



## Stakeholder-Based Risk Analysis in Post-Disaster Housing Projects: Toward Improved Risk Management Practices

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### Abstract

Reconstructing housing after a disaster is a demanding and intricate process, particularly when managing risks that affect project delivery timelines. The community-based approach, widely adopted in Indonesia, seeks to foster local participation but is often hindered by implementation challenges. This study aims to identify and analyse the critical risks contributing to delays in community-driven housing reconstruction projects in Pidie Jaya Regency, Aceh, Indonesia, as perceived by stakeholders. Research variables were developed sequentially through a literature review, semi-structured interviews, focus group discussions (FGDs), and questionnaires. A mixed-methods approach was employed, combining thematic analysis with descriptive statistics and indices, such as the frequency index (FI), severity index (SI), and risk importance index (RII). Seventy-one risk variables were identified, including 17 newly documented risks not previously addressed in the literature. Three variables were found to be particularly significant: shortage of facilitators, limited labour availability, and insufficient community construction skills. The findings contribute theoretically by broadening the understanding of operational risks during the construction phase and offer practical guidance for policymakers in developing more effective mitigation strategies, with implications for other developing nations utilising community-based reconstruction.

*Keywords:* Community-Based; Delay Risk; Housing Reconstruction; Post-Disaster; Risk Management; Stakeholder.

## 1. Introduction

Post-disaster housing restoration is a vital concern for the communities impacted [1, 2]; hence, it should be done quickly and appropriately [3]. Among the important aspects used to evaluate reconstruction efforts is the housing completion rate [4]. In its implementation, a community-based approach is widely applied in developing countries [5, 6], including Indonesia [7, 8], Turkey [9], Iran [10, 11], India [6, 12], Sri Lanka [13], Bangladesh [14], Afghanistan [15], and Pakistan and Sri Lanka [16]. Community-based reconstruction aims to actively engage residents in shaping and implementing development initiatives, ensuring that the resulting actions better reflect the specific needs and conditions of the community [17]. In Indonesia, this approach is implemented in situ through community empowerment, community-based organising, and appreciation for local wisdom and values of cooperation [18].

Involving communities in the post-disaster housing reconstruction is consistent with the 'Build Back Better' (BBB) principle, advocated by the 2015–2030 Sendai Framework for Disaster Risk Reduction (SFDRR), which prioritises communities as key actors in the recovery process and promotes long-term resilience through active participation [19].

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This approach was also implemented in the 6.5 MW post-earthquake housing reconstruction project following the earthquake on December 7, 2016, in Pidie Jaya Regency, Aceh Province, Indonesia, which serves as the study location. Community involvement is a priority aspect in all stages of the recovery process [20].

A resilient resettlement model can be developed by integrating the principles of BBB and strengthening risk reduction [21]. Community involvement is not only as a beneficiary but also as a supervisor of construction quality, accountability, and overall community satisfaction, in contrast to a contractor-based system [22, 23]. Evidence from previous research on Aceh Province following the 2004 earthquake and tsunami demonstrates that beneficiary involvement in housing reconstruction significantly contributed to medium- and long-term socio-economic recovery [24]. The most effective outcomes were achieved when communities were not burdened with construction management responsibilities or logistical challenges, such as complex material selection, which could hinder the recovery process [25]. A recent bibliometric analysis identified three main pillars, environment, society, and economy, as essential foundations for post-disaster reconstruction to ensure sustainable and equitable recovery [26]. Nevertheless, existing studies remain primarily macro in scope and have yet to examine the risk perceptions of stakeholders in community-based housing projects.

Many studies have shown that community-based housing reconstruction approaches have yielded numerous positive results. These include a stronger sense of ownership [6, 22], increased community satisfaction [7], enhanced capacity building in the reconstruction process [6, 16, 27], improved cost and time efficiency [15, 16, 27], and greater conformity with local cultural values [23, 27, 28]. However, several studies indicate that numerous challenges remain in terms of social, technical, and institutional aspects. Several factors—such as limited community participation [5, 14, 25, 26], inadequate community capacity [27], poor stakeholder coordination [15, 27], political challenges [25, 27], and resource constraints [25, 28]—are frequently cited as contributing to the failure to achieve the planned cost [10, 14, 25], time [12, 23], and quality targets [23, 25]. Factors, such as limited community participation [5, 14, 29, 30], inadequate community capacity [31], poor stakeholder coordination [15, 31], political challenges [29, 31], and resource constraints [29, 32], are frequently cited as contributing to the failure to achieve the planned cost [14, 29], time [12, 27], and quality target [27, 29]. Identifying these risk factors is crucial to ensure that the reconstruction process runs effectively, efficiently, and sustainably.

The uniqueness of each construction project results in risk factors arising from community involvement in post-disaster housing reconstruction being particular and not comparable to conventional contractor-based construction projects [33]. Moreover, the varying characteristics of each disaster event contribute to the complexity of project implementation [34]. Technical unpreparedness and the limited construction experience of the community lead to risks in community-based reconstruction projects, differing significantly from those in traditional construction settings [6]. Therefore, accurate risk identification is essential to design community-based risk management strategies tailored to the specific nature of such projects [23, 35].

Although several studies have discussed the successes and challenges of community-based housing reconstruction, few have specifically examined the risks that directly contribute to project delays, particularly during the physical implementation phase. This stage encompasses the entire construction process, from preparation to completion, adhering to government-specified design, budget, timeline, and quality standards. According to the Project Management Body of Knowledge (PMBOK), construction-related risks fall into a core category that requires thorough analysis in project management practices. In reality, however, post-disaster reconstruction is often carried out without an adequate risk management system, which may hinder the success of recovery programmes [23].

Risk management itself comprises a systematic process that includes planning, identification, qualitative and quantitative analysis, response formulation, and continuous monitoring [36]. In the context of community-based reconstruction, the application of this process is increasingly critical due to high uncertainty, the involvement of multiple stakeholders, and dynamic field conditions. This approach not only reduces the likelihood of project failure but also enhances the community's adaptive capacity and resilience, enabling it to address future disasters independently.

In Pidie Jaya Regency, Aceh Province, the Regional Disaster Management Agency is responsible for overseeing the reconstruction of community housing after disasters. However, there is currently no established list of risk factors or mitigation strategies that can be applied prior to a disaster occurring. The approach implemented in this region involves facilitators. The community companions and community groups are the direct executors of reconstruction activities, thereby reinforcing the community-based reconstruction model. Stakeholders are individuals or groups who influence project outcomes or are directly or indirectly affected by project implementation [37]. In post-disaster reconstruction, stakeholders with limited power, legitimacy, and urgency are particularly susceptible to exploitation during project implementation [38]. Each stakeholder involved assesses risk based on their own perceptions and understanding of the situation. When managed effectively, these differing perceptions can enhance inter-stakeholder collaboration, improve risk-related communication, and strengthen quality assurance systems [39].

