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Multi-Criteria Decision Approach: An Evaluation Of Coastal Tourism Vulnerability In The Mandalika, Indonesia

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ABSTRAK

Perubahan iklim menjadi topik perhatian dunia pada abad ke-21 karena dianggap sebagai ancaman serius makhluk hidup, terutama lingkungan dan kemanusiaan. Perubahan iklim diperkirakan akan memiliki dampak besar di sektor pariwisata pesisir di seluruh dunia. Pada saat yang sama, sekitar 50% pariwisata dunia berada di daerah pesisir. Salah satu isu mendasar bagi perencana pariwisata pesisir adalah perubahan lingkungan. Paper ini menyajikan aplikasi kerangka kerja model untuk manajemen dan pembangunan berkelanjutan pariwisata pesisir dalam menghadapi perubahan iklim di Kawasan Mandalika, Indonesia. Tujuan penelitian ini untuk mengkaji kerentanan, kriteria penting, dan alternatif untuk permasalahan pariwisata pesisir di kawasan Mandalika. Sumber data yang digunakan yakni data primer (interview dengan pakar ahli) dan data sekunder (kajian literatur). Metode yang digunakan Analytical Hierarchy Process (AHP) dilakukan dalam perangkat lunak Multi Criteria Decision Making (MCDM) untuk manajemen bahaya pariwisata pesisir. Pendekatan ini memungkinkan para pengambil keputusan untuk mengevaluasi dan mengidentifikasi prioritas relatif kerentanan dan kriteria bahaya serta sub-kriteria berdasarkan seperangkat preferensi, kriteria, dan alternatif. Paper ini juga menyajikan desain alternatif kebijakan yang diterapkan di Kawasan Mandalika untuk memilih bobot berkelanjutan yang penting dari kriteria dan sub-kriteria. Hasil penelitian menunjukkan bahwa aktifitas manusia menduduki bobot tertinggi sebagai kriteria yang mempengaruhi kerentanan pariwisata di Kawasan Mandalika. Adapun sub kriteria terkait pembangunan jalan menjadi faktor yang mempengaruhi kerentanan pariwisata di kawasan pesisir mandalika. Lebih lanjut, alternatif yang menjadi pilihan sebagai respon solusi kerentanan adalah tindakan adaptasi secara persistent. Oleh karena itu diharapkan penelitian ini mampu mengatasi permasalahan kerentanan akibat perubahan iklim, terutama di sektor pariwisata melalui sinergitas seluruh pelaku yang terlibat melalui rekomendasi kebijakan.

***Kata kunci*:** Perubahan iklim, Pariwisata pesisir, Kerentanan, AHP, Mandalika

ABSTRACT

Climate change has emerged as a global concern in the 21st century, posing a significant threat to ecosystems and human populations. The impact of climate change on coastal tourism sectors is expected to be substantial, particularly given that roughly 50% of global tourism is concentrated in coastal regions. Environmental change presents a fundamental challenge for coastal tourism planners, necessitating the application of a model framework to manage and promote sustainable development in the face of climate change. This study focuses on the application of such a framework in the Mandalika Region of Indonesia, with the primary objective being the assessment of vulnerability, key criteria, and potential solutions for coastal tourism issues in the area. The research draws on both primary sources, such as interviews with expert specialists, and secondary data through a comprehensive literature review. The research methodology utilizes the Analytical Hierarchy Process (AHP) within the context of Multi-Criteria Decision Making (MCDM) software for coastal tourism hazard management, enabling decision-makers to evaluate and prioritize vulnerability and hazard criteria and sub-criteria according to a set of preferences, criteria, and alternatives. The study also outlines a range of policy designs applied in the Mandalika Region to determine key sustainable weights from criteria and sub-criteria, with findings indicating that human activities carry the greatest weight as a criterion influencing tourism vulnerability in the Mandalika Region. The sub-criteria related to road construction are factors that influence tourism vulnerability in the Mandalika coastal area. Furthermore, the alternative that is chosen as a response to vulnerability solutions is persistent adaptation action. Therefore, it is hoped that this research will be able to overcome the problem of vulnerability due to climate change, especially in the tourism sector through the synergy of all actors involved through policy recommendations.

