Disaster Risk Mitigation in The Implementation of Core Construction in Kuwil Kawan

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DISASTER RISK MITIGATION IN THE IMPLEMENTATION OF CORE CONSTRUCTION IN KUWIL KAWAN

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Research Paper

Abstract: *This study endeavours to undertake a comprehensive analysis of disaster risks associated with the execution of essential construction activities at the Kuwil Kawangkoan Dam. The research involves a participant pool of 42 individuals engaged in the project, with a determined sample size of 30 employing the Slovin formula. The data collection methodology encompasses both quantitative and qualitative techniques, incorporating interviews, questionnaires, and observations. The analytical approach employed is disaster risk analysis, utilizing the formula R = H x V/C. The results uncover a spectrum of challenges, ranging from high-risk factors such as difficulties related to soil excavation to moderate and low risks, including design inconsistencies and weather-induced material damage. Noteworthy vulnerabilities identified encompass residences and critical facilities susceptible to flooding, underscoring the imperative need for robust risk reduction measures. Although the project demonstrates strengths in disaster management policies, identified weaknesses in systematic preparedness necessitate a more cohesive and integrated approach. The theoretical contribution of this study lies in its universal risk assessment, incorporating multiple dimensions to provide a nuanced comprehension of project vulnerabilities. From a practical standpoint, the research proffers tangible mitigation strategies tailored to specific risk levels, furnishing stakeholders with guidance for proactive risk management. Serving as a foundational reference for analogous construction endeavours, this research advocates for a holistic risk management approach spanning the entire project lifecycle, from planning to execution.*

Keywords: *Disaster Risk Analysis, Dam Core Construction, Dam Kuwil Kawangkoan.*

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1. Introduction

The strategic geographical positioning of the North Sulawesi Province renders it pivotal for national development, given its status as the gateway to the Sulawesi Island and bolstered by governmental developmental policies aimed at advancing the Central and Eastern regions of Indonesia. Additionally, the province boasts substantial potential in terms of abundant natural resources (Paendong et al, 2023). The expansive watercourses within North Sulawesi, specifically the Tondano River and the Titkala River, give rise to various challenges, notably exemplified by flooding incidents within the Tondano watershed (Rumbayan & Rumbayan, 2023). Addressing current flood concerns is imperative for short-term mitigation, necessitating concurrent exploration of long-term solutions, with the construction of a dam emerging as a viable remedial measure (Rumbayan & Rumbayan, 2023). The Tondano watershed, among the largest in North Sulawesi, harbours significant potential as a substantial water resource (Salim, Wahyudi, Wibowo, & Siswanto, 2023). Excessive discharge in the rainy season, if not efficiently harnessed, poses challenges along the river course and contributes to flooding in Manado City. Conversely, minimal river discharge in the dry season results in aridity, causing water shortages for agriculture and plantations in the vicinity (Yuen et al.,2023). To address this circumstance, a proposed intervention involves the construction of a dam on the Tondano River to harness and regulate the surplus discharge originating from Lake Tondano, directed towards Manado City.The designated dam site is situated within the North Minahasa Regency, specifically in the village of Kuwil Kawangkoan, denoted as the Kuwil Kawangkoan Dam (Kukaw Dam) (Yuen et al, 2023).

The Kuwil Kawangkoan Dam is situated within the administrative jurisdiction of North Minahasa Regency, North Sulawesi Province, specifically in Kuwil Kawangkoan Village, Kalawat District. Positioned approximately 18 km from Manado City, it can be reached within a minimal travel time of 39 minutes. Additionally, the dam is approximately 16 km from the capital city of North Minahasa, accessible within a brief travel duration of 36 minutes (Lumi, Budiarto, & Kusnanto, 2022; Chaiyakot et al., 2022). The Kuwil Kawangkoan Dam is positioned approximately 34 km from Bitung City, reachable within a time frame of 46 minutes. The dam is endowed with district road accessibility, facilitated by the construction of an entrance road spanning +526m and an inspection road covering +498m, both designed with a width of 7 meters. Moreover, the district road traversing Kuwil Village has undergone expansion, augmenting its width by 7 meters over a stretch of +1800m. Beyond its primary objectives of flood control, power generation, and the provision of raw water, the construction of this dam also encompasses a strategic aim of fostering tourism development (Salim et al, 2023).

