2):

$$Me = \frac{\sum X_i}{n} \quad \text{.....(1)}$$

$$P = \frac{F}{n} \times 100\% \quad \text{.....(2)}$$

where:

Me = *mean* (average);

X_i = response values of respondent i up to n;

P = percentage of answers;

F = frequency of each response;

n = total number of respondents.

Severity index (SI) analysis

The severity index was a measurable impact expressed in an index number for each risk variable, and is expressed as a severity index (SI). Measurement of the impact of risk on costs was based on the respondent's assessment for each variable questioned. Referring to Majid & McCaffer, (1997), the SI value can be calculated using Eq. 3.

$$SI = \frac{\sum_{i=1}^{5} a_i n_i}{5N} \quad \text{.....(3)}$$

Description:

i = scale index of i response (1, 2, 3, 4, or 5);
a_i = weight value of the i response;
n_i = total respondents who answered the i response;
N = total of all respondents.

Based on the severity index (SI) results, the classification of risk impact criteria for costs could be carried out as in Table 3 (Majid & McCaffer, 1997).

Table 3. The SI Impact on Costs

Response to-*i*	Impact Criteria	SI Range	Cost Impact (Hollmann, 2017)
1	No impact/very low	$0.000 \leq SI \leq 0.125$	<0.5% of budget
2	Low	$0.125 < SI \leq 0.375$	0.5-1% of budget
3	Moderate	$0.375 < SI \leq 0.625$	2-3%
4	High	$0.625 < SI \leq 0.875$	4-5% of budget
5	Very high	$0.875 < SI \leq 1.000$	>5% of budget

Results

The characteristics of respondents and companies

The questionnaire was distributed directly to contractors, with an initial focus on respondent identity and business entity profile. Respondent characteristics (position, age, education, and experience) served to strengthen the correlation between responses, while company characteristics provided a general overview of the drainage project actors in Aceh in 2021, covering qualifications and contract value. A summary of these profiles is brief in Figure 1 and Figure 2.

Figure 1 presents the personal characteristics of the participated respondents. In summary, the respondents' profiles are dominated by senior, highly educated Project Managers. The majority of respondents were Project Managers (94%) and were generally over 30 years old (79%). Related to education profile, the respondents mostly had a Bachelor's degree and had more than 5 years of work experience (77%). These profiles provide a convincing picture of their authority and ability to explain the conditions of the projects studied.

