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Prioritization Of Mitigation and Flood Risk Reduction Efforts In Kota Singkawang

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ABSTRACT

Floods present significant challenges to urban areas globally, including Kota Singkawang in West Kalimantan, Indonesia, due to its susceptibility to seasonal monsoons. Mitigation efforts are crucial to protect lives, infrastructure, and sustainable development amidst urbanization and climate change. This research delves into flood risk reduction methods by integrating technical, economic, social, and environmental dimensions to aid policymakers and stakeholders in efficient resource allocation.

This study aims to enhance flood resilience by identifying critical intervention areas through structured approaches, leveraging literature reviews, field surveys, and consultations with local authorities and communities. Prioritizing flood risk mitigation involves evaluating existing strategies and implementing structural measures like flood control buildings.

The analysis findings indicate that the primary focus for mitigation efforts and flood risk reduction in Kota Singkawang should involve structural measures, specifically implementing flood control structures like polder systems and retention ponds to effectively address sea tides and heavy rainfall impacts. However, given the preliminary nature of this study, a more thorough investigation with comprehensive data is necessary to implement these structural technologies fully. This comprehensive analysis underscores the significance of comprehending flood risk complexities to formulate sustainable urban strategies in Kota Singkawang.

Keywords: *Flood risk, Urban challenges, Mitigation efforts, Flood resilience, Kota Singkawang*

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1. Introduction

All regions within Kalimantan Barat are generally susceptible to flooding, characterized by varying inundation extents (Soeryamassoeka et al., 2018). Floods fundamentally reflect natural phenomena and accelerated damage to the earth's surface due to human activities, increasing susceptibility to flooding in specific areas (Wei et al., 2022; Alfaro et al., 2023). Presently, flooding in Kalimantan Barat is not confined solely to coastal and urban locales but also affects rural areas inland and upstream. Locations previously unaffected by flooding have become flood-prone zones, a trend.

observed since 2002 (Wendika et al., 2012; Razi et al., 2023). Flooding in Kalimantan Barat indicates environmental degradation within the upstream regions of rivers (Akafi et al., 2023; Miranda et al., 2023)), exemplified by occurrences in Singkawang, an administrative district within Kalimantan Barat (Nathaniel et al., 2023; Razi et al., 2023).

Naturally, flooding in Singkawang is caused by heavy rainfall, high tides, and a combination of both. The poor drainage system in Kota Singkawang due to rapid urban expansion worsens flooding (Nathaniel et al., 2023; Razi et al., 2023). These challenges underscore the critical need to prioritize practical flood risk reduction efforts. This research explores and analyzes methods and considerations for prioritizing flood risk reduction efforts in Singkawang.

Prioritizing mitigation and flood risk reduction involves multifaceted decision-making processes integrating technical, economic, social, and environmental dimensions (Abbas et al., 2016; Whelchel et al., 2018; da Silva et al., 2020; Maskrey et al., 2022). By identifying and prioritizing critical areas for intervention, policymakers and stakeholders can allocate resources efficiently to maximize flood resilience and minimize vulnerability (Meng et al., 2020; Percival et al., 2020). This research investigates existing flood risk management strategies in Kota Singkawang, evaluates their effectiveness, and proposes a structured approach to prioritize future mitigation efforts. Through a comprehensive review of literature, field surveys, and consultations with local authorities and community members, this research aims to provide valuable insights and recommendations to enhance flood resilience in Kota Singkawang.

Understanding the complexities of flood risk prioritization is crucial for developing targeted and sustainable flood risk reduction strategies (Berndtsson et al., 2019). By assessing and prioritizing mitigation efforts, this research seeks to contribute to developing informed policies and practices that enhance flood resilience and promote the long-term sustainability of Kota Singkawang 's urban environment.

2. Materials and Methods

2.1. Research Location

This research focuses on Kota Singkawang, located in West Kalimantan, Indonesia. Singkawang is prone to flooding due to the influence of high tides and rainfall. The study area covers urban and peri-urban areas affected by flood risk, covering a range of socio-economic and environmental conditions.