The implementation of the Kuwil Kawangkoan Dam has demonstrated overall efficacy in mitigating the repercussions offloods and landslides afflicting Manado City (Salim eta!., 2023). Nevertheless, in practice, this dam mitigates water discharge solely from one river among the five major rivers traversing the capital city of North Sulawesi (Lumi, Budiarto, & Kusnanto, 2022). This situation engenders susceptibility to flooding and the potential for landslides, constituting recurrent disaster risks that remain pivotal subjects of investigation (Sinayangsih, Nugroho, & Hadi, 2023; Mahidul et al., 2023). Disaster risk refers to potential losses resulting from a disaster within a specific timeframe. This risk can be mitigated by enhancing capacity or reducing vulnerability, conversely increasing when vulnerability is higher and capacity is lower (Wayangkau, 2021). Regarding disaster risk at the Kuwil Kawangkoan Dam, this study centres on potential disasters during the construction of the dam's core. Given the critical role of the core in containing water, its implementation is crucial, particularly considering its dependence on weather conditions, given the use of clay as the primary construction material (Salim et al, 2023; Ojeda, and Nisa, 2021). Hence, it is imperative to conduct a disaster risk analysis concerning the construction of the core of the Kuwil Kawangkoan Dam.

Wayangkau (2021) identified in their research that social environmental risks constitute the most prominent potential risk in dam construction projects, a trend consistent across various projects. The allocation of these risks to the government is attributed to the authority and policy-dependent nature of land acquisition reviews. Additionally, the categorization of risks into [illegible] and high pertains to impact rather than probability; the highest risk arises when the probability is low, but the impact is high. Therefore the importance of the government's use of information and communication technology (Sabrina et al, 2023; Akbar, 2022) to find out the potential risks that exist. Conversely, risks are deemed insignificant when probability is high and impact is low. Fatchiyati, Rahmawati, and Anggraini (2019) identified six dominant risk factors affecting time and costs in dam construction. These factors include challenges in the excavation process, damage to machinery and project equipment, design modifications to suit field conditions, material availability, unstable soil conditions, and unpredictable weather. The study also revealed 15 occupational groups with potential risks impacting the dam construction process, with three job variables carrying the highest risk. Mitigating efforts in concrete work avoidance can reduce potential cost losses by 87%, while implementing administrative and technical engineering in tunnel excavation work can prevent accidents and equipment damage. Additionally, dewatering work can minimize cost losses by up to 89%. Its modifications which can be an alternative solution to describe and analyze the model mathematically (Affandi et al, 2022; Giwanatara, and Hendrawan, 2021).

Considering the strategic role of the Kuwil Kawangkoan Dam in mitigating flood issues in Manado City, and in light of the extensive artificial dam construction involving the core, a study on disaster risk analysis is warranted. The research specifically concentrates on the disaster risk analysis during the implementation of the core construction of the Kuwil Kawangkoan Dam. The core of such a dam, constituting a sizable artificial structure, is typically composed of compacted semi plastic mounds of various soil, sand, clay, or rock compositions, featuring a semi-permeable waterproof surface cover and a resistant core to withstand erosion or seepage. Given the potential vulnerability to disaster risks in the core construction phase, this study is conducted in North Minahasa Regency, North Sulawesi Province. The research aims to identify the levels of disaster, vulnerability, and capacity during the core construction implementation of the Kuwil Kawangkoan Dam. Furthermore, the study analyses the level of disaster risk during the core construction of the Kuwil Kawangkoan Dam in North Minahasa Regency and provides recommendations for risk reduction efforts in the dam's implementation.

This comprehensive study on disaster risk assessment in the context of Kuwil Kawangkoan Dam construction holds significant theoretical and practical implications. Theoretically, it addresses the essential need for risk evaluations encompassing hazard identification, vulnerability analysis, and capacity assessment, aligning seamlessly with contemporary disaster risk management frameworks. By exploring the interplay between risks in construction projects and socio-environmental vulnerabilities, this research underscores the imperative for robust risk reduction strategies. The establishment of structured criteria for assessing threat levels contributes to a systematic understanding, guiding future risk assessment endeavours.