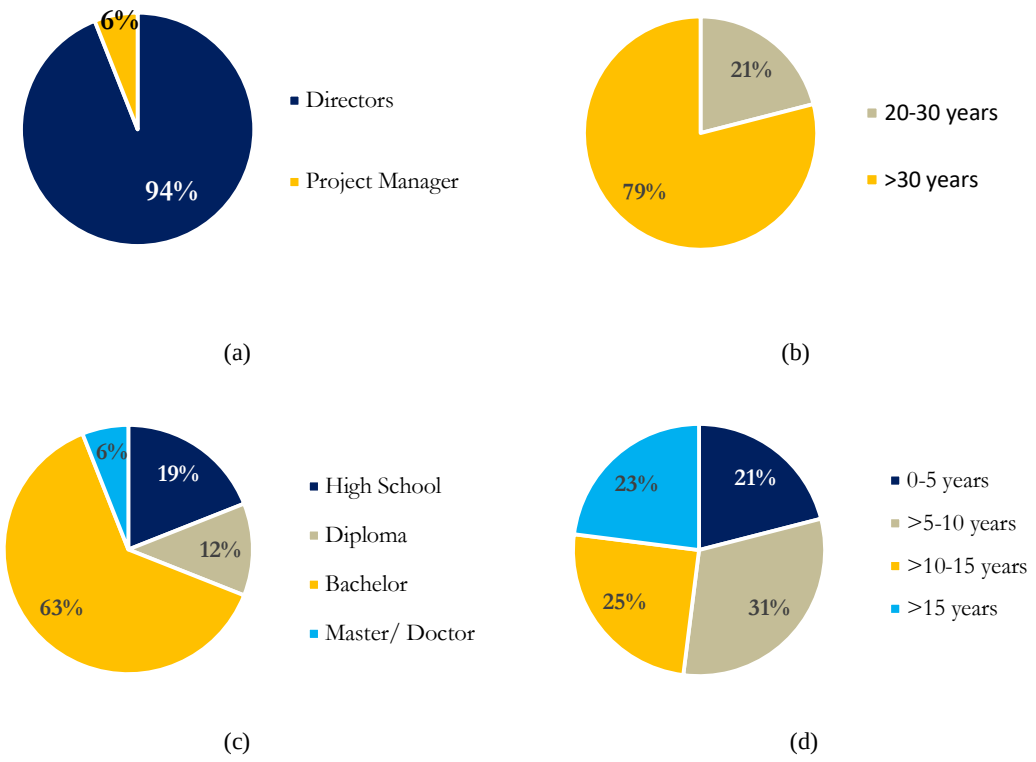
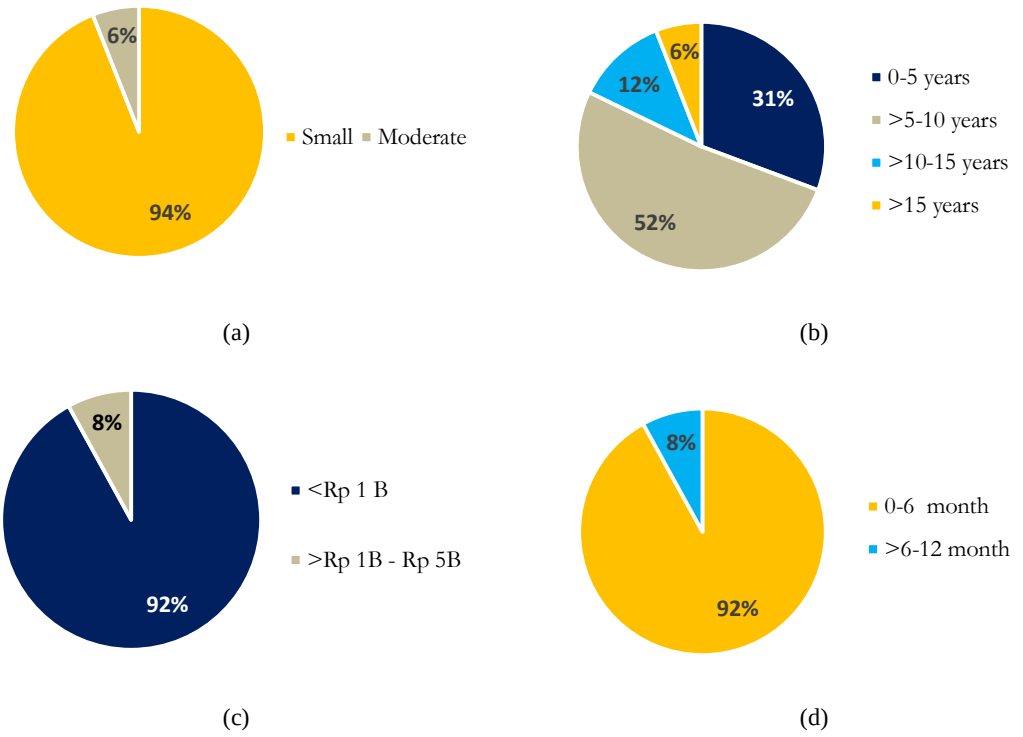
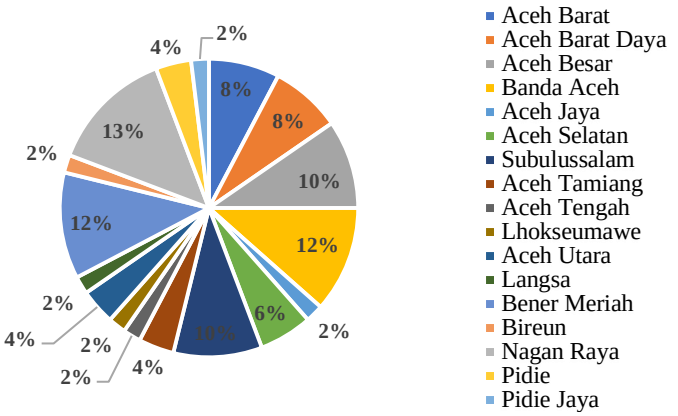


Figure 1. Respondent characteristics: (a) position; (b) age; (c) last education; (d) work experience





(e)

Figure 2. Company characteristics: (a) qualifications; (b) experience; (c) project value; (d) project duration; (e) project distribution

Figure 2 illustrates the profiles of the contractor companies involved in the surveyed projects. The survey focused on small qualification companies working on drainage projects valued at Rp 1 billion to Rp 5 billion, with construction durations generally more than six months. Project locations were spread across Aceh Province, with the highest concentrations in Aceh Besar and Banda Aceh.

