



Measuring Regional Resilience to Disasters Using a Composite Index: A Case Study of West Java Province



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Abstract: West Java Province is being exposed to a high risk of natural disasters, especially hydrometeorological disasters such as floods and landslides, hence hindering potential economic growth. The increasing frequency of disasters has shed light on the issue of regional resilience, an important concern for public authorities. Therefore, efforts to assess and strengthen regional resilience are crucial to reducing disaster risks and supporting the achievement of sustainable development. However, up till recently there has been no practical and applicable methodology for resilience assessment, which has become more complicated at the regional level, taking into account the economic, social, ecological, infrastructural, and institutional dimensions. The present paper proposed a composite indicator-based approach to evaluate the level of regional resilience to disasters in West Java Province. To describe the current conditions of resilience in each regency/city in the province, this study adopted 17 indicators that were adjusted for measurement in the actual context. The composite index combined by the macro-regional indicators in five main dimensions were calculated using arithmetic, geometric, harmonic, entropy, and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods. The integrated Regional Disaster Resilience Composite Index (RDRCI) scores across the 27 regencies/cities ranged from 6.33 to 33.98, with 9 regions recording values above the provincial mean of 15.26. The results of this analysis could be employed by policy-makers to evaluate the resilience of a region to natural disasters. Furthermore, the findings highlight the necessity of incorporating all dimensions into policy formulation to strengthen regional resilience to disasters.

Keywords: Composite index; Disaster risk; Regional resilience; West Java Province; TOPSIS; Entropy

1. Introduction

Global climate change, urbanization, and population growth have contributed to heightened human risk and exposure to natural disasters (Huang et al., 2020). Challenges arising from urban and regional development are accelerating due to the increasing frequency and intensity of natural disasters (Bhargava, 2019). Resilience is a key requirement for regional sustainability because sustainable development requires resilience in multiple indicators. This is because the ability to recover from disturbances and adapt to changes is key to maintaining regional stability and sustainability in the long term. The sustainability of a system depends on its own resilience, which depends on a series of characteristics that affect the system itself (Xu et al., 2015). The resilience of this system is influenced by various internal characteristics that affect its ability to adapt, recover from disturbances, and continue to function in the long term.

The assessment of the status quo of regional resilience is very important to encourage sustainable development. However, in the past, the assessment of regional resilience was generally carried out from the perspective of only one scientific discipline, without considering various levels of resilience and often ignoring the characteristics of regional resilience which are multidisciplinary and complex (Jabareen, 2013). Thus, the preparation of

comprehensive and scientifically-based evaluation standards or regional resilience index systems could support the process of identifying and analyzing the level of regional sustainable development effectively at various spatial scales.

Currently, there is no academic consensus on the definition of resilience (Cai et al., 2018; Xu et al., 2021). Resilience originated in the field of ecology (Holling, 1973). The concept was gradually applied to psychology, economics, engineering, urban development, and natural disasters. Resilience generally refers to the capacity of a system to adapt and recover to normal conditions after experiencing a disturbance or shock (Chang & Shinozuka, 2004). However, some other researchers argued that resilience emphasized the stability of the system or focused on how quickly a system could recover after being exposed to a risk. Resilience, the ability to recover from adversity, has become a global guiding principle for natural disaster management and an important focus of disaster mitigation, preparedness, and post-disaster recovery efforts. Natural disasters that occur repeatedly can cause more significant economic losses than disasters that emerge only once (Docherty et al., 2020). When compared with developed countries, developing countries suffer from heavier economic and social impact exerted by some natural disasters, leading to a decline in economic development (Independent Evaluation Group, 2006).

In 2015, the United Nations Office for Disaster Risk Reduction (UNDRR) proposed an initiative to monitor, evaluate, and understand the risks of disasters, strengthen resilience, and integrate disaster risk reduction efforts against multiple types of threats simultaneously (Wahlström, 2015). Research on regional resilience has important implications for sustainable regional development (Norris et al., 2008). Resilience has therefore evolved into a central concept in disaster management policies in recent years, forming a major focus in the planning and implementation of disaster risk reduction policies. Resilience is assessed by how much disturbance a system can tolerate without losing its ability to perform its primary functions (Chang & Shinozuka, 2004).

This study aims to develop a multidisciplinary framework for evaluating regional resilience and to examine the current level of disaster resilience across West Java Province. This paper adopted regencies/cities as the research scale and established a composite resilience index evaluation system from 17 indicators in 27 regions in West Java Province. These indicators were obtained from the results of Systematic Literature Review (SLR) (see Methodology) and covered five dimensions, including economic, social, ecological, infrastructural, and institutional.

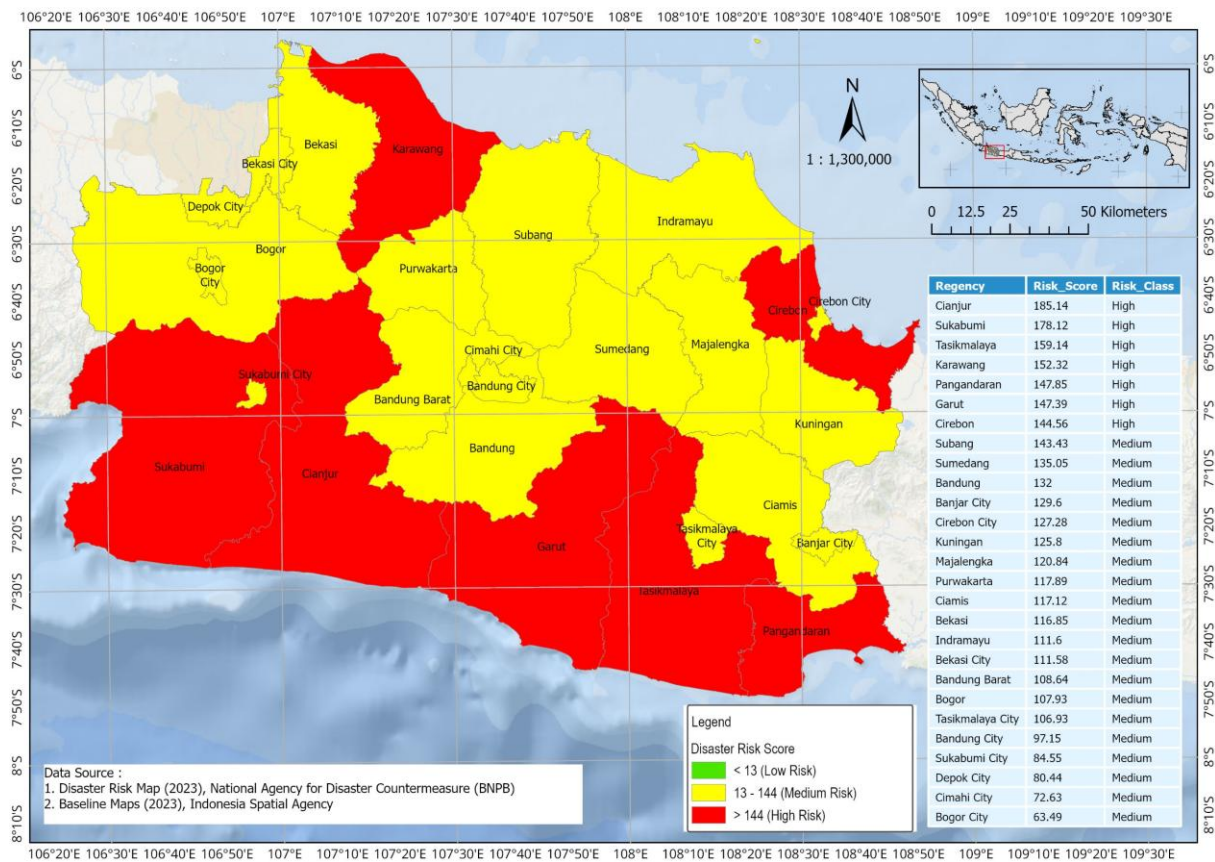


Figure 1. Map of the disaster risk index in West Java Province

In the Indonesian context, regional resilience is framed within eight dimensions, collectively referred to as *Asta*

Gatra, which encompasses geography, demography, natural resources, ideology, politics, economics, socio-cultural, and defense and security. For several dimensions, particularly ideology and politics clearly define indicators and disaggregated data at the regency/city level are not available. Consequently, this study employed a five-dimensional framework derived from a widely recognized body of literature. Nonetheless, the 17 indicators identified through the SLR broadly capture and reflect multiple dimensions of the *Asta Gatra* framework.

Economic resilience, for instance, is reflected by indicators such as gross regional domestic product (GRDP) per capita and employment rate, while socio-cultural resilience is captured through health insurance, poverty, and social cohesion. The natural resources dimension is represented by forest area and precipitation, whereas the demographic dimension is reflected in population growth rates and vulnerable people. The geographical dimension is illustrated by road area and disaster risk, while the defense and security dimension is represented by indicators such as early warning systems (EWS), safety equipment, evacuation signs and routes, river normalization, health facilities, and health workers.

The study area, West Java Province, was chosen because the region has the largest population in Indonesia and this region is a disaster-prone land, where 33% of the area has a high disaster risk index and the remaining 67% of the area has a moderate disaster risk (Figure 1). In 2022, 294,265 people were affected and displaced, 146 people were injured and 64 died due to floods, landslides, and tornadoes (Table 1). A total of 1,167 and 1,005 villages were affected by landslides and floods, respectively. The natural disaster caused damage to houses, where 30,866 were severely damaged, 21,266 were moderately damaged, 39,164 were lightly damaged, and 67,528 houses were submerged (Statistics of West Java Province, 2023).

Table 1. Number of natural disasters, houses damaged, and victims in West Java Province in 2022

	Description	Number
Number of disaster events (incidents)	Landslides	542
	Flood	250
	Tornado	489
Number of houses damaged (unit)	Severely damaged	30,866
	Moderately damaged	21,266
	Slightly damaged	39,614
	Submerged	67,526
Number of victims (inhabitants)	Deaths and missing	64
	Injuries	146
	Affected and displaced	294,265

Source: Statistics of West Java Province, 2023

Regions with elevated disaster risk are predominantly concentrated along the Pansela (South Coast) corridor, including Sukabumi, Cianjur, Bandung, Garut, and Tasikmalaya Regencies. The heightened vulnerability of this belt is mainly attributable to the interaction of active geological processes, complex hilly terrain, and hydrometeorological influences, particularly extreme weather events. The evaluation of regional resilience in West Java Province not only plays a role in directing the development and planning process in the province, but also becomes an operational example that can be used as a reference in resilience studies in developing countries.