In practical terms, the study emphasizes the critical requirement for tailored risk reduction strategies in construction, particularly in dam infrastructure. The results and recommendations, aligned with threat levels, vulnerability, and capacity, provide a tangible roadmap for stakeholders to effectively mitigate identified risks. Implementing these findings could not only enhance the safety and efficiency of the Kuwil Kawangkoan Dam project but also serve as a model for similar ventures, advocating a comprehensive risk management approach from conception to execution, thereby bolstering project success and resilience against potential hazards. The research is organized into five chapters: literature review, research methodology, data analysis and discussion, implications, and conclusion.

2. Literature Review

2.1 Disaster Risk

According to (Vaughan, 2020), risk denotes the prospect of experiencing a loss. In this context, risk is commonly employed to signify a scenario characterized by the likelihood or possibility of encountering a loss. According to the United Nation Development Program (UNDP) (Subiyakto, 2020) a disaster is an extraordinary occurrence within the natural or human environment that detrimentally impacts human life, property, or activities to an extent that qualifies it as a disaster. In the context of this research, disaster risk is delineated as the likelihood of a disaster transpiring during the course of a construction project.

2.2 Dam

A dam is a hydraulic infrastructure erected across a river, designed to elevate the adjacent water level to a specific height This elevation facilitates the controlled diversion of river water through sluice gates into distributary channels, subsequently irrigating agricultural land (Djunarsjah, Julian, Alfandi, & Baskoro, 2021). The conceptualization of a dam can be approached from various perspectives, yielding distinct dam classifications. Primarily, a dam serves as a means to elevate and store water during the rainy season when river water volume surpasses the necessities for irrigation industrial processes, potable water supply, or other utilitarian purposes (Sani & Lotfi, 2009).

3. Methodology

3.1 Research Sites

This investigation was carried out within North Minahasa Regency, focusing specifically on the Kuwil Kawangkoan Dam. Situated in North Minahasa Regency, North Sulawesi Province, the dam is precisely located in Kuwil Kawangkoan ViUage within the Kalawat District

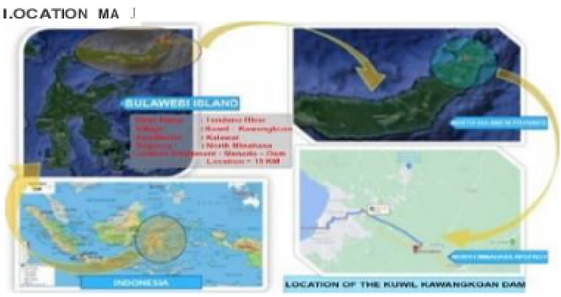

Figure 3.1 Research Location
Source: Sulawesi (2023)

The dam traverses the Tondano River downstream from the Tanggari II Hydroelectric Power Plant.

3.2 Population and Sample Determination Method

A population refers to a defined set of entities or subjects possessing specific qualities and characteristics as identified by researchers for study, from which conclusions are subsequently derived (Darmawan, Sugiyono, Liang,Tokimatsu, & Murata, 2017). The population under scrutiny in this research comprised both the community and affiliated agencies associated with the Kuwil-Kawangkoan Dam, totalling 42 individuals. The sample, drawn from this population, represents a subset reflecting the number and characteristics inherent in the larger group (Darmawan, Sugiyono, Liang,Tokimatsu, & Murata, 2017). The methodology employed for sample selection in this study adhered to the Slovin formula, resulting in the acquisition of a sample size comprising 30 individuals.

3.3 Data Types and Sources

This study utilizes both quantitative and qualitative data types, drawing from primary and secondary data sources. The data gathering process involves interviews, observations, and questionnaires, adapted from previous scholarly works (Kahwa, 2009; Kanyasan et al, 2018).

3.4 Data collection Technique

The methodologies employed for data collection in this study encompassed observation, interviews, literature review, documentation analysis, and the administration of questionnaires. According to (Zulfiani & Sugiyono, 2020), a questionnaire is a data collection technique that is carried out by giving a set of written statements to respondents to answer. The survey instrument in this research employs a modified Likert scale methodology, wherein respondents' answers are assigned scores on a 4-point scale, ranging from the highest score to the lowest score on a 1-point scale. The next stage was gathering information and studying the research literature to look for theories and related research to underlie this research (Daile et al, 2022). Prior to its utilization for data collection, the questionnaire underwent rigorous testing to establish both validity and reliability.

1) Validity Test

The validity assessment is employed to ascertain the appropriateness of a questionnaire. An instrument is deemed valid when it exhibits a correlation coefficient exceeding 0.30 and a significance level below 0.05 (Ahmad, Mohammad, & Nordin, 2019).