The conceptual framework of this study integrates three theoretical perspectives. First, risk management theory, as outlined in PMBOK, provides a foundation for the systematic identification and prioritisation of risks. Second, the stakeholder perspective is reflected in the differing perceptions of actors such as government agencies, facilitators, and community groups regarding potential risks in the reconstruction process. Third, community participation theory, as emphasised in the SFDRR, highlights the critical role of communities as active participants in reconstruction. The

integration of these three perspectives underpins a stakeholder-based risk analysis aimed at identifying and mapping the key risks that influence the successful completion of post-disaster housing reconstruction projects.

Previous research has documented delays in post-disaster housing reconstruction projects in Pidie Regency [40]. In response to these conditions, this study aims to assess the potential risks that affect the completion time of community-based housing reconstruction projects from the stakeholders' perspective in Pidie Jaya Regency, Aceh Province, Indonesia. The set of risk variables studied in this research is comprehensive and specific to the context of post-disaster housing reconstruction, which directly involves the community. Risk identification was conducted through in-depth interviews with stakeholders, followed by validation through focus group discussions (FGDs) and the deployment of questionnaires.

This study is distinct from previous works by focusing explicitly on operational risks during the construction phase of community-based projects. It successfully identifies 17 new risk variables that were previously undocumented in the literature, including issues related to delays in physical construction completion. By adopting a structured community-based approach, this study makes a significant contribution to the advancement of risk management practices in the context of post-disaster reconstruction. These findings are expected not only to strengthen risk mitigation strategies and improve project delivery timelines but also to serve as a reference in designing similar policies and programmes in other regions. More broadly, the approach and results of this study may be adapted by other developing countries that employ community-based reconstruction models, particularly in enhancing post-disaster resilience and empowering local communities.

The structure of this article begins with the research methodology, outlining the case study context, data collection techniques, and analysis methods. It then presents the results of the risk assessment and discusses the key findings from a stakeholder perspective. The final section provides the conclusions, followed by recommendations and suggestions for future research.

## 2. Research Methodology

### 2.1. Case Study

This research focused on a housing reconstruction initiative implemented in Pidie Jaya Regency, Aceh Province, Indonesia, following the earthquake. The study area is illustrated in Figure 1. Administratively, the regency comprises eight sub-districts, all of which were affected by the disaster. On December 7, 2016, northern Sumatra was struck by a 6.5 Mw earthquake centred in Pidie Jaya Regency. The tremor also extended its effects to the adjacent regencies of Pidie and Bireuen. The most severe consequence of the event was the extensive damage to residential buildings, with a total of 17,673 homes affected. The damage encompassed 2,202 houses with extensive structural destruction, 4,542 with moderate damage, and 10,929 with minor damage [35].

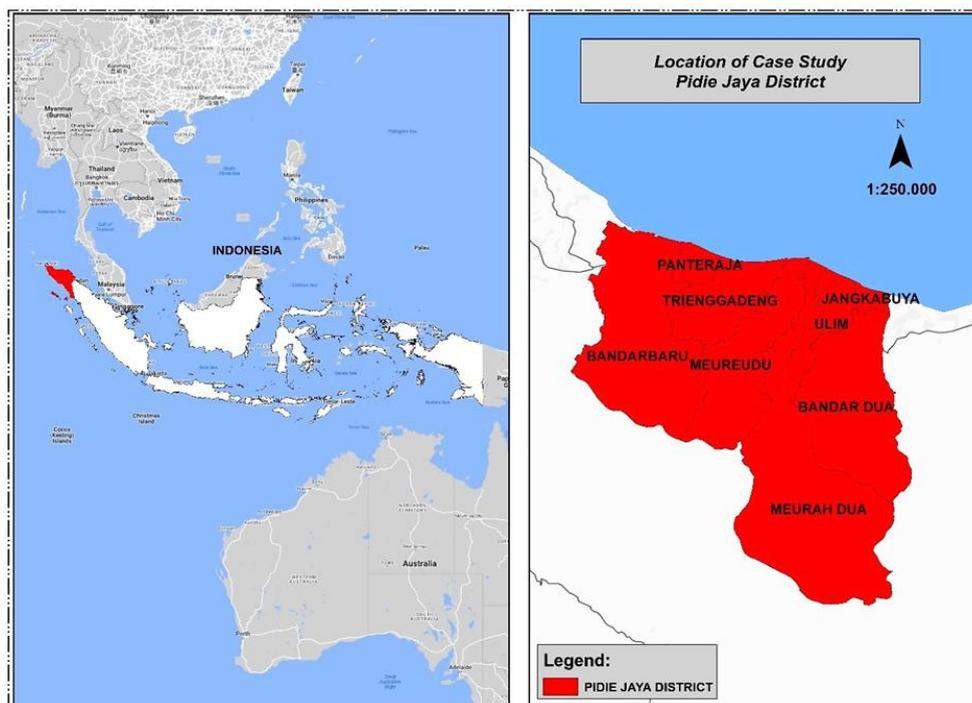


Figure 1. Research location

Community-based methods were chosen for the housing reconstruction development process. For severely damaged houses, the government has prepared the design and technical specifications for 36 m<sup>2</sup> units (referred to as Type 36

houses), with full financial support allocated from the state budget. The development of community-based permanent housing was divided into two areas: Region 1, consisting of Bandar Baru and Panteraja sub-districts, and Region 2, comprising five sub-districts: Trienggadeng, Meureudu, Meurah Dua, Ulim, and Jangka Buya, as well as Bandar Dua sub-district [41]. Two examples of the damaged houses are shown in Figure 2.



Figure 2. Examples of damaged houses after the December 6, 2016, Pidie Jaya Earthquake

To achieve the research objectives, a series of stages was conducted using several complementary methods. Figure 3 presents the methodological framework.