***Keywords*:** Climate change, Coastal tourism, Vulnerability, AHP, Mandalika

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1. Introduction

Climate change is widely recognized as the most prevalent environmental concern faced worldwide in the 21st century (Maulana & Nugroho, 2020; Suhermat et al., 2021). At the same time, nearly fifty percent of the world's tourism is located along the coastlines (Northrop et al., 2022). There have been significant alterations in weather patterns observed across different regions. Weather modifications encompass shifts in average precipitation levels, temperatures, and wind directions (IPCC, 2021). hese changes encompass variations in atmospheric conditions or norms over time periods ranging from decades to millions of years (O'Neill et al., 2020). Coastal tourism areas continually experience modifications in their physical structure and morphological attributes due to natural occurrences like increased precipitation, powerful waves, wind, rising sea levels, coastal erosion, and human interventions (Dong et al., 2024). Furthermore, land use along the coastlines has led to issues such as increased erosion, sedimentation, and damage to protected marine ecosystems (Saengsupavanich et al., 2023).

The presence of uncertain future climate poses a challenge in managing coastal environmental changes caused by global warming. Human factors in global changes introduce uncertainties that play a crucial role in assessing and adjusting to the impacts of climate change, such as rising sea levels and erosion (Bolan et al., 2024). Developing appropriate adaptation measures is a necessary step to address sea level rise in coastal tourism, thus requiring an evaluation of the impacts of sea level rise (Bongarts Lebbe et al., 2021). Understanding the vulnerability of coastal tourism can improve the capacity of scholars and decision-makers to forecast the potential consequences of rising sea levels and other effects of climate change (Santos-Lacueva et al., 2017). Therefore, this can help prioritize management efforts to reduce the risks that may occur in the future.

The most significant impact of climate change is the rise in sea levels, which is likely to accelerate in the 21st century, although the rate of acceleration is still unknown (Mimura, 2013). Studies conducted in the past regarding the increase in sea levels have revealed that climate change has led to a global rise in sea levels at a rate of +3.32 mm/year. Nevertheless, it is anticipated that there will be notable ramifications resulting from the escalation in sea levels (Jigena-Antelo et al., 2023). Over time, the stability of numerous floodgates across the globe is anticipated to be adversely affected by the changes in sea levels, waves, and river flows resulting from climate change (Griggs & Reguero, 2021).

Moreover, the human interventions along the coast within river basins, estuaries, and offshore areas contribute to the erosion of coastal tourism sites. One such example is the Mandalika coastal area, which stands as a symbol of pride for Indonesia, situated on the southern shoreline of Lombok Island. This particular area falls within a subduction zone, where the Indo-Australian plate intersects with the Eurasian plate, leading to geological instability along the coast (Minardi et al., 2023). Coastal regions characterized by sediment accumulation (alluvial) and located near subduction zones are susceptible to natural disasters, including seismic events and liquefaction.

Assessing the vulnerability of coastal tourism areas is of utmost importance for coastal change research as it aids in avoiding decisions made with inadequate data and inaccurate assessments, which may result in the depletion of coastal resources and infrastructure (CDKN, 2014). Previous studies on tourism in the Mandalika coastal area have not been conducted. This can be seen from the review of previous literature in Figure 1.