2. Methodology

This study used secondary data in 2022, collected from the West Java Provincial Statistics, the Regional Disaster Management Agency/National Disaster Management Authority (BPBD) of West Java Province, and the Ministry of Environment and Forestry, in relation to 27 regencies/cities in West Java Province. The composite resilience index was built using 5 dimensions with 17 indicators, namely (1) the economic dimension with indicators of GDP per capita, poverty, and health insurance; (2) the social dimension with indicators of employment rate, vulnerable people, population growth rate, and health workers; (3) the ecological dimension with indicators of forest area, disaster risk, and precipitation; (4) the infrastructural dimension with indicators of road area, evacuation signs and routes, health facilities; and (5) the institutional dimension with indicators of safety equipment, social cohesion, river normalization, and EWS.

Resilient regions represent a region that is capable of managing environments involving risk through vulnerability reduction and capacity building. Among the 17 indicators, vulnerability was captured through the variables of poverty, population growth rate, proportion of vulnerable populations, disaster risk, and rainfall. In contrast, capacity was reflected by indicators including GRDP per capita, health insurance coverage, employment rate, availability of health workers, forest area, road infrastructure, signs and evacuation routes, health facilities, safety equipment, social cohesion, river normalization, and EWS.

All indicators were first normalized according to the steps of compiling the composite resilience index (Figure 2).

Indicator identification was carried out by the SLR approach using 77 Scopus journals. The initial search used

the keywords "regional resilience" OR "rural resilience" OR "village resilience" OR "urban resilience" OR "city resilience" AND "indicator" in Scopus. Thus, from this stage, a total of 621 articles were obtained. Next, filters were applied based on subject areas, "social science", "environmental science", "earth and planetary science", "energy", "economics", "econometrics", and "finance", and the year range is 2010–2023, resulting in 305 papers. Further criteria included the document type "article", publication stage "final" and language "English", hence narrowing the selection to 225 papers. During the screening process, 78 papers were excluded for being non-open access, 85 for being irrelevant, leaving 62 relevant papers. Besides, manual searches using Google had identified 15 relevant journals and the total eligible papers for review was 77 pieces.

Based on the systematic review of the 77 scholarly articles, a total of 22 quantifiable indicators associated with disaster resilience were identified, for which secondary data were obtained from the West Java Provincial Statistics. Subsequently, a multivariate analysis was conducted using Principal Component Analysis (PCA) to minimize redundancy among variables. The results of the PCA indicated that several indicators were eliminated, thus yielding a final set of 17 indicators for further analysis.

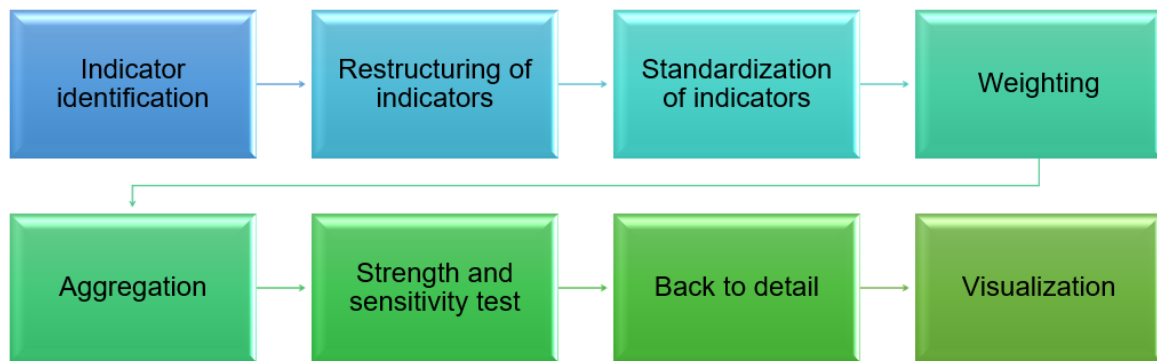


Figure 2. Steps for compiling the composite resilience index

Standardization using the Min-Max Method aims to normalize indicators to have the same distance by reducing the minimum value and dividing it by the distance of the indicator values.

$$x_{ij} = \frac{y_{ij} - \min(y_{ij})}{\max(y_{ij}) - \min(y_{ij})} * 100 \quad (1)$$

where, x_{ij} = normalized data of the i -th indicator in the j -th region; y_{ij} = the i -th indicator data in the j -th region to be normalized; $\min(y_{ij})$ = smallest data; $\max(y_{ij})$ = largest data.

For indicators that have negative polarity or bad indicators (-), normalization uses (2):

$$x_{ij}^{(-)} = 100 - \frac{y_{ij} - \min(y_{ij})}{\max(y_{ij}) - \min(y_{ij})} * 100 \quad (2)$$

The calculation of Regional Disaster Resilience Composite Index (RDRCI) using the composite indicator-based method is carried out using six types of measurement methods, namely: Arithmetic RDRCI (RDRCI-A); Geometric RDRCI (RDRCI-G); Harmonic RDRCI (RDRCI-H) which is an aggregation carried out by dividing the number of indicators q by the number 1, where this aggregation requires the weight of each indicator to be the same (equal); Entropy RDRCI (RDRCI-E); Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) RDRCI (RDRCI-T); and Integrated RDRCI (RDRCI-I).

The RDRCI-E employs Shannon entropy to assign objective weights to criteria within a multicriteria decision-making framework. As a mathematical measure of uncertainty based on probability distributions, this method has been widely applied across various fields. The weighting procedure is carried out by first determining the value of X_{ij} and then determining the value of P_{ij} with (3):

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^m X_{ij}} \quad (3)$$

where, m = number of samples to calculate the entropy value with (4):

$$E_j = -k \sum_{i=1}^m P_{ij} \times \ln P_{ij} \quad (4)$$

where, $k = \frac{1}{\ln m}$ to calculate the weighting of each indicator using (5):

$$W_j = \frac{(1-E_j)}{\sum_{j=1}^n (1-E_j)} \quad (5)$$

Having been implemented by Sanna software in this study, the RDRCI-T is a ranking method that identifies alternatives closest to the positive ideal solution and farthest from the negative ideal solution. Compared with other multi-criteria decision analysis techniques, TOPSIS has been widely applied across various fields as it effectively utilizes raw data to provide flexibility in the number of indicators. Although its use in emergency management assessment remains limited, TOPSIS provides a robust and cardinal ranking by fully exploiting attribute information. Therefore, this paper attempts to apply TOPSIS to calculate the relative proximity of the ideal solution as conducted by Long et al. (2019).

The TOPSIS steps are as follows (Conejero et al., 2021):

(a) Standardize and assign weights to the columns of matrix N to produce the normalized matrix X , where the element in row i and column j is defined by (6):

$$x_{ij} = w_j \frac{n_{ij}}{\sqrt{\sum_{i=1}^m n_{ij}^2}}, i = 1, \dots, m; j = 1, \dots, n \quad (6)$$

(b) Determine the ideal solution A^b and the negative-ideal solution A^w based on (7):

$$A_j^b = \begin{cases} \max x_{ij} & \text{if } j \in J^+ \\ \min x_{ij} & \text{if } j \in J^- \end{cases}; A_j^w = \begin{cases} \max x_{ij} & \text{if } j \in J^+ \\ \min x_{ij} & \text{if } j \in J^- \end{cases}; i = 1, \dots, m \quad (7)$$

(c) Calculate the distance of each alternative from the ideal and negative-ideal solutions using (8):

$$d_i^b = \|A_i - A^b\| = \sqrt{\sum_{j=1}^n (x_{ij} - A_j^b)^2}; d_i^w = \|A_i - A^w\| = \sqrt{\sum_{j=1}^n (x_{ij} - A_j^w)^2} \quad (8)$$

(d) Obtain the ranking of each alternative by applying (9):

$$RDRCI - T = r_i = \frac{d_i^w}{d_i^w + d_i^b} \quad (9)$$

The integrated Regional Disaster Resilience Composite Index (RDRCI-I) is an approach that incorporates a combined index, resulting from the total score derived through the integration of the TOPSIS method and Shannon entropy. This approach has been applied by various researchers, including Chen (2019), Choi (2019), and Xu et al. (2018). The RDRCI-I is defined as follows:

$$RDRCI - I = RDRCI - E * RDRCI - T \quad (10)$$

The strengths of this method become more evident when a large number of assessment indicators are involved, particularly when those indicators differ significantly in nature. In essence, this integrated evaluation approach serves as a precise reference or guideline for decision-makers in emergency response situations (Adetama et al., 2021). The results of each RDRCI method are initially scored on a scale of 0 to 100. To facilitate comparison among the RDRCI methods, each score is normalized by dividing it by 100, resulting in a standardized scale from 0 to 1. By comparing the values of RDRCI-A, RDRCI-G, RDRCI-H, RDRCI-E, RDRCI-T, and RDRCI-I, the optimal RDRCI value for each regency or city is determined. Figure 3 presents the procedural steps for calculating the RDRCI using these six measurement methods.

The use of multi-method in composite index as a robustness test where this technique can ensure that the ranking or final result of the index does not change drastically even if the construction method is changed. The development of a composite index entails multiple stages that inherently involve subjective decisions, including the selection of indicators, treatment of missing data, choice of aggregation methods, and determination of weights. These decisions constitute the foundation of index construction and directly influence the information conveyed by the resulting index values. Consequently, the quality of the model is highly dependent on the validity of the underlying assumptions. Better modeling practice therefore necessitates systematic model evaluation, including the assessment of uncertainty and the implications of subjective choices.

Within this framework, sensitivity analysis is employed to examine the extent to which variations in

assumptions affect composite index outcomes and to evaluate the dependence of outputs on the inputs utilized. This approach is closely linked to uncertainty analysis, which aims to quantify the degree of uncertainty associated with the resulting rankings. The integration of these analyses is essential for testing index robustness, enhancing transparency, and identifying the effects of alternative assumptions, including those related to indicator selection, data imputation, normalization, weighting, and aggregation techniques.