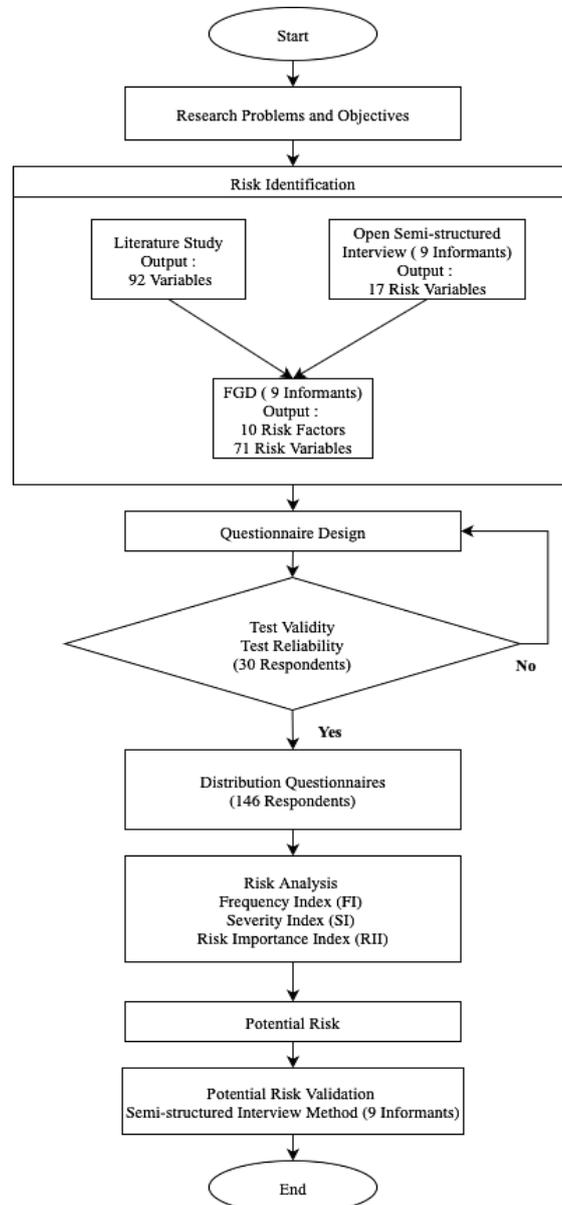


Figure 3. Research methodology flowchart

## 2.2. Data Collection

Data collection and analysis for risk identification and assessment were conducted using steps and methods aligned with risk management principles [36]. The initial stage of the study began by identifying 92 risk variables related to housing reconstruction from the literature. The next stage was a semi-structured open interview to identify new information related to risks. Interviews were conducted face-to-face with informants at the research site, who were stakeholders involved in the reconstruction process in Pidie Jaya Regency. Informants were identified using a snowball sampling technique [2]. Nine informants participated in this study: three government officials (Inf1, Inf2, Inf3), three facilitators (Inf4, Inf5, Inf6), and three members of a community group (Inf7, Inf8, Inf9). Additional data collection was conducted through interviews, during which pertinent questions were asked of the informants. Data derived from the interviews were examined using thematic analysis [12]. Based on the interviews with the informants, 17 new risk variables were identified. Focus group discussions (FGD) were then held with experts to validate all of the risk variables. The validation process has been simplified, resulting in 71 variables, comprising 54 variables from literature studies and 17 variables from the interviews. The risks were then categorised into ten risk factors: material (A), equipment (B), labour (C), community group (D), facilitator (E), government (F), finance (G), security & K3 (H), disaster (I), and social, political and regulatory (J). The complete list of risks is presented in Table 1.

**Table 1. Risk identification factors and variables**

Risk Factors	Variable Risk	Source
Material (A)	Increase in material prices (A1), late delivery of materials (A2), substandard material quality (A3), incorrect material volume (A4), suppliers unable to fulfil material orders (A5), damage during delivery and storage of materials (A6), limited material storage space (A7), inaccuracy in material ordering time (A8), scarcity of materials (A9), use of old building materials (A10)	[5, 14, 27, 30, 32, 42, 43]
	Material specifications were not the same within one community group (A11), and there was a change of material suppliers (A12)	Interview Results
Equipment (B)	Equipment incompleteness (B1), damage to the appliance (B2), additional equipment rental fees (B3), and a lack of understanding of the workforce on the process of using tools (B4)	[14, 42, 43]
Labour (C)	Lack of labour availability (C1), Lack of community skills in the construction sector (C2), lack of worker discipline (C3), low worker productivity (C4), worker disputes (C5), labour strikes (C6), absence of labour policies and unavailability of work manuals (C7), lack of team cohesion (C8), community groups as labour (C9)	[5, 12, 14, 22, 27, 30, 32, 42, 43]
	Labour turnover (C10)	Interview Results
Community group (D)	Lack of community participation (D1)	[5, 6, 9, 14, 15, 22, 27, 29, 30, 44]
	Community groups do not understand the specifications of building materials (D2), Lack of coordination and communication between community group administrators and members (D3), Lack of trust between members and community group administrators (D4), occurrence of internal conflicts within community groups (D5), community groups have difficulty in determining material suppliers (D6), community groups were deceived by material suppliers (D7), community groups have difficulty in obtaining construction workers (D8)	Interview Results
Facilitator (E)	Limited facilitators (E1), Lack of facilitator capacity (E2), lack of supervision during construction by facilitators (E3)	[7]
	Lack of communication & coordination between facilitators and community groups (E4), Lack of trust in facilitators by community groups (E5), Lack of assistance from facilitators in preparing accountability reports for funds (E6)	Interview Results
Government (F)	Insufficient government resources (F1), lack of government resource capacity (F2), Lack of communication and coordination with the agencies involved (F3), Lack of coordination and communication between owners, facilitators, and community groups (F4)	[5, 7, 14, 27, 30, 44]
Finance (G)	Lack of budget for the entire project (G1), Inflation (G2), Inadequate payments (G3)	[7, 43, 45]
	Slow process of disbursing funds (G4), losses to community groups due to errors in work implementation methods by workers (G5), excess payment of wages for workers by community groups (G6), non-transparent use of money by community group administrators to members (G7)	Interview Results
Safety and health, occupational safety (H)	Theft of materials (H1), extortion by individuals (H2), corruption (H3), attacks and demonstrations by the community (H4), non-compliance with building regulations (H5), cultural problems and attitudes of lack of commitment to health and safety (H6), workers were equipped with personal protective equipment (H7), accidents occur in the workplace (H8)	[15, 29, 32, 44]
Disaster (I)	Bad weather (I1), environmental pollution (I2), earthquake disaster (I3), flood disaster (I4), disease outbreak (I5), fire disaster (I6)	[5, 46–48]
Social, Political & Regulatory (J)	Competition between communities (J1), work patterns related to local cultural and religious factors (J2), non-governmental organisations opposing the project (J3), political sensitivity and climate (J4), changes in policies and regulations (J5), conflicts with project stakeholders (J6)	[5, 7, 15, 27, 29, 44, 49, 50]

The questionnaire was designed by adding all variables identified in Table 1. It was distributed to 30 respondents as part of a pilot study, comprising 10 individuals from each stakeholder group. The study focused on examining the consistency and accuracy of the questionnaire used. The pilot study aimed to assess the reliability and validity of the survey instrument used. In the second stage, the survey was distributed to 146 respondents using a purposive sampling method. The respondents consisted of 15 government agencies, 35 facilitators, and 96 community members affiliated with the developer. The sample size was determined using the Slovin formula to ensure a representative number of respondents [2].