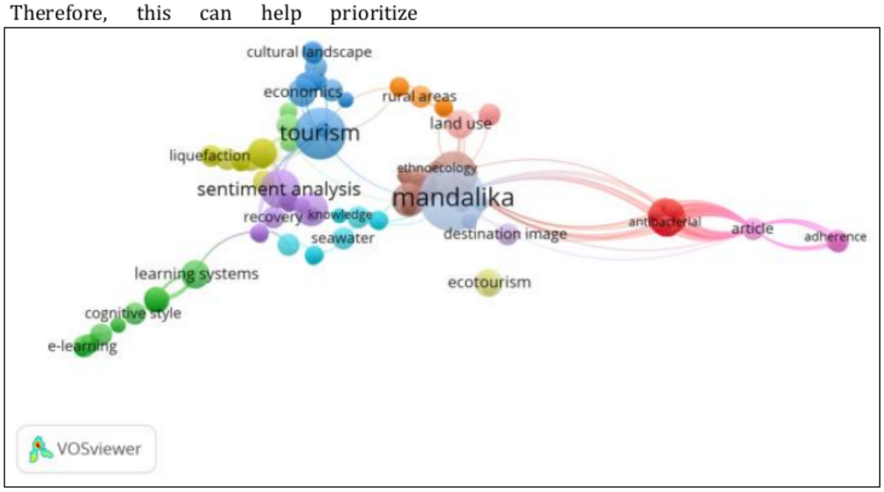

Figure 1 Previous literature review in Mandalika

The results of the literature review in Figure 1 show that the discussions that are often studied (shown by the increasingly large round shape) in the Mandalika area are related to sentiment analysis, tourism, ecotourism, antibacterial, economics, and others (Alaydrus et al., 2024; Aulia et al., 2024; Suryade et al., 2021). Therefore, research related to climate change in relation to tourism in coastal areas is the latest in this paper.

Furthermore, previous studies regarding the correlation of climate change and the coastal tourism sector, especially on the East Coast of America regarding the annual rate of change which can be used to implement preventive measures and describe the layout of coastlines that are likely to occur in the future (Capozzo et al., 2019). Alvarez (2024) research findings suggest that the adoption of landscape-level regenerative tourism practices could lead to coastal areas being converted into carbon sinks, ultimately leading to a more sustainable environment with a net increase in carbon sequestration.

Various prior research endeavors have employed decision-making techniques to assess crucial parameters when choosing criteria for assessing vulnerability to climate change in coastal regions. Research by Bagheri et al. (2021) shows that vulnerability due to climate change can be identified using climate change, environmental, coastal hazard, and human activity criteria. The research results show that human activities have the greatest weight in overcoming vulnerabilities due to climate change. Furthermore, research by Kibria et al. (2024) stated that adapting to climate change can involve preserving numerous buildings within the environment by implementing strategies such as persistent adaptation, anticipatory adaptation, or transformative adaptation. Truong & Jang (2019) explored and assessed the significance of elements contributing to the competitiveness of the coastal tourism sector in Southeast Asia. Chen et al. (2017) used the AHP method which resulted that the quality of infrastructure (road conditions, public transportation), the selection of the tourist destination was primarily influenced by the quality of tour guides and the range of tourism activities available. Andika & Subanu (2023) argue that the local government's perception of the impact of tourism dominates the economic impact. Based on previous literature discussions, the main objective of this research is to examine vulnerabilities, important criteria, and alternatives for coastal tourism problems in the Mandalika area.

2. Method

The Mandalika region is an area facing the Indian Ocean in the West Nusa Tenggara Province, Indonesia. It is situated between 8°32′30′′ S - 8°34′30′′ S and 116°16′ E - 116°20′ E. Figure 2 presents the coastal tourism facing the Bali Sea. The research area covers the coastline of the Mandalika region.