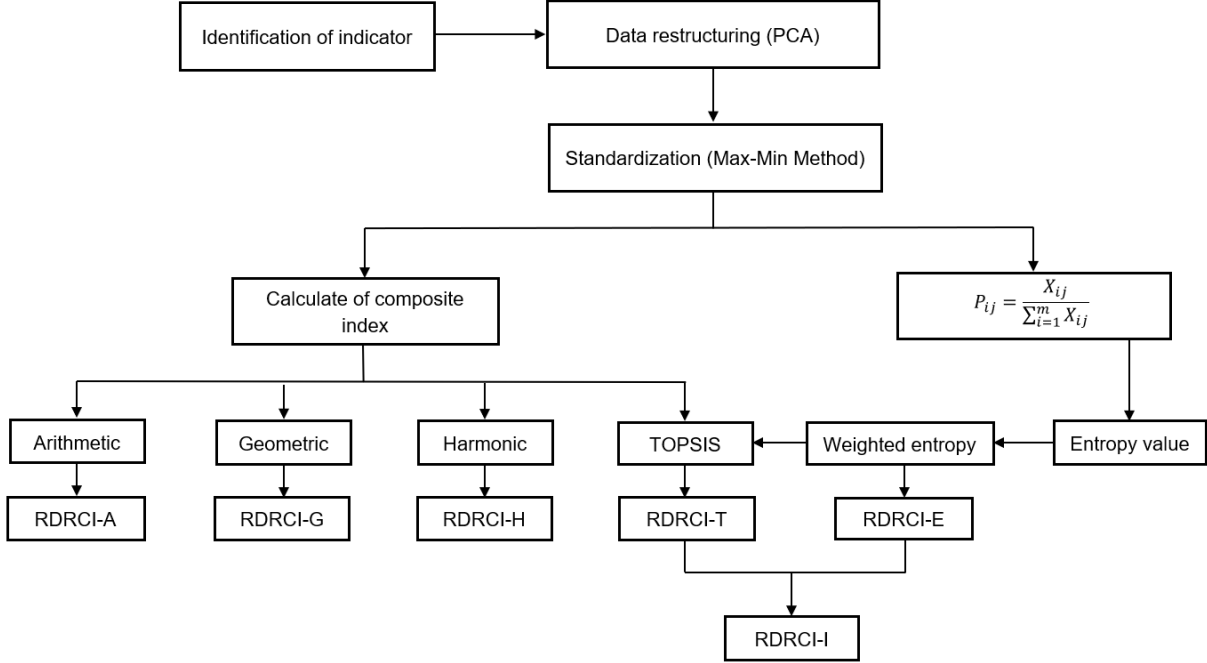


Figure 3. Flow chart of deriving the Regional Disaster Resilience Composite Index (RDRCI)

3. Results

The first step in the development of the composite index was the selection of appropriate indicators. The preceding section has described the indicator identification process based on the SLR. The following section will outline the subsequent procedures for calculating the composite index.

3.1 Indicators of the Regional Disaster Resilience Composite Index

After identifying the indicators using SLR, the next step was to restructure the indicators using PCA. PCA was used to process the contents of the indicators so that the resilience indicators became complete. PCA was used to analyze the correlation between variables, then reduce the number of initial variables to produce new variables (Song et al., 2016; Uddin et al., 2019). This procedure is referred to as dimensionality reduction, in which the transformed variables are known as principal components. When the original variables are weakly correlated, dimensionality reduction cannot be effectively achieved; conversely, strong intercorrelations among variables enable greater simplification, with higher correlations resulting in more substantial reductions (Chang et al., 2021).

Using SPSS software for PCA analysis, it was found that out of 22 indicators that affected regional resilience in West Java Province, there were 4 indicators correlated with each other, so that the 4 indicators were reduced. The indicators were the share of the agricultural sector to GRDP, asset ownership, population density, and internet access. Besides, the indicator, Regular Trading Hours (RTH), did not have complete data so it was excluded from the calculation; as a result, the total number of indicators used was 17 (Table 2). The standardization of the indicators was carried out using the Min-Max method.

Figure 4 presents the average scores of the 17 indicators that contribute to the regional resilience index to disasters in each regency/city in West Java Province. Most areas in West Java Province have GRDP per capita below average. Cianjur had the lowest GRDP values per capita in 2022. This region was still highly dependent on the agricultural and traditional trade sectors which had low productivity and added value (Statistics of West Java Province, 2023). The geographical areas are dominated by hills and mountains, leading to limited infrastructural development and connectivity between regions. This condition results in low investment and slow distribution of goods and services, hence decelerating local economic growth.

The region with the highest number of poor people was Indramayu, with an index value of 13%, above the average poverty rate of 9% in West Java Province. Indramayu Regency also had a fairly high dependence on the

agricultural and fisheries sectors. This can be seen from the majority of Indramayu residents, who work in the agricultural and fisheries sectors which are vulnerable to weather fluctuations and commodity prices, and have relatively low productivity. In addition, the average years of schooling in Indramayu—reflecting the population’s overall education level—remain relatively low, thereby limiting skill development and access to better job opportunities.

Table 2. Indicators of regional resilience to natural disasters

No.	Dimension	Indicator	Unit	Code
1	Economic	GDP per capita	Million IDR	GDRP
		Poverty	Percent	PVRT
		Health insurance	Percent	INSR
		Employment rate	Percent	EMPL
2	Social	Vulnerable people	Percent	VULN
		Population growth rate	Percent	GRWT
		Health workers	Ratio	HLTW
		Forest area	Percent	FRSA
3	Ecological	Disaster risk	Index	RISK
		Precipitation	Mm	PRCP
		Road area	Km/km2	ROAD
4	Infrastructural	Signs and evacuation routes	Percent	SEVC
		Health facilities	Ratio	HLTF
		Safety equipment	Percent	SFTY
		Social cohesion	Percent	CHSN
5	Institutional	River normalization	Percent	NRML
		Early warning systems	Percent	WARN

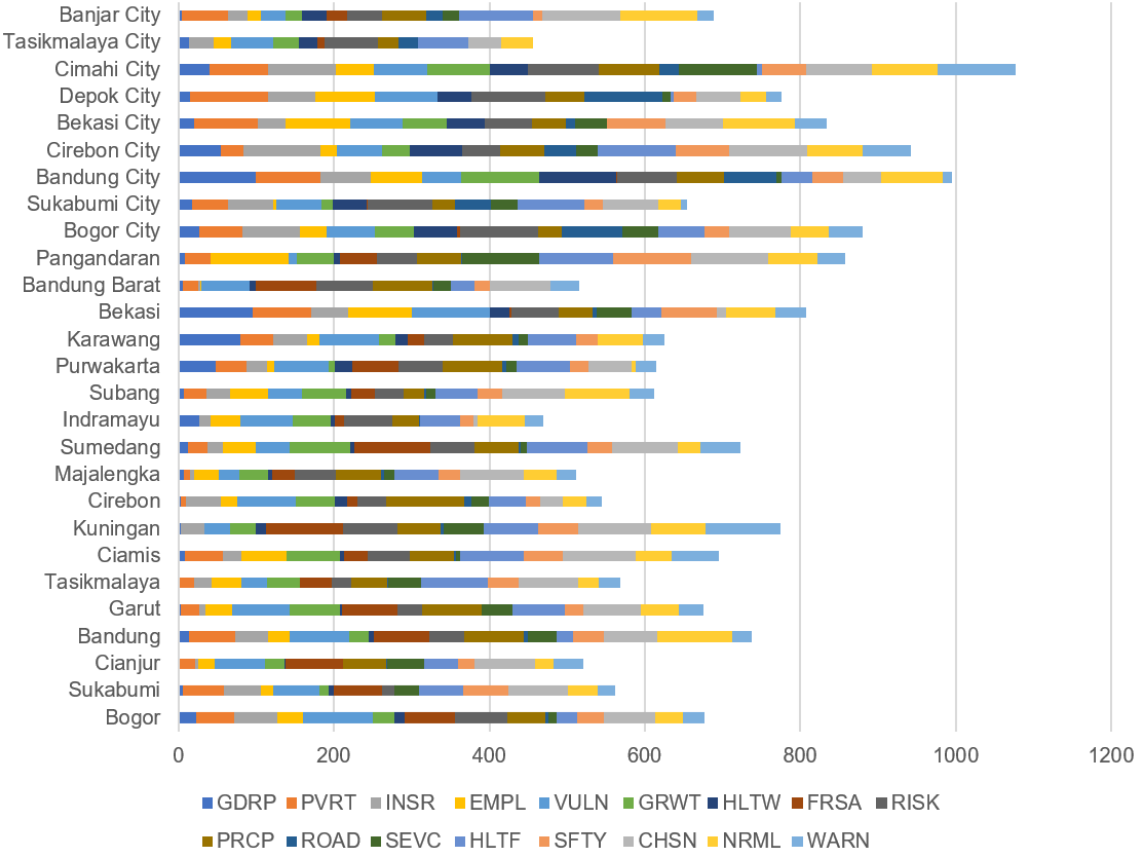


Figure 4. Indicators influencing the Regional Disaster Resilience Composite Index (RDRCI) in the regencies/cities in West Java Province

Pangandaran Regency was the region with the lowest number of participants, only 17%, in health insurance. Several factors for the low level of participation included economic constraints, as participants were burdened to pay contributions and lacked awareness and information. Where some people did not fully understand the benefits

and importance of having health insurance, a lack of adequate socialization and information caused low participation, especially in rural and remote areas.

The lowest employment rate of 40% was found in Kuningan Regency in West Java Province. The absence of large manufacturing industries that were able to absorb a significant number of workers contributes to the low employment rate in Kuningan Regency. The majority of the population still relied on the agricultural sector and Micro, Small and Medium Enterprises (MSMEs), which have limitations in absorbing workers, especially for new graduates and those of productive age. Limited job opportunities in the region have compelled many young people to migrate to urbanized industrial cities such as Bekasi, Karawang, or Jakarta, thus affecting the employment rate in Kuningan Regency.

Ciamis was the area with the highest number of vulnerable population, which was 11%. Meanwhile, the areas with the highest population growth rate were Bekasi and West Bandung at 1.86%. For the indicator of the ratio of health workers to the population, most areas had values below average. The lowest ratio of health workers was in Tasikmalaya.

Six regions including Sukabumi City, Bandung City, Cirebon City, Bekasi City, Depok City, and Cimahi City were characterized by the absence of forest cover. This condition is likely to weaken regional resilience, as forests function as natural protective buffers that mitigate impacts of disasters, whereas deforestation increases vulnerability. In the context of disaster management, the conservation and restoration of forest ecosystems represent an essential approach to ecosystem-based disaster risk reduction.

For the disaster risk index, the area with the highest disaster risk was Cianjur, with a value of 208. As regards the rainfall indicator, there were 16 areas with rainfall below the average value. The area with the highest rainfall was Sukabumi, with a value of 430 mm/month, while the lowest was Cirebon, with a value of 121 mm/month. Extreme rainfall could be the main factor triggering various hydrometeorological disasters, such as floods, landslides, and flash floods. Although large rainfall is not a direct cause of low resilience, areas will be more vulnerable to disasters and experience slow recovery if they are not supported by adaptive infrastructure, risk-based regional planning, and community education and preparedness, so the level of resilience is also low.