The questionnaire was distributed by guiding and visiting the respondents directly at the research location. The closed-ended questionnaire used a Likert assessment scale. Each respondent was asked to report the frequency of events and the severity of risk variables related to the delay in reconstruction completion. To evaluate the frequency of events, a Likert scale based on the parameters listed in Table 2 was applied, consisting of five response levels: 1 means "very rarely", 2 "rarely", 3 "occasionally", 4 "frequently", and 5 "very frequently". Additionally, the Likert scale was used to assess the severity of the impact of risk variables on delays in completing housing reconstruction projects. The impact was measured by five rating levels: 1 for "very low", 2 for "low", 3 for "moderate", 4 for "high", and 5 for "very high". Table 2 presents the criteria for frequency and impact, based on previous research in risk analysis.

**Table 2. Risk identification factors and variables**

Likert scale	Frequency	Impact
1	Very rarely (the occurrence probability < 20%)	Very low (No additional time)
2	Rarely (the occurrence probability >20% to 40%)	Low (Additional time less than 10%)
3	Often enough (the occurrence probability is >40% to 60%)	Moderate (Additional time >10% to 20%)
4	Often (the occurrence probability >60% to 80%)	High (Additional time >20% to 40%)
5	Very often (the occurrence probability >80%)	Very high (Additional time more than 40%)

The research results on potential risk variables were then revalidated with the informants involved in the FGD using a semi-structured interview method. The informants were asked to share their heuristic knowledge about the leading causes of potential risk occurrence [51]. This approach enabled the identification of the relationship between risk variables contributing to delays in the completion of post-disaster housing reconstruction and their underlying causes.

### 2.3. Questionnaire Test

Validity testing was conducted by analyzing the relationship between individual statements and the overall score through the application of product-moment correlation ( $r$ ) [52], as in Equation 1. The resulting  $r$  – value indicates the degree of variation in individual item responses ( $x_i$ ), and the total scores for the given assessment aspect ( $y_i$ ), across all respondents ( $n$ ). Validity was determined through a t-test.

The reliability of the measurement instrument, especially the questionnaire being evaluated, was assessed using Cronbach's Alpha method to determine its internal consistency [52]. A Cronbach's Alpha coefficient of 0.6 or higher is considered acceptable, indicating the level of reliability demonstrated by the questionnaire.

### 2.4. Analysis

This study employed both qualitative and quantitative risk analysis to identify threats that could delay the completion of post-disaster housing initiatives implemented through community participation. Data collected from respondents was analysed, taking into account the number of events and impacts. In assessing the number of events, the Frequency Index (FI) was used as described in Equation 1. This FI equation was also used in previous studies [53].

$$FI = \frac{\sum_{i=1}^5 a_i \cdot n_i}{5N} \quad (1)$$

where  $i$  is the index of the category,  $a_i$  is the weight of the  $i$  –  $th$  response (a Likert scale, as specified in Table 2, was utilised to construct the frequency index scale),  $n_i$  is the total of respondent responses for item  $i$  –  $th$ , and  $N$  is the total number of respondents. The assessment of the impact of risk on the completion time of housing reconstruction was analysed using the severity index (SI), as shown in Equation 2. These SI equations have been used in previous studies [54].

$$SI = \frac{\sum_{i=1}^5 a_i \cdot n_i}{5N} \quad (2)$$

where  $i$  is the index of the category,  $a_i$  is the weight of the  $i$  –  $th$  response (the severity index scale was made using a Likert scale using the criteria in Table 1),  $n_i$  is the total of respondent responses for item  $i$  –  $th$ , and  $N$  is the total number of respondents. The analysis was completed using the risk importance index (RII), as shown in Equation 3. Some studies utilised RII to identify potential risk factors [46], where FI represents the frequency index assigned to each risk variable, and SI denotes the severity index corresponding to each risk factor.

$$RII = FI \times SI \quad (3)$$

The RII analysis results are outlined as a series of potential risks influencing the duration of housing construction, which is then included in the 5x5 probability and impact matrix (PIM). The risk levels are categorised into five levels: extreme, significant, high, moderate, and low, as described in Table 3.

**Table 3. Risk level**

Risk Matrix		Severity Index (SI)				
		Very Low (>0.00 to 0.125)	Low (>0.125 to 0.375)	Moderate (>0.375 to 0.625)	High (>0.625 to 0.875)	Very high (>0.875 to 1.00)
Frequency Index (FI)	Very frequently (>0.00 to 0.125)	0.06	0.234	0.469	0.703	0.879
	Frequently (>0.125 to 0.375)	0.047	0.188	0.375	0.563	0.703
	Occasionally (>0.375 to 0.625)	0.031	0.125	0.250	0.375	0.469
	Rarely (>0.625 to 0.875)	0.016	0.053	0.125	0.188	0.234
	Very rarely (>0.875 to 1.00)	0.004	0.016	0.031	0.047	0.059

	Low Risk 0.00 ≤ RII ≤ 0.099	: The risk can be addressed through standard operating procedures.
	Moderate Risk 0.1 < RII ≤ 0.199	: The risk does not require top management involvement, but should be addressed proactively.
	High Risk 0.2 < RII ≤ 0.399	: The risks require prompt action and involve middle-level management.
	Significant Risk 0.400 < RII ≤ 0.599	: The risk requires serious attention from top-level management.
	Extreme Risk 0.600 < RII ≤ 1.000	: The risk demands strategic consideration and action by the highest organisational leadership.

### 3. Results and Discussion

#### 3.1. Characteristics of Respondents

As shown in Table 4, the demographic profile reveals that the greater portion of respondents from the government and facilitators were aged 40-60 years (53.33% and 60%), whereas the community group was dominated by those aged 20-40 years (50%). Government and facilitator respondents were predominantly men (66.67% and 82.86%), whereas the community group was more gender-balanced (57.29% male, 42.71% female). The majority of government respondents were rehabilitation/reconstruction staff (53.33%), while facilitators were predominantly in technical/empowerment roles (71.43%), and the community was represented by its members (75%). The majority of individuals from both the facilitator group and the government had completed undergraduate education (100%), whereas the community's level was primarily high school or lower (82.30%). The work experience of the community in the construction sector was low (68.75%), compared to facilitators and the government. This gap affects risk perception, technical involvement, and project success.