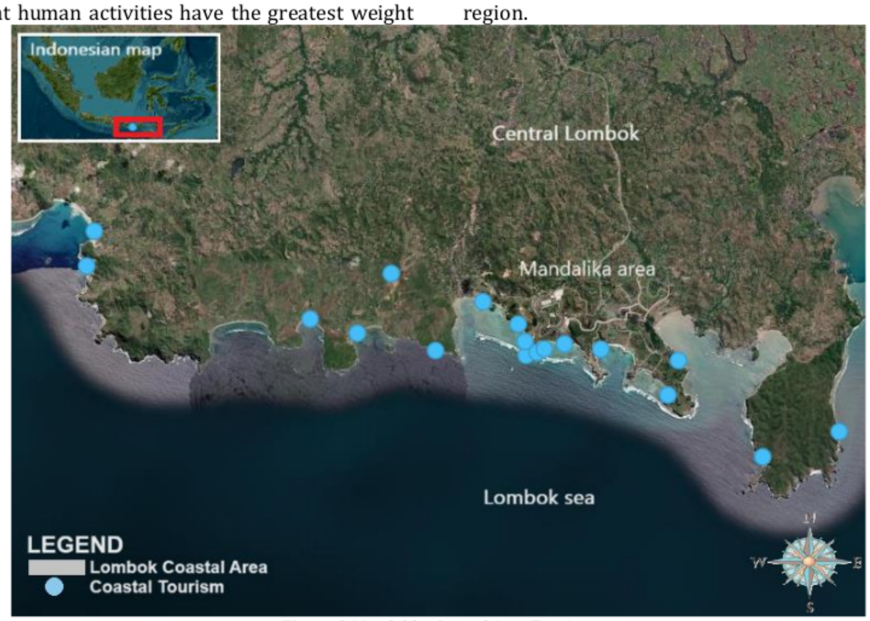

Figure 2 Mandalika Coastal Area Tourism

The majority of activities in the Mandalika area are focused along the coast, so the monitoring process is considered very important to identify locations in coastal tourism that are vulnerable to erosion or abrasion. The significant intensity of coastal erosion and its strategic location meant that the Mandalika area was chosen as the area for this research. Sustainable coastal tourism is a popular tourist activity, especially along the Mandalika coastal area. Therefore, this area needs to be developed as an economic corridor to help the Mandalika area experience socio-economic changes.

This paper uses the AHP method to identify vulnerabilities, criteria and alternatives for coastal tourism problems in the Mandalika area which requires qualitative analysis of coastal area information. In AHP, it is important to create a hierarchy by establishing the basic elements of the problem. This model assigns weights to variables using pairwise comparisons at each hierarchical level. AHP consists of two main parts, namely qualitative design and semi-quantitative design. These designs in the AHP model improve system consistency and make it easier to calculate weights for criteria and sub-criteria. The four phases of qualitative AHP are: (1) problem modeling, (2) weight assessment, (3) weight aggregation, and (4) interpretation analysis, which will be briefly explained in the next section.

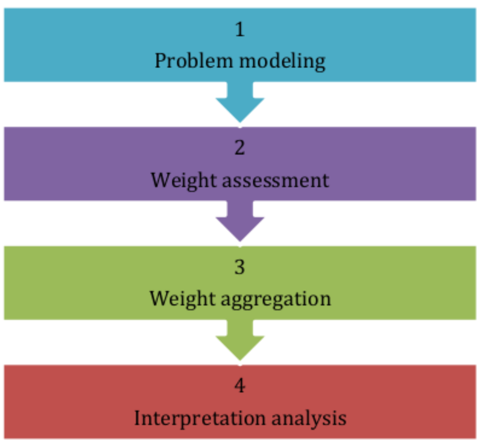

Figure 3 Phases in the AHP method

This research can predict the future vulnerability of tourism in coastal areas in decision makers and planners, which is to information collected by various ministries and institutions. MCDA provides a more well-supported methodology for comparing project options using a decision matrix, resulting in significant improvements in the environmental decision-making process. It also provides a formal method for incorporating the perspectives of project stakeholders into ordering or ranking options. One of the most important features of MCDA is its ability to highlight commonalities and areas of potential conflict among stakeholders in collective decision making. References agree, stating that AHP is the most widely used decision analysis technique as well as the fastest growing in a variety of disciplines, including environmental and resource planning, environmental management, and so on.

The AHP method is a suitable approach for evaluating the importance of vulnerability, hazard, and erosion risk criteria due to its capability to address a selection problem and establish priorities for criteria, sub-criteria, and alternatives. The AHP method offers several benefits, such as its relative ease of use, capacity to incorporate qualitative and subjective factors, ability to support rapid decision-making, capability to aggregate judgments from numerous analysts, and capacity to evaluate the consistency of these judgments. AHP has been applied in various complex decision-making scenarios, including challenges in natural resource management, coastal zone management, environmental concerns, economic analyses of risk management processes, urban planning, and the business and tourism sectors (Bagheri et al., 2021; Balwada et al., 2021; Ke, 2020; Liu & Suk, 2022; Soltani et al., 2015).