2) Reliability Test

Reliability testing is used to test the reliability of an instrument. A questionnaire is said to be reliable if it has a *Cronbach Alpha* (a) value> 0.70 (Bhatti & Kaur, 2010).

3.5 Data Analysis Technique

The analytical approach employed in this study involves the application of disaster risk analysis utilizing the formula:

R = HxV/C

Where?

R : Disaster Risk
H : *Hazard* or danger
V : Vulnerability
C : Capacity (ability)

The disaster risk level in the Kuwil Kawangkoan Dam core construction project results from the amalgamation of vulnerability and capacity levels, determined through the matrix in Table 3.1.

Table 3.1 Determination of Disaster Risk Level.

Risk Level		Capacity Level		
		High	....	Low
Level of Vulnerability	Low			
	High			

Source: Head of BNPB Regulation Number 2 of 2012.

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Low Rhlk Level
Moderute Rlxk Level
Hl!.h Hlsk L~v~l

4. Results and Discussion

4.1 Respondent Characteristics

Respondent characteristics denote the identities of those engaged in this research. Participants involved in the core construction of the Kuwil Kawangkoan Dam project exhibited diverse characteristics while completing the questionnaire, as detailed in Table 4.1. The descriptive findings reveal a predominantly male composition (90%), with a notable minority of female participants (10%). In terms of age, an even distribution is observed, with 50% falling within the 30-40 age bracket, indicating varied experience levels among participants. Regarding positions, the majority (60%) consists of project implementers, followed by 23% from government agencies and 17% serving as project supervisors, implying diverse stakeholder involvement. Educationally, a varied profile is evident, with 33% holding diplomas and 20% possessing a high school education, reflecting diverse educational backgrounds among project participants. The detailed results are presented in Table 4.1.

Table4.1: Respondents Characteristics.

No		Numbers	Percentage
Gender	Male	27	90%
	Woman	3	10%
Age	21-29 years old	8	27%
	30-40 years old	15	50%
	>40 years old	7	23%
Position	Project Implementers	18	60%
	Project Supervisor	5	17%
	Government agencies	7	23%
	High School	6	20%
	Diploma	10	33%

Education		
Bachelor	14	47%

Source: Processed Primary Data (2023)

4.2 Identification of the Hazard Level (H) in the Kuwil Kawangkoan Dam Core Construction Implementation Project

Based on observations, interviews, and prior research, potential disaster risks during the core construction of the Kuwil Kawangkoan Dam are outlined in Table 4.2. These encompass challenges such as unstable soil conditions impacting artificial slopes, discrepancies in excavated dimensions causing construction delays, and heightened rainfall leading to design alterations and material damage. Moreover, the complications arising from excavation in clay soil and the potential equipment damage due to unstable soil conditions underscore the intricacies in efficiently executing the dam project. These identified hazards underscore the necessity for robust mitigation strategies, emphasizing soil stability, precise construction planning, and resilience against weather-related risks to ensure the project's successful implementation, as detailed in Table 4.2.

Table 4.2 Identification of Hazard Levels.

No	Risk Factors	Failure Mode
1	Difficulty in carrying out excavation or dredging.	The core of the Kuwil Kawangkoan Dam is made of clay so that when there is high rainfall it will make the soil difficult for dredging or excavation which makes it difficult to carry out the project.
2	Damage to machine tools and project equipment.	Excessive use of machine capacity and project equipment in projecting soil conditions can cause damage which can ultimately cause dam core construction to be hampered.
3	Erratic rainfall can cause material damage	Rainfall in North Minahasa Regency is very high so that when materials are continuously rained on, they will experience damage.
4	Unstable ground conditions.	When the soil condition is unstable, the condition of the artificial slope will also be unstable, giving rise to the possibility of creating new slopes or embankments which will make project implementation inefficient.
5	Inconsistency in the dimensions excavated in terms of length, width and depth according to the type of foundation that has been determined.	When the dimensions excavated do not match the foundation that has been determined, the construction implementation must re-determine the appropriate dimensions to be excavated so that the construction will take longer.
6	Construction or design changed due to high rainfall.	High rainfall can cause landslides at the weir core construction site so that the construction or design must be replaced.
7	Differences in basic soil conditions.	The core of the weir is made with clay so that when there are differences in the conditions of the base soil, it will create a vulnerability to damage to the heavy equipment used that is not suitable for the soil conditions.