**Table 4. Respondent characteristics**

Characteristic	Government agencies		Facilitators		Community group	
	Freq.	%	Freq.	%	Freq.	%
<b>Age of Respondents</b>						
< 20 years	0	0.00	0	0.00	0	0.00
20 - 40 years	7	46.67	14	40.00	48	50.00
40 -60 years	8	53.33	21	60.00	36	37.50
> 60 years	0	0.00	0	0.00	12	12.50
<b>Gender</b>						
Male	10	66.67	29	82.86	55	57.29
Female	5	33.33	6	17.14	41	42.71
<b>Jobs Title</b>						
Head of rehabilitation/reconstruction	1	6.67	-	-	-	-
Technical Implementation Officer of the Activity	1	6.67	-	-	-	-
Staff rehabilitation/reconstruction	8	53.33	-	-	-	-
Rehab/reconstruction assistants	5	33.33	-	-	-	-
Senior facilitators	-	-	10	28.57	-	-

<b>Facilitators</b>						
Engineering/Empowerment/Economics	-	-	25	71.43	-	-
Head of the Community Group	-	-	-	-	15	15.63
Secretary of the Community Group	-	-	-	-	5	5.21
Treasurer of the Community Groups	-	-	-	-	4	4.17
Community Group	-	-	-	-	72	75.00
<b>Last Education</b>						
Master's Degree	3	20.00	0	0.00	0	0.00
Bachelor's Degree	11	73.33	30	85.71	12	12.50
Vocational Diploma	1	6.67	5	14.29	5	5.20
Upper Secondary Education	-	-	-	-	79	82.30
<b>Work experience in the construction field</b>						
0 years	0	0.00	0	0.00	66	68.75
1 - 5 years	7	46.67	8	22.86	23	23.96
5 - 10 years	6	40.00	16	45.71	5	5.21
10 -20 years	2	13.33	11	31.43	2	2.08

### 3.2. Validity and Reliability Test Results

The questionnaire's validity was assessed at a 95% confidence level, corresponding to a significance threshold of 5%, resulting in a critical t-value of 0.361 for 30 respondents. When the calculated t-values exceeded this threshold, the items were considered valid. Regarding the internal consistency of the frequency index, the Cronbach's Alpha scores for the identified risk variables were above the minimum benchmark of 0.6. Table 5 provides a summary of the corresponding validity and reliability analysis.

**Table 5. Validity and reliability test results**

Questionnaire Code	Risk Factors	Range Value r calculate		r table	Remark	(C-Alpha) Risk Probability	Remark
		Risk Probability					
		Minimum	Maximum				
A1-A12	Material	0.378	0.689	0.361	Valid	0.764	Reliable
B1-B4	Equipment	0.590	0.776	0.361	Valid	0.622	Reliable
C1-C10	Labour	0.370	0.742	0.361	Valid	0.797	Reliable
D1-D8	Community Group	0.395	0.701	0.361	Valid	0.614	Reliable
E1-E6	Facilitators	0.428	0.848	0.361	Valid	0.795	Reliable
F1-F4	Government Agencies	0.513	0.877	0.361	Valid	0.774	Reliable
G1-G7	Finance	0.387	0.939	0.361	Valid	0.867	Reliable
H1-H8	Safety & health, occupational	0.508	0.886	0.361	Valid	0.825	Reliable
I1-I6	Disaster	0.463	0.851	0.361	Valid	0.701	Reliable
J1-J6	Social, politics, and regulation	0.428	0.806	0.361	Valid	0.675	Reliable

Table 5 illustrates that the instrument met both validity and reliability criteria, justifying its deployment to the target sample.

### 3.3. The Risk Variables Assessment on Project Completion Time

The risk assessment on project completion time was determined by the value of the risk importance index (RII), which is a function of the occurrence probability and the impact of a risk variable. Accordingly, risk analysis must consider not only the probability of occurrence but also the potential impact of each risk variable, as neither factor should be evaluated in isolation. Table 6 displays the ratings of all risk variables that influence the completion time of the post-disaster housing reconstruction effort.

**Table 6. Analysis of FI, SI, and RII**

Risk Factors	Variables Code	FI	Rank	SI	Rank	RII	Rank	Risk Level
Material (A)	A1	0.551	16	0.530	9	0.292	10	High
	A2	0.341	41	0.518	10	0.177	25	Moderate
	A3	0.292	50	0.303	42	0.088	50	Low
	A4	0.371	36	0.375	30	0.139	36	Moderate
	A5	0.585	14	0.379	28	0.222	18	High
	A6	0.255	56	0.285	52	0.073	56	Low
	A7	0.244	58	0.238	59	0.058	60	Low
	A8	0.355	37	0.360	31	0.128	38	Moderate
	A9	0.730	3	0.508	11	0.371	5	High
	A10	0.333	43	0.285	53	0.095	47	Low
	A11	0.353	38	0.301	44	0.107	41	Moderate
	A12	0.622	9	0.588	5	0.365	6	High
Equipment (B)	B1	0.223	67	0.226	63	0.050	68	Low
	B2	0.212	71	0.226	64	0.048	69	Low
	B3	0.242	60	0.234	62	0.057	61	Low
	B4	0.222	68	0.247	57	0.055	64	Low
Labour (C)	C1	0.741	2	0.718	1	0.532	2	Significant
	C2	0.641	7	0.595	4	0.381	4	High
	C3	0.642	6	0.321	35	0.206	19	High
	C4	0.316	44	0.481	13	0.152	32	Moderate
	C5	0.270	55	0.289	50	0.078	54	Low
	C6	0.296	48	0.342	34	0.101	42	Moderate
	C7	0.482	24	0.300	46	0.145	34	Moderate
	C8	0.307	46	0.303	43	0.093	49	Low
	C9	0.299	47	0.316	37	0.094	48	Low
	C10	0.342	40	0.321	36	0.110	40	Moderate
Community Group (D)	D1	0.314	45	0.315	38	0.099	43	Low
	D2	0.521	19	0.295	48	0.153	31	Moderate
	D3	0.482	25	0.297	47	0.143	35	Moderate
	D4	0.508	21	0.293	49	0.149	33	Moderate
	D5	0.615	10	0.458	19	0.281	11	High
	D6	0.633	8	0.466	15	0.295	9	High
	D7	0.516	20	0.312	40	0.161	29	Moderate
	D8	0.540	17	0.301	45	0.163	28	Moderate
Facilitators (E)	E1	0.752	1	0.714	2	0.537	1	Significant
	E2	0.418	32	0.460	18	0.192	22	Moderate
	E3	0.597	11	0.452	20	0.270	13	High
	E4	0.590	12	0.389	25	0.230	15	High
	E5	0.588	13	0.389	26	0.229	16	High
	E6	0.442	27	0.536	8	0.237	14	High
Government Agencies (F)	F1	0.522	18	0.352	32	0.184	23	Moderate
	F2	0.381	35	0.314	39	0.119	39	Moderate
	F3	0.334	42	0.285	54	0.095	46	Low
	F4	0.279	54	0.307	41	0.086	51	Low
Finance (G)	G1	0.451	26	0.377	29	0.170	27	Moderate
	G2	0.242	61	0.216	70	0.052	66	Low
	G3	0.214	70	0.219	67	0.047	71	Low
	G4	0.703	4	0.577	6	0.405	3	Significant
	G5	0.440	29	0.404	22	0.178	24	Moderate
	G6	0.440	30	0.218	69	0.096	45	Low
	G7	0.344	39	0.392	24	0.135	37	Moderate