Garut Regency is the region with the lowest road length ratio. Meanwhile, evacuation signs and routes in West Java were still low in number, as can be seen from the average value of only 11% and as many as 15 regions had values below average. The regions with the lowest number of evacuation signs and routes were Indramayu and Tasikmalaya City, with a value of only 1%. Evacuation signs and routes are crucial elements in building regional resilience to natural disasters, because both have a direct role in saving lives and minimizing the risk of loss of life during a disaster. The existence of evacuation signs and routes is also an integral part of disaster simulation and education activities. Through this process, the community will better understand the conditions of the surrounding environment and be trained in making quick decisions when a disaster occurs. Regions that routinely carry out simulations by utilizing evacuation routes generally have a better level of preparedness.

The areas with the lowest ratio of health facilities per population were Bekasi City and Depok City. The availability of health facilities is directly proportional to the number of medical personnel, where the more adequate the number of hospitals, health centers, and clinics is, the higher is the ability to respond quickly in emergencies and accelerate the recovery process when a disaster occurs.

The average number of villages that had prepared safety equipment in each regency/city in West Java Province was 23%, and 16 regencies/cities had values below average. Tasikmalaya City was the area with the lowest number of such villages; meanwhile, the village that had the lowest mutual cooperation habits was Karawang. The culture of mutual cooperation has a strong relationship with regional resilience to disasters, because it could strengthen social solidarity, encourage community involvement in disaster mitigation and handling efforts, and accelerate recovery after a disaster occurs. In addition, mutual cooperation supports the optimal use of local resources and strengthens relationships between residents, thereby increasing community capacity in dealing with disasters.

One form of prevention and mitigation action against disasters is river normalization. An average of 49% of villages crossed by rivers in each regency/city carried out river normalization activities. West Bandung was the area with the fewest villages carrying out river normalization. In contrast to West Bandung, the Bandung Regency Government was the area with the most villages carrying out river normalization. In 2022, the Bandung Regency conducted normalization of the Cidawolong River and Cipadaulun River as a step to overcome the problem of flooding. This activity involves collaboration among the government, business actors, and the community within a Pentahelix framework. The purpose of this normalization is to increase the capacity and smoothness of rainwater flow in the river, so that the potential for flooding can be minimized.

In the regencies/cities of West Java Province, villages that had an EWS of natural disasters were still low in number, with an average of 14%. The area with the least number was Tasikmalaya City. Early EWS are intrinsically and critically associated with disaster resilience. Beyond serving as detection mechanisms, EWS constitute a core element of disaster risk management by enabling communities, governments, and institutions to undertake anticipatory actions prior to the occurrence of severe impacts. Through the provision of timely information and response capacity, EWS strengthen resilience by enhancing the ability of communities to withstand, adapt to, and rapidly recover from disaster-related shocks.

3.2 Regional Disaster Resilience Composite Index from a Regency/City Perspective

Based on Table 3, the calculation using indicators in each dimension obtained the RDRCI values for 27 regencies/cities in West Java Province based on 5 different methods, namely the arithmetic mean (average value of the indicator), geometric mean, harmonic, TOPSIS, and Shannon entropy method. Then, calculation of the integrated RDRCI value was carried out.

The six composite index construction methods employed in this study exhibited distinct strengths and limitations. The arithmetic aggregation method is straightforward, computationally simple, and easily interpretable; however, it is sensitive to outliers as it assumes linear relationships that may not capture complex realities, and allows full compensability among indicators. In contrast, the geometric aggregation method reduces compensability between dimensions and mitigates the influence of extreme values, but it involves more complex calculations and is less intuitive to interpret.

The harmonic mean method is particularly sensitive to small values, thus well-suited for datasets with high variability where lower-valued components need to be emphasized. It is especially appropriate for handling rates and ratios, as it effectively moderates the influence of extreme values. However, this method has limitations, including its sensitivity to zero values and its relatively low interpretability compared with other aggregation approaches. Meanwhile, the TOPSIS approach provides clear and quantifiable rankings as well as high computational efficiency, yet it is sensitive to the assigned criterion weights and does not account for intercorrelations among indicators. The entropy weighting method, well suited for high-dimensional datasets, offers a high degree of objectivity as weights are derived from data characteristics rather than expert judgment; nevertheless, it lacks a strong theoretical foundation and relies primarily on statistical dispersion, which may entail computational complexity.

Table 3. Regional Disaster Resilience Composite Index (RDRCI) calculation results and ranking in 27 regencies/cities in West Java Province

Regency/City	Arithmetic Mean		Geometric Mean		Harmonic Mean		TOPSIS		Entropy		Integrated	
	RDRCI-A	Rank	RDRCI-G	Rank	RDRCI-H	Rank	RDRCI-T	Rank	RDRCI-E	Rank	RDRCI-I	Rank
Bogor	39.62	14	35.69	15	30.66	16	31.75	14	39.92	15	12.67	14
Sukabumi	32.62	21	31.48	20	30.50	18	33.42	13	32.77	21	10.95	19
Cianjur	30.17	24	26.37	23	21.36	25	30.36	18	30.29	24	9.19	22
Bandung	43.05	10	39.97	9	36.85	9	33.91	12	43.37	10	14.71	11
Garut	39.15	16	34.36	18	28.11	19	30.89	17	39.67	16	12.25	16
Tasikmalaya	33.19	20	30.84	21	27.98	21	27.97	22	33.82	20	9.46	21
Ciamis	39.96	13	37.93	13	36.20	11	31.20	16	40.74	13	12.71	13
Kuningan	45.15	9	35.17	17	26.25	22	44.34	6	45.32	9	20.10	8
Cirebon	31.97	22	29.93	22	28.08	20	22.35	26	32.68	22	7.30	24
Majalengka	29.47	25	24.29	26	18.11	27	21.52	27	30.09	25	6.48	26
Sumedang	42.11	11	38.30	12	34.59	14	35.34	11	42.45	11	15.00	10
Indramayu	26.82	26	24.75	25	22.70	24	23.07	25	27.44	26	6.33	27
Subang	34.45	19	32.34	19	30.54	17	27.37	23	35.01	19	9.58	20
Purwakarta	37.30	18	35.18	16	33.57	15	29.99	20	37.73	18	11.32	18
Karawang	37.62	17	36.17	14	34.88	12	31.34	15	38.13	17	11.95	17
Bekasi	47.27	6	45.01	6	42.94	6	42.04	8	47.84	6	20.11	7
Bandung Barat	30.98	23	23.88	27	19.22	26	28.59	21	31.21	23	8.92	23
Pangandaran	49.46	5	42.96	7	34.78	13	43.05	7	50.29	5	21.65	5
Bogor City	51.93	4	51.66	4	51.40	3	50.10	4	52.31	4	26.21	4
Sukabumi City	39.37	15	38.51	11	37.74	7	36.22	10	40.03	14	14.50	12
Bandung City	58.08	2	55.16	2	52.52	2	51.60	2	58.31	2	30.09	2
Cirebon City	54.75	3	52.93	3	51.07	4	50.30	3	55.36	3	27.85	3
Bekasi City	46.62	7	41.87	8	36.63	10	40.65	9	47.11	7	19.15	9
Depok City	46.08	8	45.26	5	44.45	5	44.71	5	46.21	8	20.66	6
Cimahi City	62.22	1	60.98	1	59.73	1	54.10	1	62.81	1	33.98	1
Tasikmalaya City	26.79	27	25.57	24	24.25	23	23.71	24	27.36	27	6.49	25
Banjar City	40.31	12	38.59	10	36.91	8	30.02	19	41.09	12	12.33	15

The integrated TOPSIS–Entropy approach presents notable advantages, particularly in enhancing weighting objectivity, ensuring comprehensive and logically consistent analysis, and maintaining computational efficiency. This integrated method is considered highly suitable for composite index construction, as it minimizes subjectivity in weighting while maximizing the informational content of the data. By combining objective weighting through entropy with a robust ranking mechanism via TOPSIS, the approach yields a scientifically grounded, objective, and comprehensive composite index. However, it remains subject to certain limitations, including limited

qualitative interpretability and sensitivity to input data variations.

The regencies/cities with higher and more stable RDRCI rankings based on different methods were Cimahi City, Bandung City, and Cirebon City. Meanwhile, the regencies/cities with the lowest RDRCI rankings were Tasikmalaya City, Indramayu, and Majalengka.

As illustrated in Figure 5, notable discrepancies were observed between the rankings produced by RDRCI-A and those generated by RDRCI-H and RDRCI-T across several regions. Meanwhile, there is not very striking difference in the ranking of the arithmetic RDRCI, compared with the RDRCI-E and the RDRCI-I.

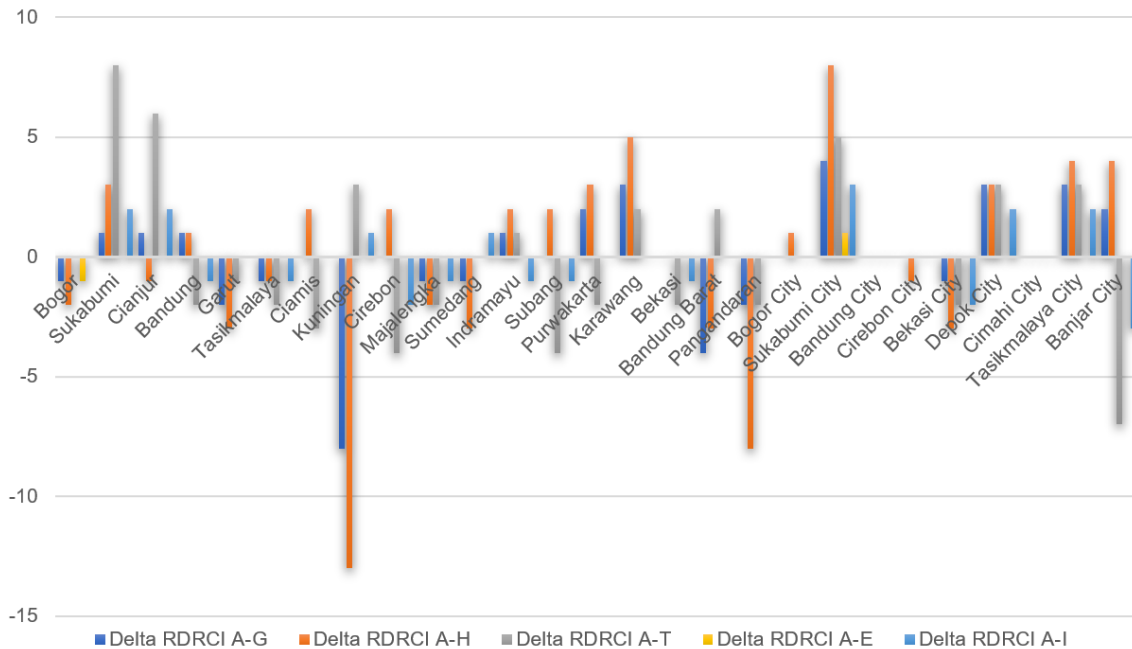


Figure 5. Delta Regional Disaster Resilience Composite Index (RDRCI)