Source: Processed Primary Data (2023)

Concerning the threat level associated with the identified risks in the construction of the Kuwil Kawangkoan Dam, an evaluation ensued through the distribution of questionnaires to the 30 respondents engaged in this study. To gauge the threat level according to respondents' perceptions, frequency is ascertained using interval values to categorize the threat level as low, medium, or high. The computation of the interval value is determined using the following formula.

$$\text{Interval} = \frac{\textit{(The highest score-lowest score)}}{\textit{Number of classes}} = \frac{(4-1)}{3} = 1$$

Utilizing the established intervals, criteria and categories for assessing respondents' responses can be formulated, as outlined in Table 4.3.

Table 4.3 Criteria and Categories for Evaluation of Respondents Answers.

Criteria	Threat level Categoly
1.00-1.99	Low (L)
2.00-2.99	Medium (M)
3.00-4.00	Hi h

Source: Processed data (2023)

Following the criteria and categories presented in Table 4.3 for assessing respondents' responses, the description of response data in this study is as follows. The data collected on threat levels, illustrated in Table 4.4 for the Kuwil Kawangkoan Dam Core Construction Implementation Project, highlights several critical challenges. High-threat indicators, such as difficulties in excavation or dredging due to unpredictable weather and construction/design changes resulting from intense rainfall, align with existing studies emphasizing the susceptibility of dam construction to weather fluctuations (Zheng et al, 2023). The instability of ground conditions and discrepancies in excavated dimensions underscore the risks related to foundation stability, echoing concerns articulated in geotechnical studies focusing on dam projects (Zheng et al, 2023). Furthermore, the importance of varying soil conditions and their implications for construction aligns with scholarly research emphasizing the necessity for thorough site investigations to mitigate risks in dam construction (Chen, Zhu, & Hammad, 2020). The moderate threat levels, specifically relating to machine tool damage and inconsistencies in dimensions, mirror apprehensions regarding equipment maintenance and precision in construction, topics underscored in research on construction project management and quality control (McGuire, Okuno, Gould, & Lake, 2017). These results underscore the challenges encountered in the Kuwil Kawangkoan Dam project, necessitating a holistic approach that integrates thorough site investigations, construction methods resilient to weather variations, and rigorous quality control measures for effective risk mitigation. The detailed findings are presented in Table 4.4.

Table 4.4 Respondents' Answer Scores Regarding Threat Level.

Threat Level Indicators	Responses 1	2	3	4	Score	Average	Category
Difficulty in carrying out excavation or dredging ..	0	5	8	17	10.2	3.40	High
Damage to machine tools and project equipment.	2	12	9	7	81	2.70	Medium
Erratic weather where the curve location of the weir has erratic rainfall which can fusel material damage.	0	1	10	19	108	3.60	High
Unstable ground condition.	4	14	2	10	78	2.60	
Inconsistency in the dimensions excavated in terms of length, width and depth according to the type of foundation that has been determined.	0	16	5	9	83	2.77	Medium
Construction or design changed due to high rainfall.							
Differences in basic sol conditions.	0	6	9	13	100	3.33	High

Source: Analysis Results (2023)

4.3 Identification of the Level of Vulnerability (V) in the Kuwil Kawangkoan Dam Core Construction Implementation Project

Vulnerability refers to a societal condition that renders an incapacity to confront the threat of disaster. The identified vulnerability factors in the construction of the Kuwil Kawangkoan Dam are presented in Table 4.5, comprising seven factors. Data on these factors were collected from respondents, and the results are detailed in Table 4.5. Analysis of the table reveals that five vulnerability indicators, namely V1, V2, V4, VS, and V7, are categorized as high. Additionally, two indicators, V3 and V6, are assessed by respondents as having a vulnerability level in the medium category. Study on dam related vulnerabilities Ghasempour, Aalami, Kirca, and Roushangar (2023) emphasize the heightened risk to communities residing downstream in cases of dam malfunction or breakage, aligning with concerns about the vulnerability of local residences and the potential for flash flood disasters. Furthermore, the proximity of residences to the dam site and the vulnerability of adjacent lands to flooding underscore the imminent threat confronting communities and infrastructure (Mutikanga et al, 2022). The interconnectedness of the dam, Tondano River, and the lake underscores research findings that emphasize heightened flood susceptibility in areas connected to dams during episodes of intense rainfall (Barga et al, 2014). Nevertheless, the moderate vulnerability level pertaining to the protected forest and the existence of critical regional facilities underscores the significance of implementing mitigative measures to protect these areas. These findings collectively underscore the pressing necessity for holistic risk mitigation strategies, community preparedness initiatives, and resilient infrastructure planning to address potential socio-environmental vulnerabilities linked to the construction and operation of the Kuwil Kawangkoan Dam.