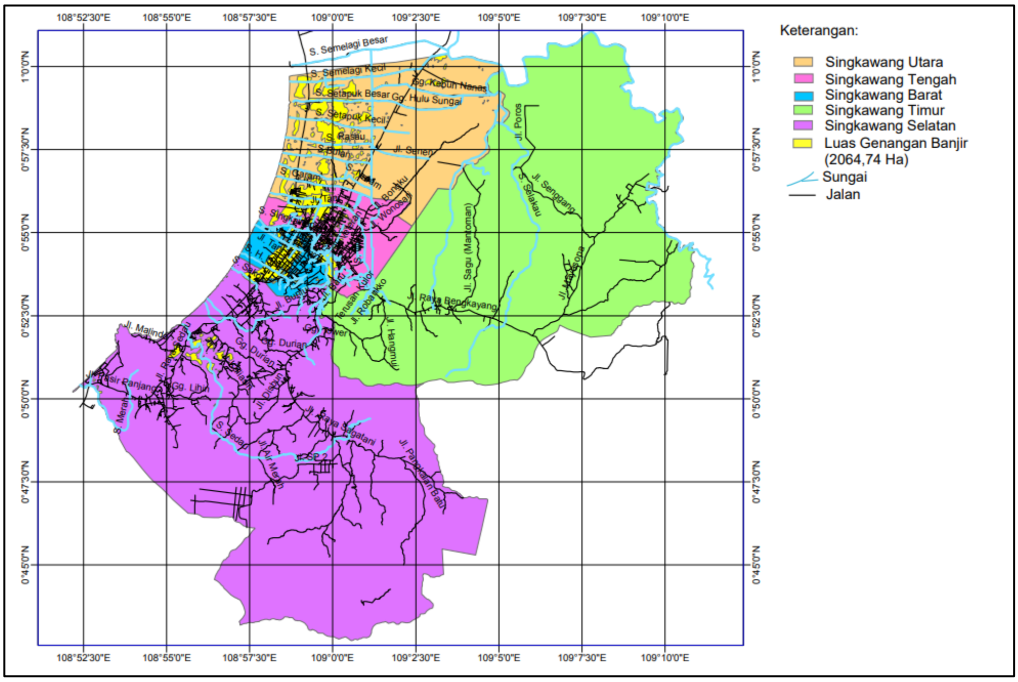

Fig 1. Kota Singkawang Map of Flood Inundation Area based on information from the Office of Public Works and Housing Water Resources Division Kota Singkawang

Based on the results of the institutional survey, it can be seen that the flood-prone areas in Kota Singkawang are (a) Singkawang Utara District, the affected villages are Sungai Garam, Setapuk Kecil, Setapuk Besar, Semelagi Kecil, Sungai Bulan, Naram, and Sungai Rasau; (b) Singkawang Barat District, the affected villages are Tengah, Melayu, Pasiran, and Kuala; (c) Singkawang Tengah District the affected villages are Bukit Batu, Condong, Sekip Lama, Roban, Sei Wie, and Jawa; (d) Singkawang Selatan District, the affected villages are Sedau, Sijangkung, and Sagatani; (d) Singkawang Timur, the affected villages are Pajintan, Sanggau Kulor, Bagak Sahwa, and Mayasopa. In addition, the river zone of Kota Singkawang was also obtained, which includes the following rivers: Semelagi Kecil, Setapuk Besar, Setapuk Kecil, Rasau, Bulan, Garam, Nangka, Wie, Singkawang, Pasiran, Kaliasin, Sedau, Merah, and Selakau.