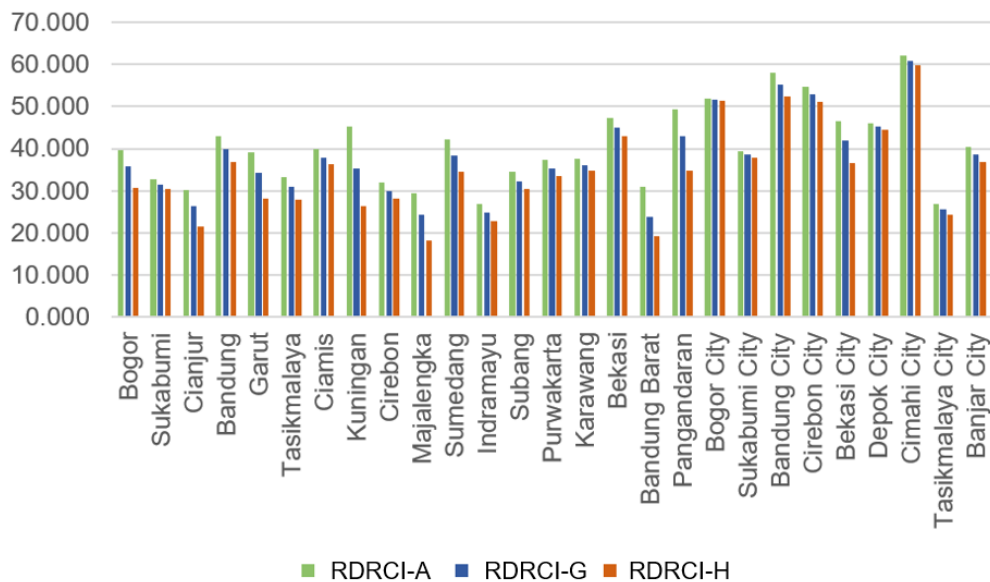


Figure 6. Distribution of calculations for Regional Disaster Resilience Composite Index (RDRCI)-A, RDRCI-G, and RDRCI-H

The results obtained using the harmonic approach exhibited substantial differences in rankings when compared with those generated by other methods (Table 3). As illustrated in Figure 6, the differences among RDRCI-A, RDRCI-G, and RDRCI-H are more pronounced in several regencies/cities, including Kuningan, Karawang, Pangandaran, Sukabumi City, and Banjar City, and the average RDRCI-H score across the 27 regencies is lower than the corresponding RDRCI-A and RDRCI-G values. The arithmetic mean had notable limitations, as it is

sensitive to extreme values, unsuitable for time-series data, assumes equal importance among observations, and performs poorly with percentage-based data, thus rendering its applicability context-dependent. In contrast, the geometric mean incorporates all observations, supports further mathematical analysis, and is less affected by sampling fluctuations, although it becomes undefined when any value is negative.

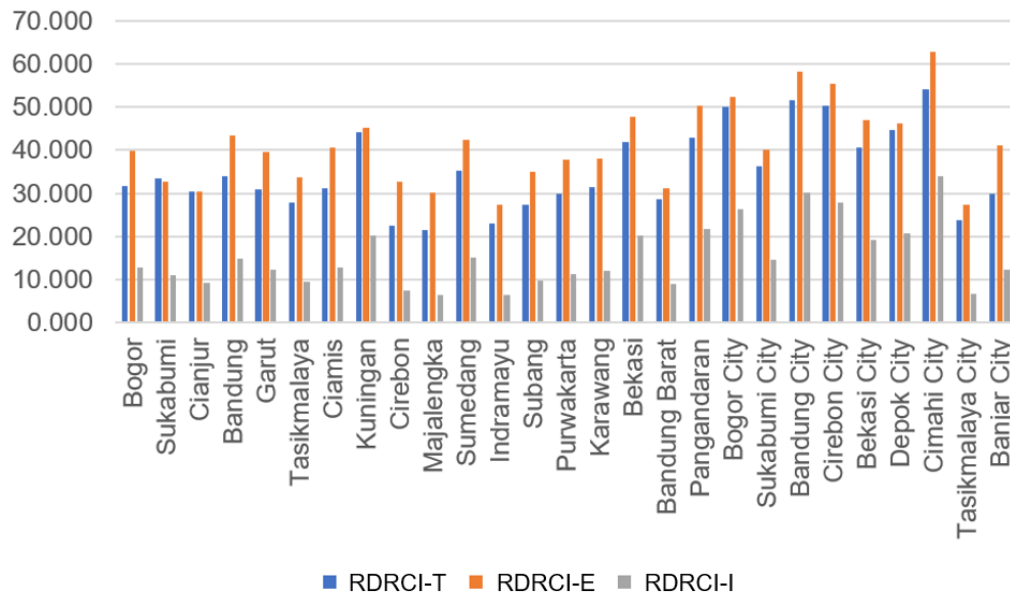


Figure 7. Comparison of Regional Disaster Resilience Composite Index (RDRCI)-T, RDRCI-E, and RDRCI-I patterns

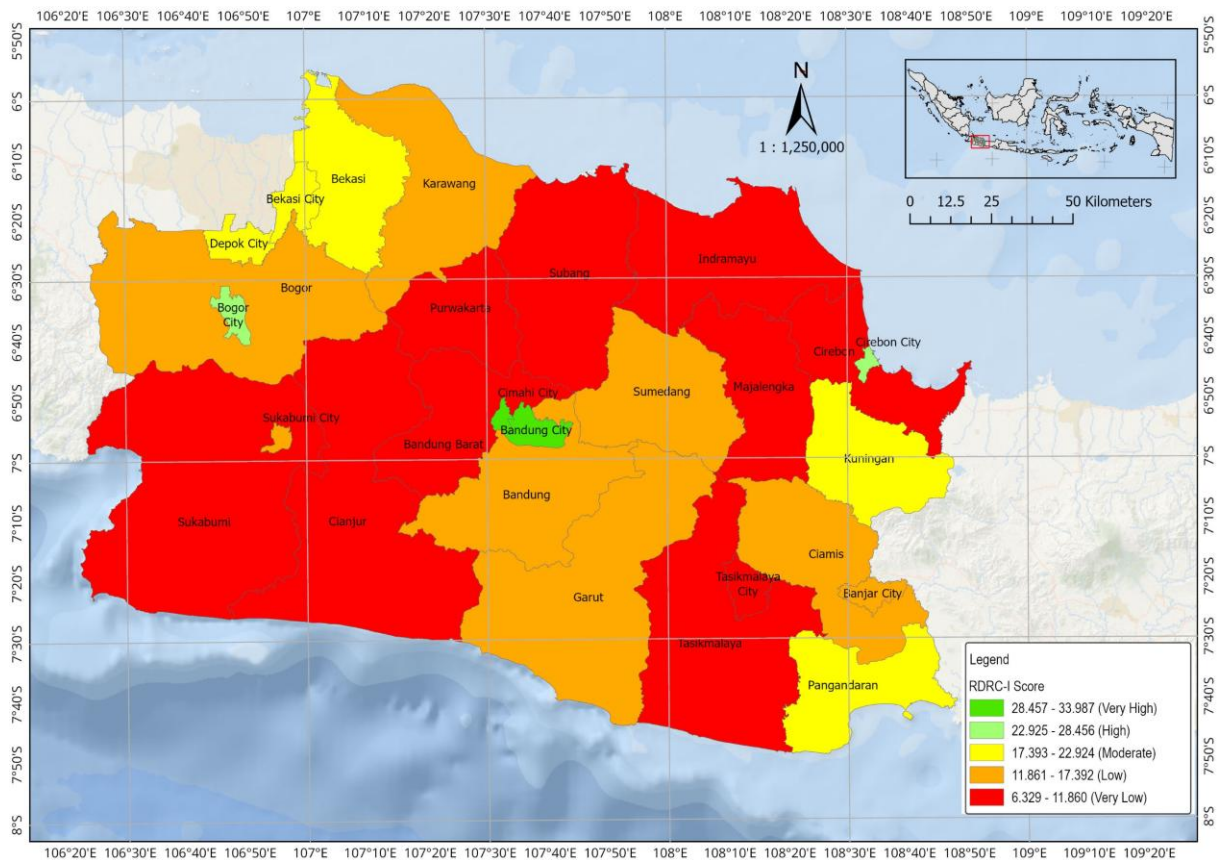


Figure 8. Map of the distribution of the integrated Regional Disaster Resilience Composite Index (RDRCI)-I values

As shown in Figure 7, different RDRCI calculation methods exhibited a high degree of similarity, indicating consistent and reliable results across the 27 regencies/cities. Although RDRCI-I and TOPSIS-based scores were generally lower than those of RDRCI-A, RDRCI-G, and RDRCI-H, they maintained the same ranking patterns and showed strong linear relationships, thus highlighting the significant influence of indicator weighting on assessment outcomes. The overall patterns were largely consistent, with Cimahi City consistently achieving the highest score, and the RDRCI-T rankings closely mirroring those of RDRCI-I. These findings demonstrated that integrated assessment approaches provided more robust and informative decision support, particularly when the number of indicators was large and internal disparities were substantial.

Figure 8 illustrates that the RDRCI values ranged from 6.33 to 33.98 across the 27 regencies and cities. A total of 9 regencies/cities had RDRCI values exceeding the provincial average of 15.26, while the remainder fell below this threshold. The highest score was observed in Cimahi City (33.98), whereas the lowest value was found in Indramayu (6.33). Cimahi City and Bandung City exhibit the highest levels of resilience (range from 28.457 to 33.987), which are attributed to relatively low rainfall intensity and disaster risk, as well as the presence of EWS and river normalization initiatives. Overall, the results indicated that the combined use of the Shannon entropy and TOPSIS methods yielded rankings that more closely aligned with the integrated index. This underscores the significance of applying weights in composite index calculations, as doing so helps address disparities among indicators that influence regional disaster resilience.