Table 4.5 Rese.ondents Answer Scores Re9.ardin9. Level o[Vulnerabilit]:

Vulnerability Level Indicator	Response Freguence[:				Score		egor
	1	2	3	4			
Residents resideces buildings, school buildings and other facilities are vulnerable to the impact of the kuwail kawangkoan dam not fuctioning property.	3	3	11	14	96	3.30	High
Rainfall is high in the North Sulawesi area so that she river water volume is higher and if the dam is not functioning property it will cause a flood disaster.	2	0	15	13	99	3.30	High
Many of houses of local residents are located near the kuwail Kawangkoan Dam location so that when a flash flood occures due to the dam breaking, residents will be vulnerability to the risk of flash flood damage.	7	5	11	7	78	2.60	High
There is a lot of products lands that is vulnerabile to the risk of flooding.	1	6	11	12	94	3.13	High
There is a critical regional facilities with roads that are in good conditions.	0	5	12	13	98	3.27	High
There is a protected forest in the dam area.	11	1	8	10	77	2.57	Medium
The Kuwail Kawangkoan Dam is connected to the Tondano river and lake so that during extreme rainfall it is erone to flooding.	0	1	16	13	102	3.40	High

Source: Primary data processed (2023)

4.4 Identification of Capacity Levels (C) in the Kuwil Kawangkoan Dam Core Construction Implementation Project

Capacity or capability encompasses the resources, methods, and strengths inherent in society that empower it to defend, prepare, prevent, overcome, reduce, and swiftly recover from the repercussions of disasters. Community capacity manifests in both physical and non-physical (social) components. The identified capacity factors in the Kuwil Kawangkoan Dam construction project are detailed in Table 4.6. The anticipated results indicate that respondents' assessments relate to the level of disaster capacity in the Kuwil Kawangkoan Dam construction project. Specifically, two indicators of disaster capacity, namely C3 and CS, fall within the high category. Additionally, three capacity level indicators, namely CZ, C4, and C6, are evaluated by respondents as having a capacity level in the medium category. Meanwhile, capacity level indicators Cl and C7 fall within the scores indicated. Notably, high scores in indicators such as the engagement of disaster management volunteers in capacity-building activities and the presence of legalized disaster risk reduction policies signify robust initiatives toward preparedness, aligning with the findings of (Aronsson-Storrier, 2021). However, of concern are the diminished scores pertaining to disaster management groups and systematic endeavours aimed at enhancing preparedness and response capacity (Aitsi-Selmi et al, 2015). Intermediate scores for evacuation routes, planning documents, and active disaster reduction forums indicate a moderate state of readiness but underscore specific areas necessitating additional focus. This aligns with existing studies emphasizing the imperative for comprehensive disaster management frameworks that involve community engagement and systematic capacity-building measures (Paton & Johnston, 2017). To enhance the overall disaster resilience of the Kuwil Kawangkoan Dam project, there is a requirement for heightened emphasis on fortifying disaster management groups, augmenting systematic initiatives for preparedness, and ensuring extensive community involvement to strengthen the project against potential hazards.

Table 4.6 Respondents Answer Scores Regarding Capacity Levels.

Capacity Level Indicator	Response 1	2	3	4	Score	Average	Category
There is a disaster management group in the Kuwil Kawangkoan *Dam* area.	11	disaster preparedness and response 10 ca aci					
There are disaster evacuation routs and disaster response posts.	1						
There is a team of disaster management volunteers who are routinesly activity involved in capacity building, knowledge and disaster edcation activities for their member and the community in general.	0						
There is a disaster risk reduction policy that has been regalized in the form of legal regulations.	0						
There are planning documents for disaster risk rudction policy that has been leglized in the form of legal regulations.	10						
There is a disaster reduction forum consisting of community reprensentitives, including womens group, vulnerable group, and village that functions actively.	0						
There are systematice efforts to increase							

Source: Primary data processed (2023)