Safety and health, occupational safety (H)	H1	0.295	49	0.236	60	0.069	57	Low
	H2	0.289	51	0.279	55	0.081	53	Low
	H3	0.288	52	0.266	56	0.076	55	Low
	H4	0.574	15	0.488	12	0.280	12	High
	H5	0.240	62	0.236	61	0.056	62	Low
	H6	0.423	31	0.474	14	0.201	21	High
	H7	0.252	57	0.222	66	0.056	63	Low
	H8	0.230	65	0.205	71	0.047	70	Low
Disasters (I)	I1	0.441	28	0.462	17	0.204	20	High
	I2	0.227	66	0.223	65	0.051	67	Low
	I3	0.493	22	0.463	16	0.228	17	High
	I4	0.244	59	0.396	23	0.097	44	Low
	I5	0.238	64	0.347	33	0.083	52	Low
	I6	0.218	69	0.289	51	0.063	59	Low
Social, Politics, and Regulations (J)	J1	0.240	63	0.219	68	0.053	65	Low
	J2	0.660	5	0.544	7	0.359	7	High
	J3	0.281	53	0.244	58	0.068	58	Low
	J4	0.486	23	0.636	3	0.309	8	High
	J5	0.386	34	0.445	21	0.172	26	Moderate
	J6	0.407	33	0.389	27	0.158	30	Moderate
Low		29 Risk variables						
Moderate		21 Risk variables						
High		18 Risk variables						
Significant		3 Risk variables						
Extreme		0 Risk variables						

Table 6 shows that the five highest ratings of the delay risk variable had an RII index value ranging from 0.537 to 0.371. Of the five variables, three were at a significant risk level (E1, C1, G4), while the remaining two were at a high risk level (C2, A9). Referring to Table 3, significant risks warrant serious attention from top-level management, including the officials responsible for residential recovery and reconstruction, as well as the head of the Regional Disaster Management Agency. The three significantly ranked risk variables were directly influenced by the likelihood of their occurrence and the severity of their effect on the project's completion schedule. These risk variables exhibited a probability of 60% to 80%, and the project had the potential to experience a delay in completion time of 20% to 40% of the planned schedule. High-risk variables require immediate action by middle-level management, particularly the head of rehabilitation and housing reconstruction. Notably, no extreme risk variables were identified in this study.

The informants confirmed the five highest-rated risk variables through semi-structured interviews conducted at the study site. These five risk variables were also confirmed in various international studies conducted in developing countries. They were used to validate and strengthen the findings of this empirical study, as described in the following paragraph.

The variable risk of a lack of facilitators (E1) is a potential risk in the early stages of implementing this reconstruction project. Stakeholders acknowledge the essential role of facilitators in ensuring the effective implementation of the reconstruction process. The lack of sufficient numbers of facilitators is one of the primary risks that may hinder the project's timely completion. The role of facilitators is crucial in providing technical direction and administrative guidance to community groups. According to Inf1, *"the increase in the amount of house damage is beyond the government's expectations, so that facilitators work with an excessive load."* Inf4 added, *"The number of contracted facilitators is not balanced with the conditions on the field."*

Following the verification and confirmation of data on housing damage, the number of damaged houses increased, resulting in an increase in the number of beneficiary community groups without the addition of facilitators. As explained by Informant 2 (Inf2), this condition is justified by the fact that *"Due to budget constraints that prevent any increase in the contract value, each facilitator team, originally intended to consist of five members, was reduced to three members. This adjustment was made to ensure that all community groups could still be supported and was implemented with the mutual agreement of both the government and the facilitators"*. This lack of facilitators triggers the emergence of other risk variables, namely weak supervision during development by facilitators (E3), lack of communication and

coordination between facilitators and community groups (E4), and insufficient facilitator assistance in preparing fund accountability reports (E6). All variables in the facilitator's risk factors contribute to the potential variable because they are at the moderate risk level.

Facilitators, such as supervisors and companions provided by the government during the reconstruction of people's houses after disasters, enable individuals to build their houses as planned [55]. However, studies of housing reconstruction in India showed that the competence of the facilitators significantly influences the success or failure of a home-building programme. The role of the facilitator includes direct involvement with the community and active participation in the residential restoration process [56]. Facilitators are essential in ensuring smooth and effective communication, adapting programmes to local conditions, and ensuring that implementation remains consistent with established principles [57].

In response to budget constraints, the government can implement community-based extension by training experienced community members as part-time facilitators or mobilisers to extend the reach of technical assistance. This approach is consistent with the ODHR-UNDP guidelines [58], which emphasise the training of social and financial facilitators as well as field officers. It aligns with the experience of Pakistan (ERRA/World Bank), where social mobilisers were employed to train Village Reconstruction Committees. A similar strategy is highlighted in the IFRC ODHR Guidelines through the mainstreaming of social mobilisation and in Nepal's PDRE, which identifies technical facilitation and training as prerequisites for achieving universal coverage of owner-driven reconstruction.

Another risk variable is a lack of labour availability (C1), which persists despite the implementation of a community-based method. Although the workforce was reported to include local and non-local labourers, as well as members of the community groups themselves, the risk associated with insufficient human resources remains a concern. This is largely due to uncertainty and limited understanding among stakeholders regarding the implementation of participatory, community-driven methods. This method should be able to reduce dependence on local and foreign workers. However, community groups have been unable to implement it effectively due to the C2 risk variable, specifically the lack of community skills in the construction sector, despite having received prior training.

The C2 risk variable requires immediate handling by the government, and following Inf1, "*construction training to the community was carried out by facilitators before the implementation of construction, and some were carried out in line with the implementation of construction, but it was sub-optimal because it was within the disaster period*". As a result, community groups still relied on local and non-regional construction workers.

Prior to the disaster, the local community generally lacked adequate technical knowledge and skills in housing construction, including earthquake-resistant design and the selection of materials that meet safety standards. Consequently, when damage occurred, they were not technically prepared to undertake reconstruction independently. The finding that community training had not been optimal is consistent with studies in Zimbabwe [59] and Indonesia [60], which show that vocational training programmes employing participatory approaches, such as on-site apprenticeships and collaboration with vocational education institutions, can significantly enhance community capacity in reconstruction and accelerate socio-economic recovery. In the context of Pidie Jaya, implementing apprenticeship-based training on-site, simulation-based training at the community level, and collaboration with local vocational institutions is considered more effective in strengthening technical skills and reducing reliance on external labour.