3.3 Regional Disaster Resilience Composite Index from a Development Area Perspective

West Java Province divides its territory into six development areas (Wilayah Pengembangan, WP), namely WP Bodebekpunjur, WP Purwasuka, WP Ciayumajakuning, WP Pratiim-Pangandaran, WP Sukabumi, and WP Special Area of Bandung Basin. The purpose of dividing the territory into development areas (WP) is to optimize the potential and resources of each region, as well as to encourage sustainable and equitable economic growth throughout the province. This division allows more focused and effective planning and implementation of development policies, in accordance with the unique characteristics of each region.

The Bodebekpunjur Development Area (WP Bodebekpunjur), comprising Bogor, Depok, Bekasi, and Cianjur, emphasizes metropolitan development driven by industry, trade, and services, alongside the promotion of agropolitan areas in buffer zones to enhance regional connectivity through transportation and logistics infrastructure. Similarly, the Ciayumajakuning Development Area (WP Ciayumajakuning), covering Cirebon, Indramayu, Majalengka, and Kuningan, focuses on agriculture-based development, including fisheries and livestock, while optimizing coastal and marine resources and promoting tourism based on natural and cultural assets. The Pratiim-Pangandaran Special Region further integrates agriculture, agro-industry, fisheries, mining, and tourism within a framework that includes conservation areas, buffer zones, and tourism activity zones.

In contrast, the Purwasuka Development Area (WP Purwasuka), consisting of Purwakarta, Subang, and Karawang, has emerged as a strategic economic corridor and major industrial hub supported by national infrastructure projects, integrating industrial, residential, and commercial functions within a smart city framework. Its development is driven by industrial-based economic activities, particularly in the electric vehicle (EV) sector, alongside infrastructure expansion. Meanwhile, the Sukabumi Development Area (WP Sukabumi) prioritizes nature-based tourism and agro-based development, while the Bandung Basin Special Region (WP Kawasan Khusus Cekungan Bandung) focuses on metropolitan development emphasizing cultural identity, tourism, and integrated infrastructure.

Figure 9 shows that the development area with the lowest GRDP per capita is WP Pratiim-Pangandaran, where the average GRDP value was only 6.18. WP Pratiim-Pangandaran is largely dependent on the agriculture, fisheries, and forestry sectors which have relatively low economic added value, compared with the industrial or service sectors. This heavy reliance and the low contribution of these sectors has a direct impact on GRDP per capita. Unlike other WPs such as the Bandung Basin Area or Ciayumajakuning which have industrial areas and trade centres, WP Pratiim-Pangandaran is relatively lagging behind in terms of large-scale manufacturing and service industry investment. This limits the potential for regional economic growth, particularly when this area consists mostly of rural areas with low urbanization. Cities in this development areas, such as Pangandaran or Ciamis, have not yet developed into large economic centers, so the economic scale and productivity per capita are still limited. Accessibility and connectivity between regions, especially transportation and logistics, are still challenges in WP Pratiim-Pangandaran. This has an impact on the limited movement of goods, services, and people that can support economic growth. The availability of skilled labor and the level of education in the community of this region tend to be lower than other development areas; this affects the productivity and ability of the region to attract high value-added economic sectors. Although development areas such as Pangandaran Beach has a great potential to attract tourism, its management and supporting infrastructure for tourism are not yet optimal. As a result, the tourism sector has not been able to provide maximum contribution to GRDP per capita.

The poverty rate can describe the ability of the community in the area to mitigate and recover from disasters. WP Ciayumajakuning had the highest poverty rate in 2022. This area has a fairly large disparity in development.

Cirebon City has a relatively more advanced level of development, while Indramayu and Kuningan Regencies have quite high poverty rates. This inequality causes the average poverty rate of development areas as a whole to be high. Most areas in Ciayumajakuning, especially Indramayu and Kuningan, are still very dependent on the agricultural sector, especially food crops and plantations. This sector tends to have low productivity and added value, and is very vulnerable to weather and price fluctuations, making it less capable of significantly increasing people’s income. Several regencies in this development areas still face limitations in terms of access and quality of basic services, especially education and health. This has a direct impact on the low quality of human resources (HR), which then strengthens the cycle of poverty. Cirebon City is indeed relatively advanced, but other areas have not yet developed enough in terms of urban or industrial development. As a result, job opportunities in the formal sector are limited, and people work more in the informal or seasonal sectors. Many individuals depend on informal economic activities, such as street vending, culinary MSMEs, and seasonal or agricultural labor, which are characterized by irregular and uncertain income. Areas like Indramayu are known as migrant worker enclaves. Many households depend on remittances from family members abroad, which are not always stable and do not create strong local economic resilience. Although some residents are employed, underemployment, especially in the agricultural sector, is serious. This means they work less than full hours and have low productivity, leading to poverty. Although Ciayumajakuning has begun to receive attention with the development of infrastructure such as Kertajati Airport and Patimban Port, their utilization is not optimal and does not have a positive impact on the welfare of the poor in the area.

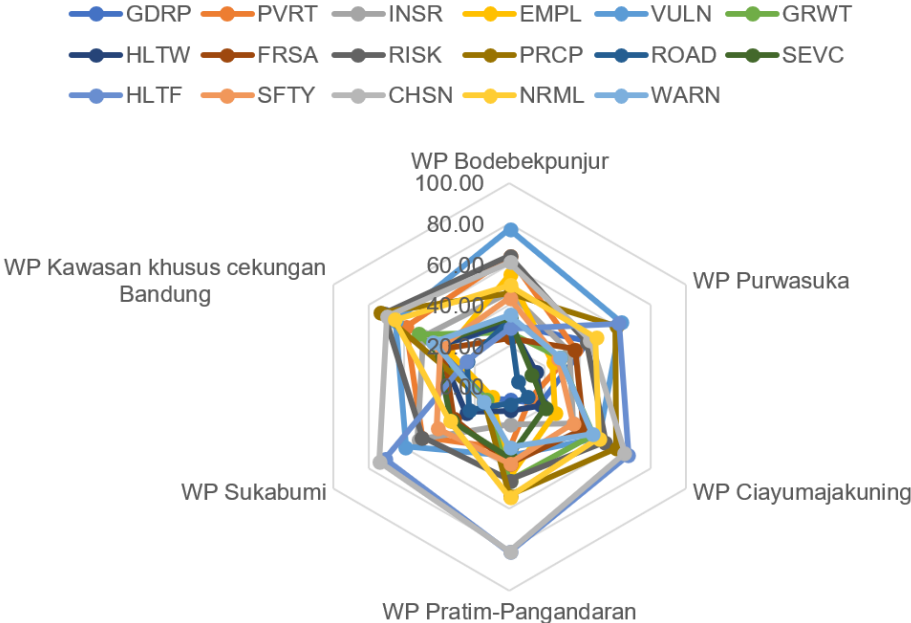


Figure 9. Radar diagram of indicators affecting each development area in West Java Province

The lowest level of population participation in health insurance was in WP Pratim-Pangandaran. This rate was influenced by low community income, minimal literacy and awareness of the importance of health insurance, and limited access to health service facilities and information. Besides, many residents have not been registered in the contribution assistance scheme, and traditional lifestyles that still rely on alternative medicine contribute to the low participation in the health insurance program.

In the social dimension, the lowest employment rate in West Java Province was found in WP Sukabumi, where the informal sector such as subsistence farming and seasonal work dominated and these could not be recorded as permanent jobs. In addition, the level of education and skills of the workforce is limited, rendering access to the formal labor market difficult. A lack of employment opportunities in modern industry and services also cause many working-age residents not being optimally absorbed in productive economic activities.

Another social dimension is the number of vulnerable population, WP Pratim-Pangandaran had the highest value because it is dominated by rural areas with low urbanization rates and there was a tendency for productive age population migrating to work in big cities. As a result, the composition of the remaining population consists mainly of children, the elderly, and other vulnerable groups. In addition, the relatively high birth rate and slackening economic growth have strengthened the dominance of vulnerable age groups in this area.

For population growth rate, WP Sukabumi was the region recorded with the highest growth rate in West Java because it had experienced a significant increase in infrastructure and housing development, especially as a buffer zone for Jakarta and Bogor. This condition encourages inflow of migration from other regions, especially by

productive age residents who are looking for more affordable housing or job opportunities in the informal sector. The relatively high birth rate in rural areas also contributes to rapid population growth.

The number of health workers in WP Pratiim-Pangandaran was the lowest in West Java because this area was dominated by rural and remote areas with limited accessibility, rendering it less attractive for health workers to work. In addition, limited health facilities and regional budget support are obstacles in the equal distribution and placement of medical personnel in this area.

While forest area is one of the indicators in the ecological dimension, the least forest cover area was WP Bodebekpunjur because it was a metropolitan area experiencing the most rapid urbanization and infrastructure development. High population growth and expansion of settlements, industry, and public facilities have caused massive land conversion from green areas to built-up areas, thus significantly reducing the forest cover area.

The highest disaster risk was recorded in WP Purwasuka in West Java because this area had a combination of complex geographical and geological factors, such as being on an active fault line and close to areas prone to flooding and landslides. Apart from high population density, massive land conversion and suboptimal disaster mitigation infrastructure increase their potential impact when a disaster occurs, raising the risk level to the highest compared with other development areas.

The highest rainfall in West Java occurs in the WP Sukabumi area because this area has a mountainous topography that triggers the formation of rain clouds through the orographic process. Moreover, its proximity to the Indian Ocean enables WP Sukabumi to receive more water vapor from the sea, so the intensity of rain tends to be higher than other areas.

In terms of infrastructure, the lowest ratio of road length in West Java was recorded in WP Purwasuka because this area had a high population density and rapid urbanization rate. Yet, the development of road infrastructure is not yet balanced with regional growth. Land conversion and limited space for the development of road network also restrict the increase in the road length ratio in this area. Meanwhile, the lowest number of signs and evacuation routes were recorded in WP Purwasuka. The lowest signs and disaster evacuation routes in WP Purwasuka were caused by the high level of urbanization and development that had not been balanced with adequate disaster planning. Limited open space, lack of socialization, minimal integration of evacuation maps, and plans and procedures in urban spatial planning affect placing the provision of signs and evacuation routes the top priority in the infrastructure of this area.

Furthermore, for the institutional dimension, the area with the lowest safety equipment was WP Purwasuka. The WP Purwasuka area had the lowest safety equipment in West Java because the rapid population growth and urbanization had not been followed by the provision of adequate safety facilities. In addition, budget allocation and policy priorities were more focused on physical development and basic infrastructure; aspects of disaster preparedness still receive less attention.