11	8	0	57	1.90	Low
9	18	2	81	2.70	Medium
6	18	6	90	3.00	High
9	10	11	92	3.07	high
12	8	0	58	2.90	Medium
11	11	8	87	2.90	Medium
12	8	0	58	1.93	Low

4.5 **Disaster Risk Level in the Kuwil Kawangkoan Dam Construction Project**

The disaster risk assessment within the Kuwil Kawangkoan Dam construction project identified three distinct risk categories. The high-risk group emerges when vulnerability to potential risks is medium to high, yet capacity remains low to moderate, indicating inadequate preparedness to address potential disasters. Factors contributing to this high risk include the clay composition of the dam core leading to challenges in excavation during heavy rainfall, potential equipment damage due to excessive machine use, instability in artificial slopes impacting project efficiency, and the vulnerability of heavy equipment to unsuitable soil conditions. Medium risk arises when vulnerability is low with low capacity or vulnerability is medium with moderate capacity. This risk level encompasses issues like inconsistencies in excavated dimensions causing construction delays and design alterations due to high rainfall• induced landslides. Lastly, the low risk is associated with low vulnerability and medium to high capacity, such as the risk of erratic weather causing material damage due to continuous rainfall in the North Minahasa Regency. Studies by disaster management experts (Fahad & Wang, 2020; Paton & Johnston, 2017) underscore the significance of evaluating vulnerability and capacity as integral components in determining disaster risk, in accordance with the findings that demonstrate the interplay between vulnerability, capacity, and risk levels in the dam construction project. The aforementioned outcomes are anticipated in the forthcoming Table 47.

Table 4.7 Level o[Disaster Risk in the Kuwil Kawan9.koan Dam Core Construction Project.

Risk	Indicator		Category		Risk Level
	Vulnerability	Capacity	Vulnerability	Capacity	
Difficulty In carrying out excavation or dredging.	Vt	C1	High	Low	High
Damage to machine tools and project equipment.	V2	C2	High	Medium	High
Erratic weather where the core location of the weir has erratic material damage.	V3	C3	Medium	High	Low
Unstable ground conditions.	V4	C4	High	Medium	High
Inconsistency In the dimensions excavated In terms of length, width and depth according to type of foundation that has been determined.	VS	CS	High	High	Medium
Construction or design changed due to high rainfall.	V6	C6	Medium	Medium	Medium
Differences in the basic soil condition.	V7	C7	High	Low	High

Source: Primary data processed (2023)

4.6 **Disaster Risk Reduction Efforts for the core construction implantations in Kuwil Kawangkoan Dam**

Disaster risk reduction initiatives encompass minimizing regional threats, reducing vulnerability in threatened areas, and enhancing the capacity of those areas.

Regarding efforts to diminish disaster risk in the Kuwil Kawangkoan dam construction project, several recommendations for risk reduction or mitigation measures are outlined in Table 4.8. For high-risk scenarios like challenges in excavation due to clay soil and potential equipment damage, the suggested actions involve replacing heavy equipment in accordance with soil conditions and optimizing machinery usage. Unstable ground conditions and inconsistencies in excavated dimensions, categorized as high and medium risks, respectively, call for interventions such as reinforcing slopes and implementing improved risk management strategies to ensure appropriate excavation dimensions, with the aim of mitigating construction delays. Moderate risks, such as construction or design changes due to high rainfall, suggest rectifying damaged designs and adjusting heavy equipment in alignment with changing ground conditions. Low-risk factors, like erratic weather causing material damage, advocate proactive construction management strategies focused on weather prediction and project planning to anticipate and counter rain-induced material damage. These recommendations are in accordance with studies on risk reduction (Aitsi-Selmi et al, 2016; Paul et al, 2018) that underscore the importance of adaptive strategies, equipment adjustments, and robust risk management to minimize vulnerabilities and mitigate potential disruptions in construction projects. The anticipated outcomes of the aforementioned recommendations are detailed in the forthcoming Table 4.8.

Table 4.8 Risk Reduction Efforts.