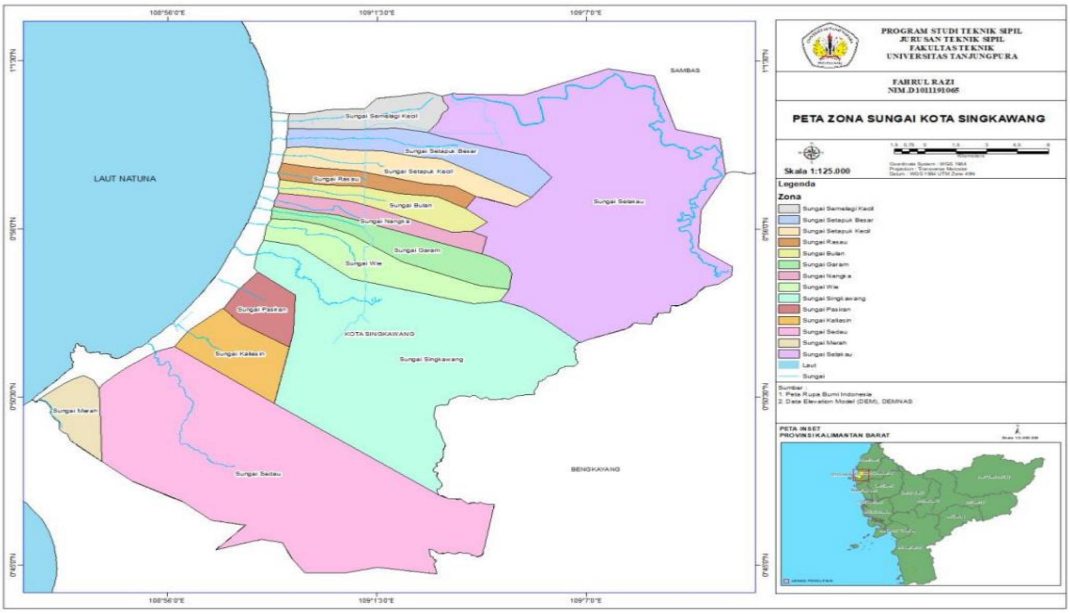

Fig 2. Kota Singkawang River Zone (Razi et al., 2023)

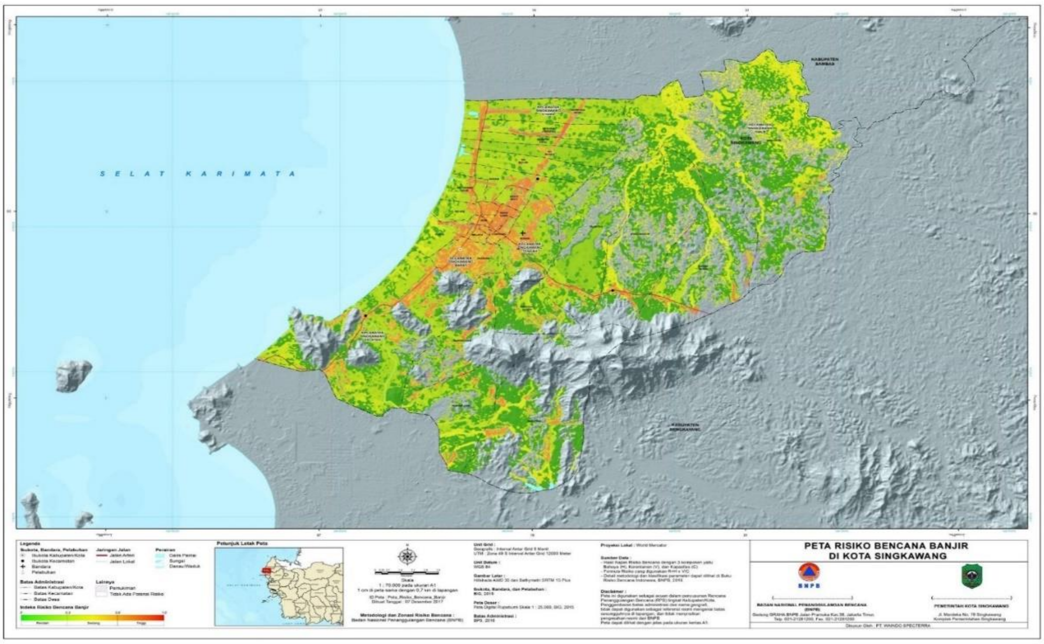

Fig 3. Kota Singkawang Flood Disaster Risk Map Based on Kota Singkawang Disaster Management Authority, 2023

2.2. Data

In this study, the data used were Focus Group Discussions (FGDs) attended by stakeholders involved in flood control in Kota Singkawang. Interviews and questionnaires were conducted to re-verify the input results obtained during the FGD. This activity was carried out on Wednesday, June 21, 2023, at the Office of Public Works and Housing Kota Singkawang (PUPR).

When conducting FGDs, the participants were explained what mitigation had previously been determined based on locations often affected by flooding in Singkawang City based on cases. After that, the participants adjusted it to the conditions in the field.

Fig 4. Documentation during the Focus Group Discussions (FGDs), 21 June 2023

2.3. Analysis Method

The analysis used the Analytic Hierarchy Process (AHP) method to prioritize flood risk mitigation and reduction efforts in Singkawang City. AHP is a model of approaching complex unstructured conditions into parts or variables in a hierarchical arrangement, then assigning numerical values to repressive assessments of the relative importance of each variable and synthesizing assessments for which variables have the highest priority that will affect the resolution of the condition (Brunelli, 2014; Jayant & Dhillon, 2015).