The survey results showed strong consistency between the profiles of the personnel who completed the questionnaire and the types of projects handled by their companies. This consistency ensures the validity of the information collected.

The results of descriptive statistical analysis

The descriptive statistical analysis explains the description or indication of the objects observed based on sample data. This research applies indicators in the form of mean values and percentages to explain the impact pattern for each variable (see Figure 3). These indicators refer to the response scale given for each variable. This research uses a scale of 1 (no impact/very low); 2 (low); 3 (moderate); 4 (high); and 5 (very high).

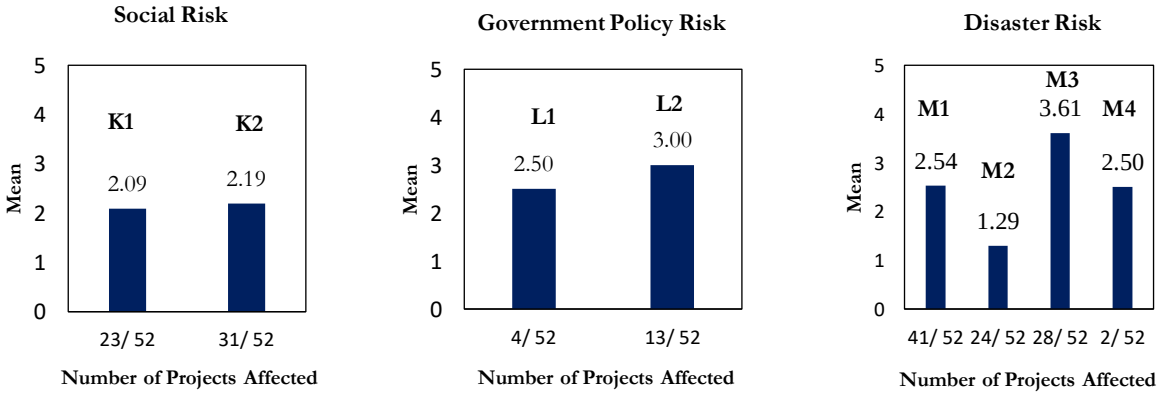


Figure 3. The descriptive results of the impact of risks on external factors on costs

These figures present the mean score and number of affected projects for variables in three external risk factors: Social Risk, Government Policy Risk, and Disaster Risk. In social risk, variable K1 (Mean: 2.09) has the lowest average score of all items and influences 23 of 52 projects, while variable K2 (Mean: 2.19) has a slightly higher average score, and influences the largest number of projects in this factor (31 of 52 projects). In general, social risks have the lowest average impact/probability scores compared to the other two risk categories, indicating the perception that social risks have a relatively lower impact, even though K2 affects a significant number of projects.

The government policy risk consists of variable L1 (Mean: 2.50) and affects the fewest number of projects of all risk items surveyed (4 out of 52 projects). Variable L2 (Mean: 3.00) had the highest mean score in this factor and influenced 13 of the 52 projects. The higher average value on L2 reaching 3.00 indicates that when policy risks occur, the impact is perceived as more significant, even though the frequency of affected projects is relatively low.

The analysis results for disaster risk factors show that variable M1 (Mean: 2.54) influences the highest number of projects (41 out of 52 projects) overall, and vice versa for variable M2 which has the lowest average score of all risk items surveyed (Mean: 1.29) even though it influences 24 out of 52 projects. Variable M3 (Mean: 3.61) is the variable with the highest average score of all risk variables in all factors and shows the most critical impact perception by influencing 28 of 52 projects. The last variable M4 (Mean: 2.50) is the variable that has the lowest influence (2 out of 52 projects). This factor shows the highest volatility. Item M3 is the most significant risk in terms of average impact, while M1 is the risk that occurs most frequently or impacts the project the most.

The results of the analysis of the two previous indicators can at least explain aspects of (i) Disaster Risk Dominance in Impact (based on Mean Score results); and (ii) Risk Occurrence Frequency (based on the number of occurrences on the project). For the first aspect, the most critical finding is that the M3 risk item in the Disaster Risk category has the highest average score (3.61). This is logical considering Aceh's geographical location which is prone to natural disasters (such as earthquakes and tsunamis). These conditions emphasize the need for resource allocation and specific mitigation for these disaster risks, which are perceived to be the most destructive when they occur. In the second aspect, although M3 had the highest impact, M1 items in the same category were the ones that most frequently influenced the project (41/52). This suggests that project management should be more alert to M1 due to its high frequency, while M3 requires a strong contingency plan due to its severe impact.