The workforce consists of local and non-regional workers, as well as community groups themselves. Inf6 stated that "*community groups had the right and authority to seek labour independently based on community-based methods established in the reconstruction policy*". However, Inf7 and 9 explained that "*this labour shortage was increasingly occurring when projects had to be postponed due to waiting for the disbursement of the second phase of funds. Those often cause the workforce to move to other projects, making it difficult for community groups to find replacements*."

In addition, the lengthy administrative process of disbursing funds (G4) exacerbates this condition, triggering additional risks, such as labour turnover (C10) and the difficulty of community groups in obtaining construction labour (D8), which will hinder the completion of housing reconstruction implementation. The lack of community skills in construction, despite training, further strengthens the linkage between C1 and C2 risks, illustrating the failure of community-based methods in reducing dependence on outside labour. Project timelines may be extended as a result of constraints in essential resources, including workforce availability and construction materials, during the reconstruction phase [61, 62].

The significant difference in this study compared to the previous study was in the variable of risk associated with the slow disbursement of funds (G4). The G4 risk variable was initially identified through insights obtained from informant interviews at the start of the study and later revalidated after being incorporated into the potential risk analysis, guided by the RI analysis. Administrative processes, including the implementation of tiered approvals and reform of slow bureaucratic systems, must be immediately improved by the government, especially in the financial sector. As explained by Inf1, "*the requirements for fund disbursement had to be fulfilled by the community groups, with support from the facilitators. In practice, community groups generally faced difficulties. They required additional time to*

*complete the necessary documentation*". Inf4 explained that *"the facilitators also helped community groups in completing documents"* but Inf5 and 6 stated further that *"facilitators worked with excessive burden, while the government was not ready with the resources in accelerating the process of checking documents for the disbursement of funds"*. So that the FI variable, namely the lack of government staff, and the F2 variable, namely the lack of government capacity, trigger the emergence of the G4 risk variable. A prolonged fund disbursement process can significantly hinder long-term recovery [25, 63]. These efforts can be reinforced through the application of digitalisation to enhance project efficiency, including data integration, document management, and stakeholder collaboration by utilising technologies such as BIM, IoT, and digital platforms [64]. This approach not only accelerates administrative processes but also ensures transparency and accuracy of information, thereby minimising the risk of delays.

The variable risk of material shortage (A9) is the fifth variable contributing to the RII value. Similar to the C1 risk variable, the simultaneous implementation of reconstruction across the three affected districts led to material shortages at the impacted sites. This community-based reconstruction policy granted freedom to community groups to choose material suppliers, but did not include criteria for suppliers meeting the government's standards. Many community groups sought materials from outside the region to secure lower prices. However, this shortage of materials led to other risks, such as losses incurred by community groups due to fraudulent suppliers who failed to deliver the promised materials (D7), as well as difficulty in identifying reliable materials suppliers (D6). *"This is because the government issues no criteria and policies in determining technically appropriate material suppliers"*, stated Inf 6. According to Inf 1, *"the government had tried to cooperate with several building material distributors, such as cement and iron distributors, but it had not succeeded because the public considers that the government received commissions from distributors. To avoid this assumption, the government decided to cooperate with distributors"*.

The shortage of post-disaster materials needs to be a serious concern for the government. In Sri Lanka, this issue was anticipated through a mechanism for the mass procurement of building materials, while in Pakistan, the government had established material distribution centres to suppress price spikes during the housing reconstruction process [57]. Other research revealed that the role of NGOs was limited to providing materials and technical advice, while beneficiaries rebuilt their homes independently. Participants called the project participatory and successful [65].

The impact of these risks extends beyond project delays, influencing multiple aspects of successful reconstruction. In addition to timeliness, the identified risk variables can compromise construction quality and reduce the long-term durability of dwellings. For example, limited facilitator capacity and weak supervision may lead to substandard construction practices, increasing vulnerability to damage in future disasters. Similarly, shortages of skilled labour and delays in material supply can result in the use of low-quality materials or rushed workmanship, ultimately affecting resident safety and long-term maintenance costs.

The findings of this study also reveal differences in perception among the government, facilitators, and community groups regarding responsibility for risks during reconstruction. The government maintains that most risks should be borne collectively, with local government assuming a coordinating role, given its authority over project supervision and funding. Facilitators, by contrast, acknowledge direct responsibility for technical and administrative risk control in the field but consider their capacity limited when faced with delays in fund disbursement or material shortages. Community groups, meanwhile, tend to view the government as primarily responsible for risks of delay, while considering their role limited to the proper use of funds. This distribution of risk responsibility often creates tension among stakeholders, particularly when institutional capacity and technical support are insufficient. Clarifying roles and accountability among government, facilitators, and communities is therefore essential to achieving the BBB principle [66].

These findings align with studies in other developing-country contexts, which demonstrate that power imbalances, information asymmetry, and role ambiguity frequently lead to exploitation or disproportionate risk burdens for weaker stakeholders, such as local communities [67]. Accordingly, community-based post-disaster housing reconstruction should incorporate mechanisms that ensure equitable risk distribution and meaningful participation from all stakeholders.

Within the framework of community-driven residential rebuilding efforts following disasters in Indonesia, the parties bearing and owning risks are not always the same. These differences encompass aspects of funding sources, the roles of each stakeholder involved, and the parties most affected. This study positions the government as the primary risk manager, given that funding is sourced from the state budget and that the government oversees the coordination of community-driven housing reconstruction initiatives. If risks are not managed effectively, they may result in project delays, the need for refunds to the central government, and a decline in the quality of development outcomes. Ultimately, these consequences can contribute to a poor assessment of government performance.

### **3.4. Assessment of Risk Factors on Project Completion Time**

Further risk analysis can also be carried out on risk factors. Risk intensity was assessed by considering the cumulative contributions of FI, SI, and RII from all variables within each factor. The pattern of potential occurrences and impacts of all risk factors is illustrated in Figure 4. Variations in frequency and impact will provide information about the

mitigation required for each variable. The treatment can be implemented through various actions, which will also vary in nature. This variability helps determine the level of urgency in risk management based on its value. As such, a holistic approach is necessary to comprehensively address the entire risk, taking into account all aspects (frequency, severity, and importance), rather than focusing solely on one dimension of risk.