Dr. Thomas L. Saaty, a mathematician at the University of Pittsburgh in the 1970s, developed AHP. Using AHP, a problem is solved in an organized framework so that it can be expressed to make effective decisions (Saaty, 2004). The Analytic Hierarchy Process (AHP) is a mathematical method for multi-criteria decision-making, particularly useful in complex problems with hierarchical structures of criteria, sub-criteria, and alternatives. Researchers gather input data through pairwise comparisons to determine the importance of decision criteria and evaluate alternative performance against each criterion (Darko et al., 2019). AHP involves classifying problem factors into a structured hierarchical arrangement, providing a systematic approach to solving complex problems. This method is recognized for its effectiveness in decision-making, offering a mathematical system for weighting criteria and assessing alternatives based on specified criteria (Moslem et al., 2023).

According to Saaty, there are three main principles in problem-solving in AHP: decomposition, Comparative Judgment, and Logical Consistency (Aulady et al., 2023). In outline, the AHP procedure includes the following stages: (a) Problem decomposition, which is a step where a goal that has been set is then systematically decomposed into structures that compose a series of systems so that the goal can be achieved rationally. In other words, an intact goal is decomposed (solved) into its constituent elements. (b) Assessment/weighting aims to compare elements If the decomposition process has been completed and the hierarchy is well organized. Next, a pairwise comparison assessment (weighting) is carried out on each hierarchy based on relative importance.

Table 1. Rating Scale in Decision Support System with AHP

Level of Importance	Definition	Interpretation
1	Equally preferred	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly favour one activity over another
5	Strongly	Experience and judgment strongly or essentially favour one activity over another
7	Very strongly	An activity is strongly favoured over another and its dominance demonstrated in practice
9	Extremely	The evidence favouring one activity over another is of the highest degree possible for affirmation
2, 4, 6, 8, ...	Intermediate values	Used to represent a compromise between preferences listed above

(c) Matrix compilation and consistency test is done if the weighting process or filling out the questionnaire has been completed; the next step is the preparation of a pairwise matrix to normalize the weight of the level of importance of each element in its respective hierarchy. At this stage, the analysis can be done manually or using a computer program such as Expert Choice. (d) Pairwise comparisons determine priorities for each criterion and alternative in each hierarchy. The relative comparison values are then processed to determine the ranking of alternatives from all alternatives. Qualitative and quantitative criteria can be compared to predetermined assessments to produce weights and priorities. Weights or priorities are calculated by matrix manipulation or through solving mathematical equations. (e) Synthesis of priorities: The synthesis of priorities is obtained by multiplying the local priority with the priority of the relevant criteria at the upper level and adding it to each element in the level affected by the criteria. The result is a combination, better known as a global priority, which can then be used to weight the local priorities of the elements at the lowest level in the hierarchy according to the criteria. (f) Decision-making: Decision-making is a process in which the best alternative is chosen based on the criteria.

The FGDs results determined that four criteria were established to prioritize flood risk mitigation and reduction efforts in Kota Singkawang: technical, environmental, socio-economic, legal, and institutional. The alternatives are flood control buildings, erosion and sedimentation control, early warning systems, flood area zoning, strengthening regulations, and socialization programs for the community.

Therefore, the completion chart consists of a goal (Priority flood risk mitigation and reduction efforts in Kota Singkawang) and criteria, namely technical, environmental, socio-economic, legal, and institutional alternatives, namely flood control buildings, erosion and sedimentation control, early warning systems, flood area zoning, strengthening regulations, and community outreach programs.

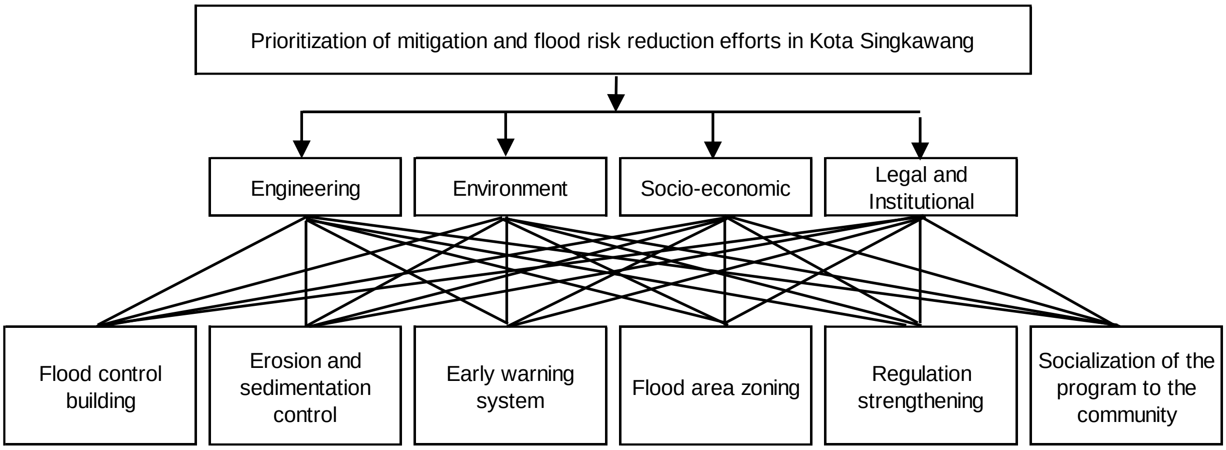

Fig 5. Hierarchy to Determine Prioritization of Mitigation and Flood Risk Reduction Efforts in Kota Singkawang