The risk impact on cost

The risk impact on costs was determined based on the SI values, that measure the severity of the risk variables in an index on a scale of 0 to 1. This index is then

mapped into five levels of severity: Very Low, Low, Moderate, High, and Very High. The results of the SI analysis on all variables of external factors are presented in Figure 4.

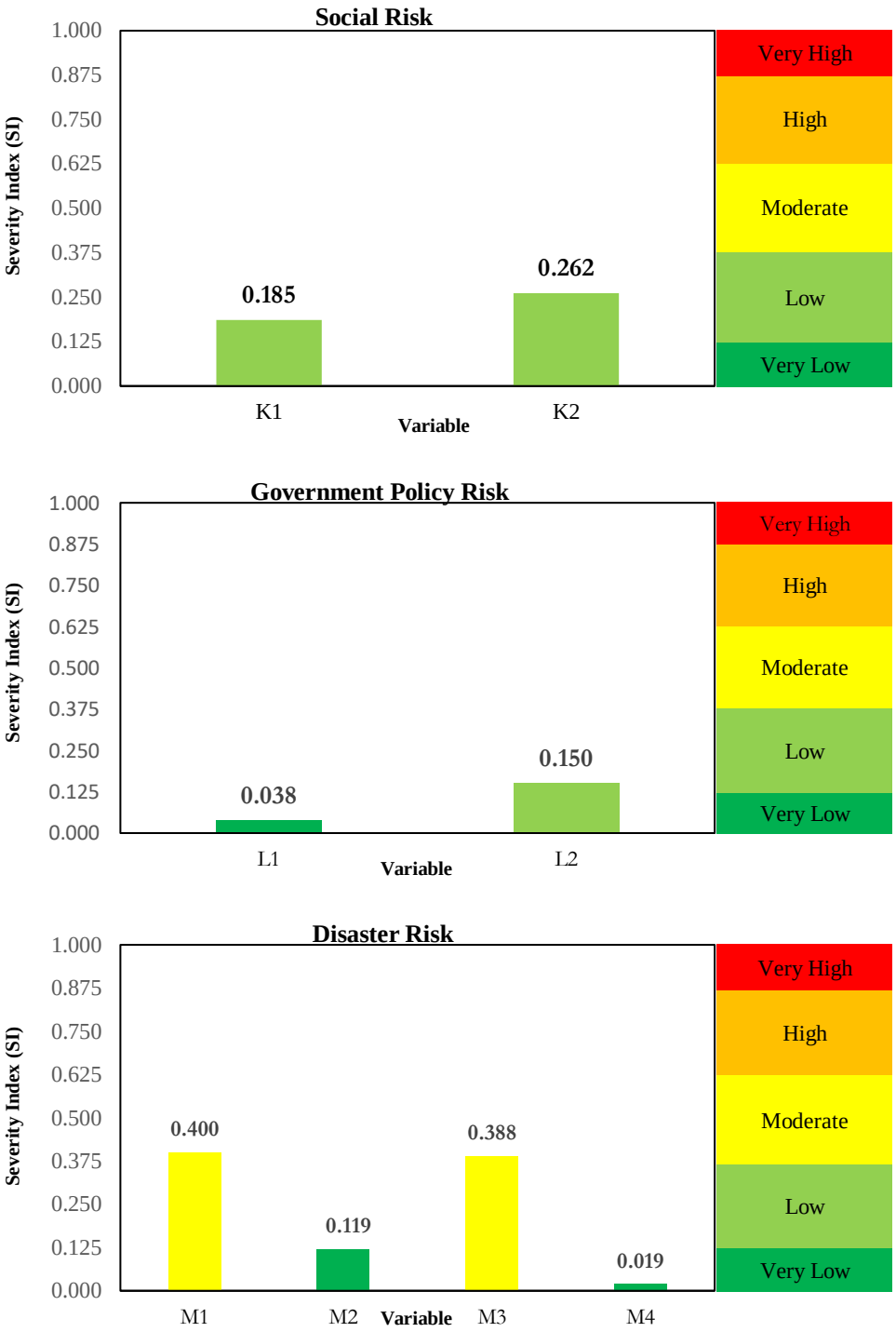


Figure 4. Results of severity index (SI) of external risk factors

The variables in the social risk factors show relatively low levels of severity. Variable K1 (SI = 0.185) is in the very low range, and variable K2 (SI = 0.262) is in the low range. In general, social risk factors in the context of this survey are considered to have the lowest level of severity compared to other risk categories. For the variables in the government policy risk factor, in general, they also show low levels of severity, although a minor variation in the severity index between variable L1 (SI = 0.038) and variable L2 (SI = 0.150). Variable L1 has the lowest SI value in this factor group. Furthermore, for the disaster risk factor, the severity of the variables varies the most and is the highest among all the variables in the other risk factors. Variable M1 (SI = 0.400) and variable M3 (SI = 0.388) are in the moderate severity range, while the other two variables, variable M2 (SI = 0.119) and variable M4 (SI = 0.019), are in the very low severity range. In fact, variable M4 was the variable with the lowest severity of all the variables and risk factors analyzed. The overall SI analysis results showed that disaster risk factors, particularly uncertain weather conditions (M1) and flood occurrence (M3), were perceived as having the highest severity level in the project, while social risk factors and government policies consistently ranked at Very Low to Low levels.

Discussions

This study has demonstrated that the impact of risks on costs can originate from all external project variables and factors, with the intensity of impact differing across variables. The most significant cost impact, categorized as "moderate" intensity, were identified in two key risk variables related to weather conditions and flooding. These two variables are closely interrelated, as weather conditions are typically associated with rainfall during project execution. Increased rainfall often leads to the occurrence of flooding. Drainage infrastructures are classified as construction works carried out directly in the open air. For small projects, the works are generally carried out using conventional construction methods such as stone masonry. With this work method, it can be ensured that if the weather is not favorable, for example due to heavy rainfall, or even flooding, then the project completion process cannot continue, and of course this can have an impact on the emergence of additional costs. These additional costs can be in the form of costs to repair damage to newly built construction, replacement of damaged materials, or even possible fines that the contractor must pay if the work is delayed beyond the time specified in the contract.

The results of previous studies specific to the Aceh region indicate that risk impacts with "moderate" intensity also consistently appear in variable uncertain weather condition and variables flood events (Mubarak et al., 2017; Fu et al., 2023). Almost similar patterns can also be recognized when the potential impacts are compared with studies in other regions in Indonesia. This impact pattern has also been previously reported in the research results of Rustandi (2017) which stated