In the decision-making process, the initial step involves the organization of the problem. This entails breaking down the problem into three key components: objectives, criteria, and sub-criteria. By categorizing choice issues into segments with shared characteristics and building a multi-level hierarchical model, a decision hierarchy is constructed. Data sources were obtained from secondary data and primary data. Secondary data was obtained from a literature review to understand problems and identify criteria, sub-criteria and alternatives. Meanwhile, primary data is obtained from interviews with experts to identify problems in the field and solve problems.

The second step is related to collecting input data through pairwise comparison of decision components and obtaining a rating scale. Once the issue has been structured using a hierarchical approach, the subsequent task involves assessing the relative importance of the criteria and sub-criteria with an overarching goal. This research employs the identification of the top and most crucial criteria from an expert's perspective, as well as the application of the Saaty 9-point scale for qualitative assessment of criteria and sub-criteria.

In the Analytic Hierarchy Process (AHP), the quantification process involves the pairwise comparison of criteria using an unconditional rating scale, commonly referred to as the Saaty 1-9 scale. This scale is utilized to ascertain the degree of dominance of one item over another with respect to a specific feature. Through the use of pairwise relative comparisons, the AHP model solicits preferences between criteria and sub-criteria in order to derive weights. The relative significance of each variable is assessed using the Saaty 9-point scale, as detailed in Table 1.

Table 1. Scale of absolute numbers

Intensity of Importance	Definition
1	Equal Importance
2	Weak or slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

Sources: (Saaty, 2008)

There are several inconsistencies that emerge during pairwise comparisons (Saaty, 2008). In the case where the values of the elements of matrix A are inconsistent, the priority prediction and value techniques for the input matrix are as follows (Equation 1).

$$(A - \lambda_{max} I)q = 0, where\ \lambda_{max} = \sum_{i-1}^{n} \frac{AW_I}{nW_i} \quad (1)$$

The largest eigenvalue of matrix A, denoted as λ_{max}, is accompanied by a true eigenvector q and the unit matrix I. The true eigenvector q serves as an approximation of the relative priorities, representing the first principal component of the pairwise comparison matrix. In cases where the matrix exhibits no inconsistencies, implying that the decisions made by the decision maker are coherent, q transforms into the anticipated priority vector. The sum of each eigenfactor is computed to derive the priority. A higher level of consistency in the comparison process suggests a closer alignment between the calculated value of λ_{max} and the value of n. The Consistency Index (CI) is expressed through Equation 2.

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (2)$$

CR is utilized to assess the overall consistency of the response, as it is not reliant on n, which is the basis for CI. It measures the error in response to a regularity and is considered the maximum acceptable error rate for this type of analysis. If the CR value is below 0.1 or 10%, pairwise ranking is deemed acceptable (Melillo & Pecchia, 2016; Saaty, 2008). CR is calculated as follows (Equation 3).

$$CR = \frac{CI}{RI} \quad (3)$$

The Consistency Index (CI) represents the measure of consistency, while the Random Index (RI) is the value generated for a random matrix of order n. The Consistency Ratio (CR) is denoted by CR. The values of RI are derived from Saaty's (2008) random generation of the matrix presented in the Table 1.

Tabel 1. Random Index of AHP

n	1	2	3	4	5
RI	0	0	0.52	0.89	1.11

Sources: (Saaty, 2008)

3. Result and Discussion

The AHP hierarchy analysis was carried out in several stages, such as asking questions directly through literature studies, interviews with people who were experts, and visits to the study area. This research applies three criteria, based on the results of a literature review and expert survey, namely (1) human activity, (2) environmental, and (3) coastal threat. One of the main goals is to choose one particular alternative from various alternatives to determine the appropriate form of adaptation, namely (1) Autonomous, (2) Anticipatory, and (3) Persistent. Based on these criteria and alternatives, the decision making problem is very challenging because the number of alternatives is very large.