No.1	Risk	P[iori!}'.	Proposed Action
1	Difficulty in carrying out excavation or dredging.	High	Replace heavy equipment for excavation or dredging according to the condition of the soil being excavated
2	Damage to machine tools and project equipment.	High	Replace machine tools and project equipment accord lng to needs.
3	Erratic weather where the area where the core of the weir is located has erratic rainfall which can cause material damage.	Low	Carry out construction management by predicting the weather and planning the project appropriately so that you can anticipate the possibility of material damage due to rain.
4	Unstable ground conditions	High	Unstable soil conditions determine the stability of the dam slop, so slope strengthening is needed in the form of additional structure to stabilize the slope.
5	Inconsistency in the dimensions excavated in length, width and depth according to type of foundation that has been determined.	Medium	Carrying out risk management in determining the suitability of the dimensions excavated based on the type of foundations.
6	Construction or design changed due to high rainfall.	Medium	Repair or design construction that was damaged due to rainfall.
7	Differences in the basic soil conditions.	High	The core of weir is made with clay condition of the basic soil, it will create a vulnerability to damage the heavy equipment used that is not suitable for the soil conditions. Therefore, it is necessary to replace heavy equipment according to ground conditions.

Source: Primary data processed (2023)

5. Implications and future Directions

The study yields various theoretical and practical implications based on the assessment of the Kuwil Kawangkoan Dam construction. Theoretically, the study underscores the importance of comprehensive risk assessments that integrate multiple dimensions, including hazard identification, vulnerability analysis, and capacity evaluation. This approach aligns with contemporary disaster risk management frameworks, emphasizing the significance of comprehending not only the hazards present but also the vulnerabilities within the socio-environmental context and the capacity to effectively mitigate these risks. The study's detailed evaluation of hazards, such as unstable ground conditions, erratic weather impact, and equipment vulnerability, contributes to the theoretical understanding of how complex risks in construction projects intertwine with socio-environmental vulnerabilities, necessitating a robust risk reduction strategy. Moreover, the establishment of criteria and categories for evaluating respondents' answers provides a structured method for assessing threat levels, enabling a systematic understanding of perceived risks that can guide future risk assessment endeavours.

Practically, the implications emphasize the critical need for tailored and adaptive risk reduction strategies in construction projects, especially in dam infrastructure. The recommendations for risk reduction efforts, aligned with findings on threat levels, vulnerability, and capacity, offer actionable insights for project stakeholders. Prioritizing high-risk scenarios, such as soil instability and equipment vulnerability, and providing specific actions like equipment replacement and strengthened slope structures, the study offers tangible steps to mitigate identified risks. Moreover, the identification of medium and low-risk areas, along with corresponding mitigation strategies, empowers project managers to allocate resources and prioritize efforts effectively. This practical guidance aligns with contemporary project management paradigms that stress proactive risk management and adaptive strategies to ensure project success. Implementing these findings would not only enhance the safety and efficiency of the Kuwil Kawangkoan Dam project but also serve as a blueprint for similar construction ventures, highlighting the necessity of a comprehensive risk management approach from inception to execution.

The study has several limitations that could be addressed in future research to enhance generalizability. Firstly, the reliance on a relatively small sample size may limit the generalizability of findings to broader contexts. Future directions could involve expanding the scope of data collection to include a more diverse set of respondents or employing additional methodologies to validate and strengthen the conclusions drawn. Secondly, conducting longitudinal studies to track the implementation of recommended risk reduction measures over time could provide insights into their effectiveness and the adaptability of strategies in real-world scenarios. Integrating more robust predictive models or simulations might enhance the accuracy of risk assessments and facilitate proactive risk management for similar construction projects.

6. Conclusion

This study focuses on conducting a disaster risk analysis during the core construction of the Kuwil Kawangkoan Dam. The population comprises the community and related agencies at the dam, totalling 42 individuals, with a sample of 30 determined using the Slovin formula. The analysis reveals challenges ranging from high-risk factors like excavation difficulties and potential equipment damage to medium and low risks such as inconsistencies in excavation dimensions and weather-induced material damage. Identified vulnerabilities, particularly local residences and critical facilities prone to flooding, underscore the necessity for robust risk reduction measures. Additionally, varying capacity levels within the project, indicating strengths in disaster management policies but weaknesses in systematic preparedness efforts, warrant a more integrated approach. The assessment calls for targeted actions, such as adapting equipment to soil conditions, reinforcing slopes, and proactive construction management, to mitigate vulnerabilities. Overall, a comprehensive approach incorporating adaptive strategies, effective risk management, and community engagement is imperative to enhance the resilience of the Kuwil Kawangkoan Dam project against potential hazards and ensure its successful implementation.

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