In AHP, the decision maker is asked to provide relative comparison values between the elements being compared, such as criteria or alternatives, and construct paired comparison matrix A with a reference such as Table 1 (Qi & Zhou, 2020).

$A = (a_{ij})$, $a_{ij} > 0$, $a_{ij} = \frac{1}{a_{ji}}$, $a_{ii} = 1$..........(1)

The formula utilizes a_{ij}, representing the importance ratio between indicators, quantified based on the comparison scale of indicator factors. Table 1 illustrates the quantitative comparison table for indicator factors.

The pairwise comparison matrix A provides the relative weight comparisons between the indices but does not directly determine the specific weight of each index. A single ordering of the indices is arranged to calculate the weight vector of each index in the first-level index layer without considering the influence of other indices. The weight vector for each index is then calculated using the geometric mean of each row element in the pairwise comparison matrix, following the formula below:

$$W_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}} ; i, j = 1, 2, \cdots, n \qquad (2)$$

$W = [W_1, W_2, \ldots, W_n]$..........(3)

Vector W is normalized;

$$w_i = W_i \left(\sum_{i=1}^{n} W_i\right)^{-1} \qquad (4)$$

The weight is determined as follows:

$w = (w_1, w_2, \ldots, w_n)$..........(5)

After all pairwise comparisons have been made, a comparison matrix is created. Consistency ratio (CR) checks the extent to which pairwise comparisons are consistent. A low CR indicates that the pairwise comparisons are relatively consistent, while a high CR indicates significant inconsistencies.

Consistency ratio (CR) is a measure used in the AHP to evaluate the consistency of the results of pairwise comparisons performed on a comparison matrix. Pairwise comparison is a stage where the decision maker compares one set of criteria or alternatives with another to assess their relative importance. The consistency ratio (CR) assists decision-makers in evaluating the quality of pairwise comparisons. Consistent comparisons are essential to ensure the accuracy and reliability of the results from the AHP process, which ultimately supports better and more informed decision-making. The steps to calculate the consistency ratio (CR) are as follows:

a. Calculate the comparison matrix's eigenvalue (λ_{max}). This eigenvalue shows the relative priority of the compared criteria or alternatives.
b. Calculate the Consistency Index (CI) with the formula:

$$CI = \frac{\lambda_{Max} - N}{N-1} \quad (6)$$

$$CR = \frac{CI}{RI} \quad (7)$$

CI : Consistency Index
λ_{Max} : Comparison matrix's eigenvalue
N : Number of criteria or alternatives being compared
CR Consistency Ratio
RI The Random Index is a consistency value determined based on the number of criteria or alternatives being compared. The RI value is determined from Table 2.

Table 2. The value of the Random Consistency Index

N	1	2	3	4	5	6	7	8	9	10	11	…
R I	0	0	0,5799	0,8921	1,1159	1,2358	1,3322	1,3952	1,4537	1,4882	1,5100	…

If CR < 0,1, then the judgment matrix is considered to meet the consistency test requirements; If CR > 0,1, then the judgment matrix is considered not to meet the consistency test standards and needs to be modified.

3. Result and Discussion

In the Analytic Hierarchy Process (AHP), each criterion within the decision hierarchy is assigned a weight representing its relative importance or contribution to the overall decision-making process. These weights are derived from pairwise comparisons made by decision-makers to assess the relative significance of criteria to each other. The weight of each criterion is calculated based on the consistency of these pairwise comparisons.

The Analytic Hierarchy Process (AHP) is a structured technique for complex decision-making. It involves breaking down a problem into its constituent parts, organizing them into a hierarchical structure, and then evaluating the parts relative to each other using pairwise comparisons.