As regards the indicator of mutual cooperation habits, the lowest value was noted in WP Purwasuka because this area was dominated by urban areas with high population mobility and a large level of social heterogeneity, so social ties between residents tended to be weak. The individualistic lifestyle developed in urban environments and the lack of free time for people to engage in collective activities also reduce the practice of mutual cooperation in this area.

Preventive activities in the form of river normalization were conducted the fewest in WP Sukabumi among the regencies/cities in West Java. WP Sukabumi has many areas with mountainous contours and small rivers that are scattered, so access to and technical intervention of normalization become more difficult and require considerable costs. Limited regional budgets and the lack of integrated programs for river management mean that normalization efforts are not carried out routinely or evenly throughout the region.

WP Sukabumi was also the region with the lowest availability of EWS. The implementation of EWS is still low in this development area, owing to inadequate communication and technological infrastructure in its large coverage of rural and remote land. Local institutional awareness and capacity in building EWS are also limited; therefore, the implementation of early disaster detection technology has not been a top priority even though this region has a fairly high potential for disaster risk.

Figure 10 illustrates that the WP Special Area of Bandung Basin dominated the top RDRCI ranking with various measurement methods, compared with other Indonesia WP which had an average of 41.20 while the highest documented RDRCI was 48.92. Based on the calculation, the lowest RDRCI of 30.24 was registered in WP Purwasuka.

From the perspective of transportation networks, West Java Province was categorized into three regional corridors: the Northern Coastal Route (Pantura), the Southern Coastal Route (Pansela), and the Central Route. As illustrated in Figure 11, the Central Route demonstrated the highest level of resilience. In contrast, the lowest resilience was observed in areas along the Pansela route. This is primarily due to the higher disaster risk associated with the Southern Coastal Route compared with the Northern Coastal Route. The Pansela corridor features more varied geography and topography, including rugged terrain and steep coastal slopes, rendering it more susceptible to natural hazards. The southern part of Java, where Pansela is situated, faces greater exposure to disasters such as earthquakes, landslides, and tsunamis, due to its proximity to a subduction zone and tectonic plate boundaries.

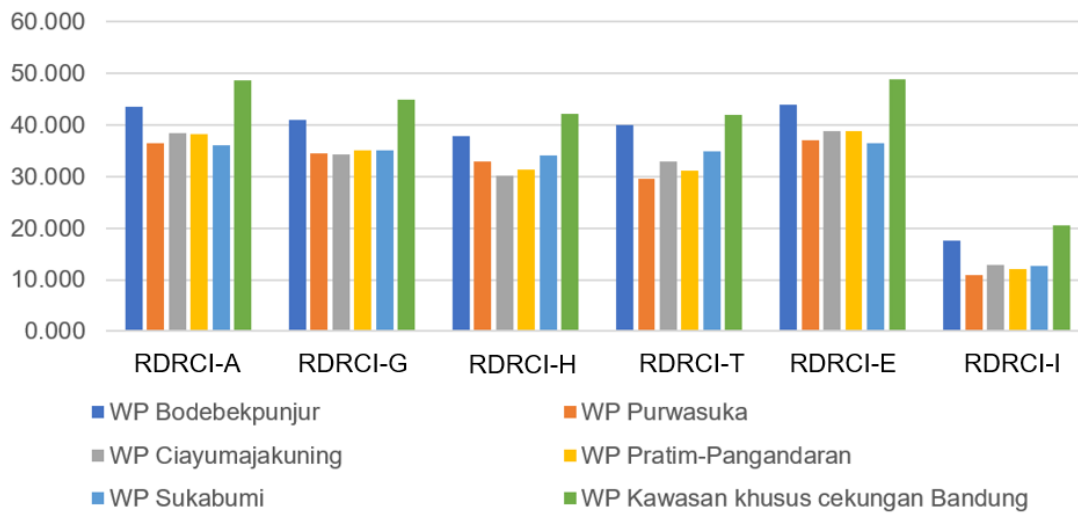


Figure 10. Regional Disaster Resilience Composite Index (RDRCI) grouping by development area in West Java Province

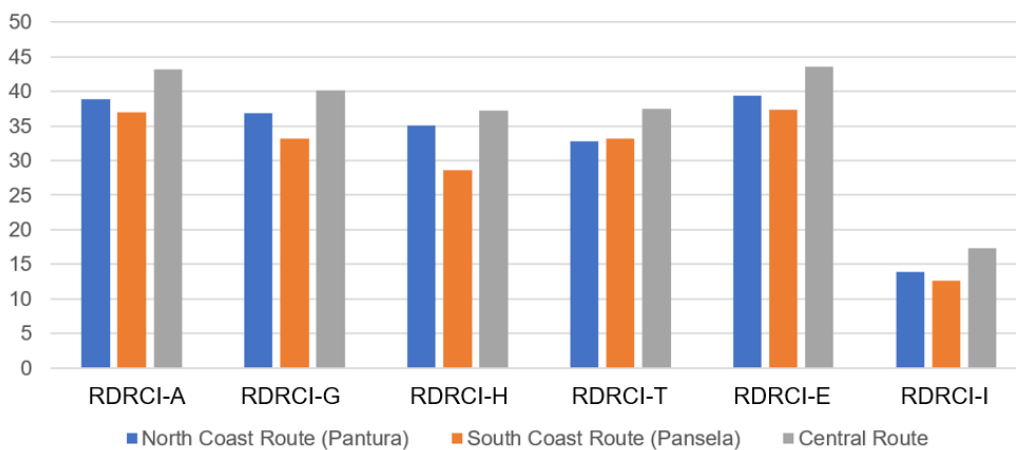


Figure 11. Regional Disaster Resilience Composite Index (RDRCI) grouping by transportation networks in West Java Province

4. Discussion

For RDRCI-A, RDRCI-G, RDRCI-H, RDRCI-T, RDRCI-E, and RDRCI-I, the Bodebekpunjur Development Area and the Special Area of the Bandung Basin consistently exhibited the highest values compared with other regions. The patterns produced by the six methods are largely similar though differ primarily in magnitude. The consistency of the graphical patterns observed under various aggregation and weighting approaches suggests that the model is robust. This suggests that the method is both reliable and consistent when applied, aligning well with the specific context of West Java Province. The findings carried significant implications for the measurement of disaster resilience in the region. Firstly, efforts to enhance regional disaster resilience should take into account all relevant dimensions, not only economic, ecological, and social, but also infrastructural and institutional factors. Focusing on individual dimensions in isolation risks generating biased outcomes. Besides, the typological characteristics of development areas across the province vary, thus necessitating tailored approaches in resilience assessment.

For the economic dimension, it was dominated by WP Purwasuka, Bodebekpunjur and Sukabumi. WP Purwasuka dominated the GRDP indicator. This is in line with the high industrial activity in the region. The Purwasuka development area (Purwakarta, Subang, and Karawang) excelled in GRDP compared with other development areas in West Java due to the strategic combination of geographical location, strong manufacturing industry base, and supporting infrastructure. The Purwasuka area is one of the largest manufacturing industry centres in Indonesia, especially Karawang and Purwakarta. There are international industrial areas such as Karawang International Industrial City (KIIC), Suryacipta, and Bukit Indah Industrial Park as well as leading industries including automotive, electronics, food and beverages, and logistics. The contribution of the processing

industry sector to the GRDP of this region is notable. WP Purwasuka serves as a strategic connector between The Special Capital Region of Jakarta (DKI Jakarta) and Central Java, supported by its location along major transportation corridors, including the Jakarta–Cikampek Toll Road, railway networks, and the Pantura (North Coast) Route, thus forming an ideal location for logistics and distribution of goods. This accessibility attracts a lot of domestic and foreign investment (PMA/PMDN). The strength of the economy represented by the GRDP value could also indicate the enhancing resilience of the region (Cardoni et al., 2021; Zhou et al., 2022).

Meanwhile, the Bodebekpunjur region exhibits relatively low poverty rates, which can be attributed to its proximity to Jakarta, the center of national economic activity. This strategic location provides access to a broad labor market, particularly in the formal sector, while also offering diverse economic opportunities across the service, industrial, and informal sectors. In addition, the region benefits from more advanced investment flows and well-developed infrastructure connectivity. The poverty rate in the Bodebekpunjur area was the lowest because this area could benefit directly from its proximity to Jakarta, rapid urbanization, more economic opportunities, and convenient infrastructure and public services. The combination of geographic, economic, and social factors facilitate the area to become more resilient to poverty than other areas in West Java. The poverty rate is inversely proportional to the resilience of the area, where the lower poverty rate is conducive to its accelerating resilience (Cao et al., 2023).

The indicator of community participation in health insurance was dominated by WP Sukabumi. The high level of community participation in health insurance in WP Sukabumi was due to the high proportion of vulnerable residents, strong support from local governments, the active role of local facilitators, and high awareness and values of social solidarity in the community. Support from the centre through the contribution assistance (PBI) scheme is also significant. Most of the population working in the informal sector, such as farmers, farm laborers, fishermen, or MSME actors tends to be more vulnerable to health risks and medical costs, so awareness of the importance of health insurance is higher. Many of them are registered as PBI recipients, whose contributions are paid by the central or regional government. Health insurance is related to regional resilience because when there is an external disturbance that affects health, the chance of recovery will be higher if the residents have subscribed to health insurance (Qiao & Pei, 2022; Shi et al., 2023).

In respect of the social dimension, it was dominated by WP Bodebekpunjur and the Bandung Basin Special Area. WP Bodebekpunjur dominated the indicator of a relatively high employment rate and a relatively low number of vulnerable population. The Bodebekpunjur area had the highest employment rate due to direct access to the national economic centre, labor-intensive economic structure, high connectivity, rapid urbanization, and concentration of industrial and service areas. These factors encourage the creation of broad and diverse employment opportunities, hence absorbing more working-age residents in the workforce. The higher the average employment rate is, the greater the regional resilience will be (Lu et al., 2023; Rahimi et al., 2023; Yang et al., 2022).

The Bodebekpunjur area was the main destination of urbanization from other areas because of its proximity to Jakarta. Many working-age migrants (15–64 years) migrated to this area to find jobs in the industrial, service, and informal sectors. As a result, the demographic composition was dominated by the productive age population, not the vulnerable age group such as the elderly. Apart from these, the number of vulnerable population in the Bodebekpunjur area was the lowest owing to a relatively low birth rate. Factors of urbanization, economic structure, and migration patterns greatly influence the demographic composition that is “younger and more productive”, compared with other development areas in West Java Province. Previous studies proposed that the high number of vulnerable population would affect the resilience of the region (Feofilovs & Romagnoli, 2021; Narieswari et al., 2022).