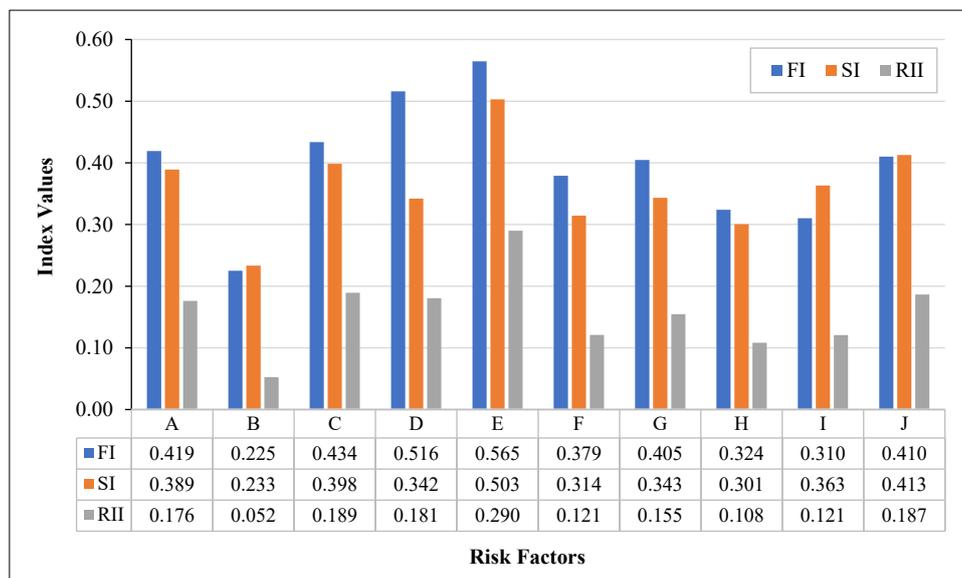


Figure 4. Risk parameters for all factors

The risk factor analysis results in Figure 4 indicate that the risk event rating, with a probability ranging between 40% and 60%, is affected by the FI value in the risk factors E, D, C, A, G, and F. On the other hand, the risk factors H, I, and B have a lower probability, ranging from 20% to less than 40%. The Frequency Index (FI) for each risk factor is determined by computing the mean score of the corresponding risk variable. Risk factor E was the highest rated with an FI value of 0.565. In contrast, risk factor B was ranked the lowest with an FI value of 0.225, as all respondents consistently rated equipment risk factors as very rare, as they only used simple tools to build a type 36 house.

Moderate severity was found in four risk factors (E, J, C, and A), indicating that an increase of 10% to 20% or less of the planned time is required. The severity index (SI) of 0.503 is the highest among the facilitator risk factors (E). Meanwhile, the other six risk factors (I, G, D, F, H, and B) are all at low severity, meaning that the time increase is greater than 0% but less than or equal to 10% of the planned time. Furthermore, the risk factors at the mediation level based on the RII are found in six factors sorted from the highest index, namely facilitator (F), labour (C), social, political, policy (J), community group (D), material (A), and financial (G). In comparison, the four risk factors: government (F), disaster (I), safety and health (H), and equipment (B) are at a low risk level.

These findings indicate that a combination of managerial, administrative, and technical factors influences delays in community-based housing reconstruction. A comparative analysis of Aceh, Yogyakarta, and Lombok shows that although all three regions implemented community-based housing reconstruction with government funding, significant differences emerged in implementation outcomes [68]. In post-tsunami Aceh, mechanisms for facilitation and support distribution were generally more organised and rapid. In contrast, in Yogyakarta and Lombok, delays were more strongly associated with administrative barriers, material distribution, and labour shortages. This highlights the value of cross-regional comparative studies, which not only enrich the interpretation of research findings but also identify the influence of local factors, such as institutional capacity, local policies, and social dynamics, on the effectiveness of reconstruction policies.

The findings further show that the 10 factors and 71 risk variables identified are not only relevant to post-disaster housing reconstruction in Pidie Jaya Regency, but are also largely generic and applicable to other regions with similar characteristics. This is supported by empirical evidence from various countries, including Palestine [69], China [70], Vanuatu [71], Angola [72], Thailand [73], India [56] and Turkey [74], where similar risk factors have been observed. These parallels reinforce the argument that the identified risk variables possess a high degree of transferability and can serve as a foundation for risk identification in community-based projects across other developing countries.

Moreover, the results of this study provide a basis for developing a standardised risk framework for community-based housing reconstruction. Such a framework can serve as a practical guide for policymakers and project implementers, adaptable to local contexts by accounting for cultural factors, institutional capacity, and resource availability. In this way, the study contributes not only to academic literature but also to global risk management practices, while supporting the BBB objectives outlined in the SFDRR 2015–2030.

## 4. Conclusions

This research examines and assesses the risk factors that contribute to delays in completing community-based housing reconstruction projects following a disaster in Pidie Jaya Regency, Aceh Province, Indonesia. Employing a mixed method, the study identified five primary categories and 71 specific risk factors, which were further examined using the frequency index (FI), severity index (SI), and risk importance index (RII).

The results of the analysis showed that three risk variables were at a significant level, namely, Lack of number of facilitators (E1), Lack of labour availability (C1), and low community skills in construction (C2). In addition, the slow disbursement process (G4) and material shortage (A9) are also significant risks that have a major impact on project time delays. These variables occur frequently and exert a considerable influence on the overall success of the reconstruction process. These findings highlight the importance of careful resource planning, effective stakeholder coordination, and proactive risk management.

They underscore the need for more operational policies, such as adjusting the number of facilitators in proportion to the workload of beneficiary groups, supported by continuous technical and administrative training programmes to ensure the provision of optimal assistance. Fund disbursement procedures should be simplified through the adoption of an online digital system for document submission and verification, thereby reducing bureaucratic processing times and minimising delays. The government should also strengthen material procurement mechanisms by establishing district-level distribution centres and fostering long-term partnerships with certified suppliers to ensure material availability and stabilise prices. In terms of community capacity, more structured, practice-oriented construction training is required during the pre-disaster period to enhance technical skills. Furthermore, a comprehensive risk management framework that clearly defines the roles and responsibilities of each stakeholder is essential to ensure fair risk distribution, minimise conflict, and enhance the overall effectiveness of reconstruction. With well-structured policies, delays can be significantly reduced and the BBB objectives, in line with the SFDRR, can be effectively achieved.

This study also makes a theoretical contribution by integrating the perspectives of multiple stakeholders, including beneficiary communities, facilitators, and government authorities, into the risk management of reconstruction projects. Also, it provides a practical contribution as a reference for governments and other developing countries with similar characteristics in formulating community-based risk mitigation strategies. Further research is recommended to expand the scope by considering the impact of risks on project quality and cost, as well as to conduct cross-regional validation to enrich the generalisation of findings.

## 5. Declarations

### 5.1. Author Contributions

Conceptualisation, N.M.; methodology, M.; software, M.; validation, S., formal analysis, N.M.; investigation, M.; resources, S.; data curation, S.; writing—original draft preparation, N.M.; writing—review and editing, M. and S.; visualisation, N.M.; supervision, M.; project administration, N.M.; funding acquisition, N.M. All authors have read and agreed to the published version of the manuscript.

### 5.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available because they contain sensitive responses from interviews and questionnaires that could compromise participant confidentiality and are subject to ethical research approval.

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### 5.5. Conflicts of Interest

The authors declare no conflict of interest.

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