Experts (Participants of FGDs) compare each criterion in the hierarchy with every other criterion using a predefined scale (1 to 9, as presented in Table 1) to express how vital one criterion is compared to another. This comparison is captured in a pairwise comparison matrix. The results of the assessment carried out by the expert are then calculated as geometric mean with the equation;

$$G = \sqrt[n]{X_1 . X_2 . X_3 \dots \dots . X_n} \quad (8)$$

G : Geometric mean (geomean)
X : Data
n : Amount of data

Table 3. Geometric Mean (Geomean)Value Criteria

Expert Id	Eg Vs Ev	Eg Vs SE	Eg Vs LI	Ev Vs SE	Ev Vs LI	ES Vs LI
1	3,000	0,200	1,000	0,143	0,333	5,000
2	3,000	1,000	1,000	1,000	1,000	0,333
3	1,000	0,333	3,000	0,333	3,000	5,000
4	5,000	5,000	3,000	3,000	3,000	3,000
5	3,000	3,000	1,000	1,000	0,333	0,200
6	3,000	0,200	1,000	0,143	0,333	5,000
7	7,000	5,000	5,000	5,000	3,000	3,000
8	1,000	3,000	5,000	3,000	5,000	5,000
9	0,333	1,000	5,000	3,000	7,000	5,000
10	0,333	1,000	5,000	0,200	0,333	1,000
11	3,000	0,200	1,000	0,143	0,333	5,000
Geomean	**1,864**	**0,955**	**2,192**	**0,718**	**1,131**	**2,297**

Description: Eg : Engineering
Ev : Environment
SE : Sosio-economic
LI : Legal & Institution

The results of the geomean analysis are then included in the comparison matrix, and the value of each criterion in each column is summed up. Matrix normalization is carried out by dividing the value of each comparison by the number of columns. After all, comparisons are normalized.

Column 1, row 1, column 2, row 2, column 3, row 3, and column 4, row 4, presented in Table 4, are diagonal matrices with a value of 1,000. The value on the diagonal presented in Table 4 is the geometric mean value of each comparison between criteria in Table 3. The value on the bottom diagonal of Table 4 is the opposite of that on the top diagonal. For example, the value of 0.536 contained in row 2 column 1 in the comparison of Engineering (Eg) and Environmental (Ev) criteria is the opposite of the value in row 1 column 2 on Eg and Ev criteria, namely 1/1.864 = 0.536.

Table 4. Comparison Matrix of Criteria

Criteria	Comparison Matrix			
	Eg	Ev	SE	LI
	1	2	3	4
Eg	1,000	1,864	0,955	2,192
Ev	0,536	1,000	0,718	1,131
SE	1,048	1,392	1,000	2,297
LI	0,456	0,884	0,435	1,000
SOR	**3,04**	**5,14**	**3,11**	**6,62**

The normalization matrix is calculated by dividing the value of each comparison by the number of columns. For example, dividing the value in row 1, column 1, presented in Table 4, by the total value in column 1, 1/3.040 = 0.329. The value is placed in row 1, column 1 in the normalization matrix table (Table 5).

Table 5. Normalization Criteria Matrix

Criteria	Eg	Ev	SE	LI	Priority
	1	2	3	4	5
Eg	0,329	0,363	0,307	0,331	0,332
Ev	0,176	0,195	0,231	0,171	0,193
SE	0,345	0,271	0,322	0,347	0,321
LI	0,150	0,172	0,140	0,151	0,153
SOR	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**

Calculations are carried out on all comparison values in the comparison matrix between criteria to obtain the criteria normalization matrix from the calculation results. Similarly, the same method is used for the next step to normalize all comparisons. The weight value of each criterion is calculated by calculating the average value of each row of criteria in the criteria normalization matrix (Table 5). For example, the calculation to get the weight of the Eg criteria is presented.

Priority = $\frac{0{,}329+0{,}363+0{,}307+0{,}331}{4}$ = 0,332.

After all the weight values of each criterion are obtained, the calculation of the consistency ratio (CR) value is continued. To find the CR value, the first step is to find the eigenvalue (λ) by multiplying the criteria comparison matrix (Table 4) with the weight value that has been obtained (Table 5). For example, the following calculation can be seen.