that unpredictable weather conditions are one of the variables that most influence projects and have the greatest probability and impact on costs.

In another study, weather condition variables and the occurrence of flooding were even risk variables that had the greatest impact on project implementation costs (Ali, 2018; Anshuka et al., 2025). When referring to Amani & Safarzadeh, (2022), the impact of additional costs that could potentially arise on a project can vary according to the intensity of the impact of each variable. As an illustration, for variables with moderate impact intensity, potential additional costs can appear in the range of 2 to 3 percent of the total project costs. If this percentage is the contribution of each risk variable, then efforts to minimize it need to receive further attention by all project developers.

Practical implications are required to mitigate or even to avoid the negative impact on project costs. The mitigation process is based on indicators of the potential occurrence and severity level of each risk variable. For variables in social risk factors, continuous operational management is necessary to mitigate small, cumulative disruptions. Furthermore, for variables related to government policy risk factors, contingency-based mitigation strategies and contractual flexibility are among the efforts that can be considered. Finally, variables in disaster risk factors should be a top priority in cost risk management planning. Mitigation efforts can be implemented by preparing contingency cost allocations and project resilience strategies.

Conclusion

This research was a study that analyzes the impact of risk on costs from 3 external factors in the drainage infrastructure projects. Impact measurement and assessment was carried out on 8 variables from all external risk factors for the 52 projects observed in Aceh Province which was implemented in the fiscal year 2021. The risk impact was measured using the parameter of severity index (SI).

The research results have shown that unpredictable weather conditions and flood events were the variables that have the highest risk impact on costs. These two variables have the potential to have an impact with "moderate" intensity. Because it is part of the disaster risk factors, the time period when it occurs cannot be predicted. However, understanding the potential events and impact intensity will provide early chances for construction contractors in terms of mitigation and impact reduction.

The occurrence of risk variables and their impact levels can be used as further study material in determining risk management priorities. For frequently occurring variables, if the overall severity is low, the impact on costs tends to be gradual or indirect, and not a significant cost spike. This condition is evident in variables for social factors and government policies. The opposite condition appears in disaster risk factors. This factor is the most critical risk factor for project costs. This is indicated by the emergence of relatively significant risk variables and the highest

level of severity compared to variables in other risk factors. The resulting impacts can include physical damage, temporary work stoppages, and increased logistics and material costs.

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Conflict of interest

The authors declare that there is no conflict of interest from the work reported in this paper.

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