WP Bandung Basin Special Area dominated the indicator of a relatively low population growth rate and a relatively high number of medical personnel compared with other areas in West Java. The Bandung Basin is an urban and metropolitan area that has experienced an advanced demographic transition, as characterized by a declining birth rate and reducing natural growth (births minus deaths). People in this area generally have a higher level of education, access to family planning services, and an urban lifestyle that encourages delayed marriage and having fewer children, so this condition reduces the natural population growth rate. The number of medical personnel in the Bandung Basin Special Area is relatively high because this area is an administrative centre for educating and training health workers with tertiary health facilities, so as to confront the high demand for services in the face of urbanization. A combination of these factors enables this area to be structurally attractive and to accommodate more medical personnel than other development areas in West Java. The number of medical personnel could therefore affect regional resilience (Liu et al., 2021; Wang & Long, 2023).

Regarding the ecological dimension, it was dominated by WP Ciayumajakuning and WP Bandung Basin Special Area. WP Ciayumajakuning dominated the indicator of forest cover area while WP Bandung Basin Special Area dominated the indicators of disaster risk and rainfall. The overall forest cover area in West Java Province increased from 642,843.71 hectares in 2016 to 669,897.10 hectares in 2022, an increase of 27,053.39 hectares. Kuningan had the highest proportion of forest cover area, namely 36.80%. Forest cover area is one of the indicators that affects regional resilience (Huang et al., 2020; Liu et al., 2021; Lu et al., 2023). A high proportion of forest cover

area could prevent disasters and reduce the impact of the disaster itself. The area of green cover also reflects a good ecosystem that has the capacity to accommodate and store water, thereby increasing resilience.

The infrastructural dimension was dominated by WP Bodebekpunjur, WP Special Area of Bandung Basin and WB Prati-m-Pangandaran. WP Bodebekpunjur dominated the road area indicator. The ratio of road length in WP Bodebekpunjur (Bogor, Depok, Bekasi, Puncak, and Cianjur) was the highest compared with other development areas in West Java Province because this area had a strategic function as a metropolitan area and urban agglomeration centre, which drove the need for and development of road infrastructure intensively. WP Bodebekpunjur is often a priority for national strategic projects (PSN), such as the 100 Smart City Program and connectivity infrastructure projects for the construction of toll roads and non-toll roads. The central and provincial governments allocate a large budget for building roads in this area so that the volume of road projects in this area is greater than other development areas. Road areas would positively affect regional resilience (Shi et al., 2022; Wang et al., 2023) by enlarging the capacity of transportation service to increase resilience.

WP Bandung Basin Special Area dominated the indicator of availability of signs and evacuation routes. WP Bandung Basin Special Area had the highest number of signs and evacuation routes compared with other development areas in West Java Province due to a combination of high disaster potential, population density, strategically regional function, and institutional preparedness. The Bandung Basin is located in an area with multiple hazards, including active volcanoes (Mount Tangkuban Parahu, Mount Malabar, and Mount Patuha), the Lembang Fault, active and passing through densely populated residential areas, and probabilities of landslides and flooding on mountain slopes and the Citarum River, respectively. This has led the government to identify this area as a high-risk zone, so a complete warning and evacuation maps, plans, and procedures are needed. In addition, Bandung is the capital city of West Java Province, where governmental, educational, economic, and regional transportation activities take place. Many government offices, strategic public facilities, and crowded centres must have minimum disaster mitigation standards, including evacuation routes, disaster signs, and emergency gathering points. Evacuation routes are one of the most important things in regional resilience (Carvalhoes et al., 2021; Kim et al., 2023). The number of signs and evacuation routes increases resilience by offering ease of saving lives and securing property during a disaster.

WP Prati-m-Pangandaran dominated the indicator of availability of health facilities. The ratio of health facilities in the East Priangan Development Area (Prati-m-Pangandaran) was relatively high compared with other development areas in West Java Province due to the affirmative policy of developing disadvantaged areas, tackling geographic factors, and committing strongly to basic services. Several regencies in WP Prati-m such as southern Tasikmalaya, southern Garut, and Pangandaran were previously included in the category of underdeveloped or disadvantaged areas. The regional and central governments (Ministry of Health, Ministry of Home Affairs, Bappenas) are encouraging increased access to basic services through the construction of new Community Health Centres, upgrading the status of Community Health Centers, and adding Assistant Community Health Centers (Pustu), Village Health Centers, and Village Health Posts. These measures increase the ratio of health facilities per population. The availability of health facilities reflects regional resilience (Ye et al., 2022). The more health facilities there are, the larger the health security capacity of a region becomes.

As regards the institutional dimension, it was dominated by WP Bodebekpunjur, WP Prati-m-Pangandaran, WP Special Area of Bandung Basin, and WP Ciayumajakuning. WP Bodebekpunjur dominated the indicator of the number of villages that prepare disaster safety equipment. Meanwhile, WP Prati-m-Pangandaran dominated the indicator of the number of villages whose communities have the habit of mutual cooperation. The East Priangan-Pangandaran Development Area (WP Prati-m-Pangandaran) had the largest number of villages with the habit of mutual cooperation compared with other development areas in West Java due to cultural, social, and geographical factors that still strongly maintain the collective values of traditional communities. The Prati-m-Pangandaran area is part of the Tatar Sunda Priangan, which is very rich in local cultural values such as *Sabilulungan* (working together), *Sauyunan* (one heart), *Silih asah, silih asih, silih asuh* (educating, loving, and guiding each other). These values are internalized in the lives of village communities, especially in activities such as building houses, repairing village roads, and joining community services. Many villages in Prati-m still actively run traditional social institutions, such as *Lembur Tohaga*, *Karang Taruna*, Customary Institutions, Farmer Groups, *Gotong Royong* Groups, and community religious studies. These institutions encourage routine mutual cooperation, especially during harvests, celebrations, or local disasters. This institutionalizes the spirit of mutual cooperation in village life. The habit of mutual cooperation reflects the solidarity of the community so that it could be more resilient. Good social cohesion will increase regional resilience (Shi et al., 2022).

WP Bandung Basin Special Area dominated the indicators of normalization activities carried out by villages that are crossed by rivers. WB Bandung Basin Special Area has a relatively high number of villages carrying out river normalization activities compared with other development areas in West Java Province due to a combination of flood-prone geographical conditions, dense settlements, environmental degradation, and strong institutional responses to and community participation in environmental issues. The Bandung Basin is a bowl-shaped basin (natural basin), so rivers such as the *Cikapundung*, *Citarum*, and their tributaries flow into and are retained in this area. When it rains heavily, water easily overflows and causes local flooding in lowland villages. This condition

renders river normalization an urgent need to maintain smooth water flow and reduce the risk of inundation. Many villages in the Bandung Basin have environmentalist communities, such as the Waste Bank, the Clean Cikapundung Community, and the Zero Waste Movement. These communities often initiate river normalization as part of education and joint action. River normalization activities reflect disaster prevention and mitigation efforts to make the region more resilient (Carvalhaes et al., 2021; Zhang et al., 2020).

WP Ciayumajakuning dominated the indicator of the number of villages that have an EWS. Indramayu and Cirebon are prone to tidal flooding, river flooding, and extreme weather owing to its geographical location on the north coast of Java. Majalengka and Kuningan are prone to landslides, flash floods, and earthquakes due to their proximity to active faults and mountain slopes (Ciremai). These disasters occur repeatedly and are predictable, so it is easier for villages to adopt EWS based on sensors, sirens, or SMS gateways. The clarity of disaster patterns makes EWS a relevant and effective investment. This area receives a lot of attention from the Provincial and BPBDs, mitigation programs from non-governmental organizations (NGOs) such as Mercy Corps, PLAN, or other local environmental NGOs, and corporate social responsibility (CSR) funding from industrial companies (especially in the Pantura area). Many villages in Ciayumajakuning receive grants or training in community EWS development, especially for floods and extreme weather. Ciayumajakuning is an area with a high level of village risk reporting and mapping, especially since the “Disaster Resilient Village (Destana)” program was launched. These villages have disaster-prone maps, evacuation standard operating procedures (SOPs), routine simulations, and EWS devices such as automatic sirens, communication radios, or standby Whatsapp groups. The community is active in mutual cooperation, disaster preparedness patrols, and local volunteer communities (village TAGANA, PRB Forum). EWS reflects mitigation efforts in the form of early warnings in the region to ensure timely communication and rescue, so that the region could become more resilient (Narieswari et al., 2022).

Based on the foregoing discussion, the integrated TOPSIS–Entropy approach was considered the most suitable method for constructing a composite index, as it combines the strengths of objective and data-driven weighting with robust ranking performance. This hybrid technique addresses the limitations of single-method approaches by incorporating entropy-based weights within a distance-based evaluation framework. Consequently, the integrated method yields more consistent and rational results as well as providing a closer representation of real-world conditions.

5. Conclusions

Based on the available regional data, the composite index approach produced an integrated RDRCI, which is practical and easy to be applied at the regency and city levels. This study highlighted the importance of strengthening regional disaster resilience through a new measurement paradigm based on 17 key indicators specifically for West Java Province. The results provided a useful reference for local governments to design interventions, monitor resilience performance, and evaluate policy outcomes. This approach is aligned with national regulations, including laws on disaster management, spatial planning, and regional governance that emphasizes risk reduction, community participation, and institutional responsibility.

The RDRCI reflects overall resilience across regions, where higher scores indicate stronger disaster resilience. The findings showed that high performance in one or two dimensions did not guarantee high overall resilience, thus emphasizing the requisite for balanced development across economic, social, ecological, infrastructural, and institutional dimensions. Focusing on a single dimension is considered insufficient because other dimensions could moderate its impact. The composite index offers an integrated and evidence-based tool that supports comparative regional analysis and informed policy-making. Nevertheless, the present study did not fully encompass all *Asta Gatra* dimensions, especially aspects of ideology and politics, due to limited availability of reliable and disaggregated data at the regency/city level in West Java Province. The findings should therefore be interpreted as data-driven approximation rather than within a complete *Asta Gatra* framework. Future studies on disaster resilience in Indonesia are encouraged to incorporate ideological and political dimensions, in order to produce a thorough assessment in line with the *Asta Gatra* framework.

Author Contributions

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

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Data Availability

This study adopted secondary data from the Central Statistics Agency of West Java Province, the Regional Disaster Management Agency of West Java Province, and the Ministry of Environment and Forestry of the Republic of Indonesia.

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Conflicts of Interest

The authors declare no conflicts of interest.

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