(1,000 x 0,332) + (1,864 x 0,193) + (0,955 x 0,321) + (2,192 x 0,153) = 1,335

$$\begin{bmatrix} \mathbf{1,000} & \mathbf{1,864} & \mathbf{0,955} & \mathbf{2,192} \\ \mathbf{0,536} & \mathbf{1,000} & \mathbf{0,718} & \mathbf{1,131} \\ \mathbf{1,048} & \mathbf{1,392} & \mathbf{1,000} & \mathbf{2,297} \\ \mathbf{0,456} & \mathbf{0,884} & \mathbf{0,435} & \mathbf{1,000} \end{bmatrix} \times \begin{bmatrix} \mathbf{0,332} \\ \mathbf{0,193} \\ \mathbf{0,321} \\ \mathbf{0,153} \end{bmatrix} = \begin{bmatrix} \mathbf{1,335} \\ \mathbf{0,776} \\ \mathbf{0,910} \\ \mathbf{2,296} \end{bmatrix}$$

Then, the eigenvalue obtained will be divided by the weight value of each criterion and averaged, and the maximum eigenvalue (λmax) will be obtained equal to 4.02. After that, proceed with calculating the consistency index (CI) value using Equations (6) and (7). The RI value used is the value presented in Table 2. Because the amount of data (N) = 4, the RI is 0,90.

CI = $\frac{\boldsymbol{\lambda_{Max}-N}}{\boldsymbol{N-1}} = \frac{\mathbf{4{,}02-4}}{\mathbf{4-1}}$ = 0,00554. → CR = $\frac{\boldsymbol{CI}}{\boldsymbol{RI}} = \frac{\mathbf{0{,}00554}}{\mathbf{0{,}9}}$ = 0,00615 < 0,1 → Ok**.**

The consistency calculation (CR) results show that the consistency ratio of the data obtained is smaller than 0.1, which means it meets the requirements. Thus, the order of criteria used to compile the Prioritization of mitigation and flood risk reduction efforts in Kota Singkawang from highest to lowest rank, as presented in Table 6, is Engineering (Eg) 33,24%, Socio-economic (SE) 32,13%, Environment (Ev) 19,31, and Legal & Institution (LI) 15,32.

Table 6. Criteria Ranking Results

Criteria	Rank	%
Eg	1	33,24%
SE	2	32,13%
EV	3	19,31%
LI	4	15,32%

The steps in the alternative prioritization analysis are the same as the criteria prioritization steps. So, the results of the analysis are presented in the following tables.

Table 7. Geometric Mean (Geomean)Value Alternative

Respondent Id	FCB x ES	FCB x EWS	FCB x FAZ	FCB x RS	FCB x SC	ES x EWS	ES x FAZ	ES x RS
1	5,00	3,00	1,00	3,00	3,00	5,00	3,00	0,33
2	5,00	3,00	1,00	1,00	3,00	3,00	0,33	1,00
3	1,00	1,00	1,00	0,33	0,20	0,33	0,20	5,00
4	5,00	3,00	0,33	0,33	0,20	3,00	1,00	0,33
5	7,00	5,00	1,00	1,00	1,00	1,00	5,00	3,00
6	5,00	5,00	3,00	1,00	0,20	1,00	3,00	3,00
7	0,33	0,33	0,20	1,00	0,14	1,00	3,00	1,00
8	7,00	5,00	5,00	5,00	1,00	1,00	5,00	5,00
9	5,00	3,00	3,00	1,00	1,00	1,00	1,00	3,00
10	1,00	1,00	0,33	0,20	0,14	0,33	0,20	0,20
11	1,00	0,20	5,00	1,00	3,00	0,33	1,00	7,00
Total	**2,679**	**1,81**	**1,16**	**0,90**	**0,61**	**1,05**	**1,22**	**1,53**

Description :
FCB : Flood control building
ES : Erosion and sedimentation control
EWS : Early warning system
FAZ : Flood area zoning
RS : Regulation strengthening
SC : Socialization of the program to the community

Table 7. (Continued) Geometric Mean (Geomean)Value Alternative 1

Respondent Id	ES x SC	EWS x FAZ	EWS x RS	EWS x SC	FAZ x RS	FAZ x SC	RS x SC
1	1,00	1,00	5,00	1,00	5,00	1,00	1,00
2	0,20	1,00	3,00	1,00	5,00	1,00	1,00
3	1,00	7,00	0,33	1,00	5,00	0,33	0,33
4	0,33	1,00	5,00	1,00	3,00	3,00	1,00
5	1,00	5,00	1,00	3,00	5,00	1,00	0,20
6	1,00	1,00	1,00	1,00	5,00	0,33	0,20
7	1,00	0,20	0,14	1,00	0,33	0,33	1,00
8	1,00	5,00	3,00	3,00	0,33	0,33	1,00
9	3,00	1,00	5,00	0,20	5,00	0,20	5,00
10	1,00	1,00	1,00	1,00	0,20	0,33	7,00
11	7,00	5,00	1,00	1,00	1,00	1,00	1,00
Total	**1,03**	**1,60**	**1,44**	**1,05**	**1,88**	**0,58**	**0,93**

Description
FCB : Flood control building
ES : Erosion and sedimentation control
EWS : Early warning system
FAZ : Flood area zoning
RS : Regulation strengthening
SC : Socialization of the program to the community

Table 8. Comparison Matrix of Alternative

Alternative	FCB	ES	EWS	FAZ	RS	SC
FCB	1	2,68	1,81	1,16	0,90	0,61
ES	0,37	1	1,05	1,22	1,53	1,03
EWS	0,55	0,95	1	1,60	1,44	1,05
FAZ	0,86	0,82	0,63	1	1,88	0,58
RS	1,11	0,66	0,70	0,53	1,00	0,93
SC	1,64	0,97	0,95	1,73	1,07	1,00
SOR	**5,53**	**7,08**	**6,13**	**7,24**	**7,82**	**5,21**

Table 9. Normalization Alternative Matrix

Alternativ	FCB	ES	EWS	FAZ	RS	SC	Priority
FCB	0,18	0,38	0,30	0,16	0,12	0,12	0,208
ES	0,07	0,14	0,17	0,17	0,20	0,20	0,157
EWS	0,10	0,13	0,16	0,22	0,18	0,20	0,168
FAZ	0,16	0,12	0,10	0,14	0,24	0,11	0,144
RS	0,20	0,09	0,11	0,07	0,13	0,18	0,131
SC	0,30	0,14	0,15	0,24	0,14	0,19	0,193
SOR	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**

Table 10. Alternative Ranking Results

Criteria	Rank	%
FCB	1	20,91%
SC	2	19,41%
EWS	3	16,59%
ES	4	15,49%
FAZ	5	14,41%
RS	6	13,18%

The analysis shows that mitigation and flood risk reduction efforts in Kota Singkawang should be prioritized by taking structural engineering measures and building flood control buildings at flood-prone points. For areas influenced by sea tides and high rainfall, such as Singkawang City, flood control structures suitable for implementation include polder systems and retention ponds.

Polder systems are sophisticated flood control strategies employed in low-lying coastal or riverine regions prone to seawater or river overflow. Researchers (Ali, 2002; Vos et al., 2015; Adnan et al., 2019) emphasize compartmentalizing flood-prone territories with robust embankments known as polder dikes, acting as barriers against external water (Wamer et al., 2018). Polders are likened to "closed water boxes," managed by sluice gates to regulate water levels (Schultz, 2008). Components include embankments, sluice gates, pumping stations, and land reclamation (de Rooij, 2015), offering flood control and land development benefits despite maintenance costs. The Netherlands showcases successful polder systems controlling sea and river water reclaiming flood-prone areas for farmland and housing (de Boer, 2020).

Retention ponds, or stormwater basins, manage urban and suburban stormwater runoff by capturing rainwater, allowing sedimentation, filtration, and controlled discharge (Khan et al., 2013). They mitigate flooding, reduce peak flow rates, and improve water quality with impermeable linings and control structures. Landscaping with native vegetation enhances aesthetics and supports wildlife, making retention ponds integral to sustainable stormwater management and environmental stewardship (Yazdi et al., 2021).

4. Conclusion

In Kota Singkawang, flood mitigation and risk reduction efforts are recommended, focusing on structural engineering interventions and flood control infrastructure at vulnerable points. Given the area's susceptibility to sea tides and high rainfall, flood control structures such as polder systems, retention ponds, and tidal barrage dams are suitable for implementation. Polder systems, highlighted by researchers, involve dividing flood-prone regions into enclosed segments using robust embankments known as polder dikes. These dikes act as barriers to external water, resembling a "closed water box" managed by sluice gates to regulate water levels. Components of polder systems include embankments, sluice gates, pumping stations, and land reclamation, offering flood control and land development benefits despite ongoing maintenance costs. Retention ponds, also known as stormwater basins, manage stormwater runoff by capturing rainwater, allowing sedimentation, filtration, and gradual discharge into water systems. These engineered water bodies are lined to prevent seepage, improve water quality through natural filtration, and support wildlife habitats. However, as this is still a preliminary study, a more in-depth study using more complete data is needed to apply these structural technologies.

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6. Author’s Note

I sincerely declare that this paper is my own original work and is not plagiarized from the work of others. I have conducted research and writing with high academic integrity, and have followed the ethical principles of scientific writing. All sources of information used have been clearly listed by me and accompanied by appropriate references. I take full responsibility for the authenticity and originality of this work, and am ready to provide clarification or additional information if needed.

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