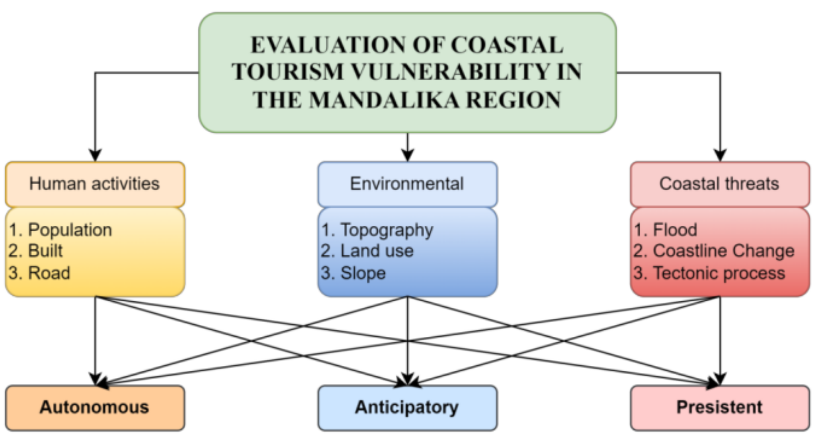

Figure 4 Analytical hierarchy process design

Based on the three existing criteria, each consisting of three sub-criteria, namely (1) human activity criteria consisting of population, built, and road sub-criteria. (2) environmental criteria consist of topography, land use, and slope sub-criteria. (3) coastal threat criteria consist of flood, coastline change, and tectonic process.

The investigation establishes the criteria, sub-criteria, and alternatives through the application of the AHP model. Expert judgments are employed to calculate the weights for each criterion. The weightings for all criteria and sub-criteria are determined using Multi Criteria Decision Making (MCDM) software for qualitative analysis. The results of prioritizing elements for each criterion and sub-criterion by conducting calculations based on the AHP calculation stages are displayed in Table 2.

Table 2. Results of calculating the criteria for Coastal Tourism Vulnerability in the Mandalika

Criteria	Human activities	Environmental	Coastal threats	Priorities	Rank
Human activities	1.00	3.00	4.00	0.61	1
Environmental	0.33	1.00	3.00	0.27	2
Coastal threats	0.25	0.33	1.00	0.12	3
Number of comparisons	3				
Consistency Ratio (CR)	0.07				

Sources: MCDM, process

From the results of the pairwise comparison values, we then calculate the priority weight to obtain the priority weight value for each criterion which shows that human activities is the highest ranking criterion with a weight of 0.61 (61%), followed by the second ranking environmental criterion with a weight of 0.27 (27%), and third place with a weight of 0.12 (12%).

Criteria analysis (See Figure 5) shows that the criterion ranked first is human activities with the sub-criterion ranked first namely road with a weight of 0.65. This indicates that road conditions are still a significant problem regarding the vulnerability that occurs in tourism in the Mandalika coastal area. These results are in accordance with interviews with experts who stated that the road to tourism locations is still not suitable because of the topographic conditions of the area which pass through the mountains.

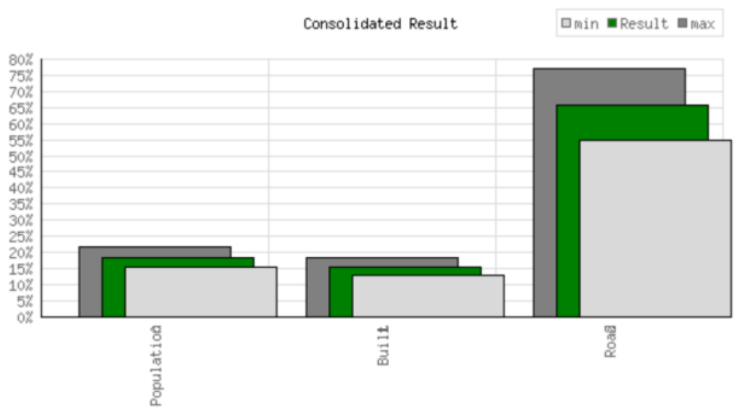

Figure 5 Weight of human activities sub-criteria

Apart from that, good road conditions also have a positive impact on national transportation, traffic and transportation must be improved in terms of their potential and role in order to achieve security, safety, order and smooth traffic and road transportation in order to support economic development and regional development. Furthermore, the criterion that is ranked second (See Figure 6) is environmental with the sub-criterion that is ranked first which influences vulnerability, namely slope with a weight of 0.55.

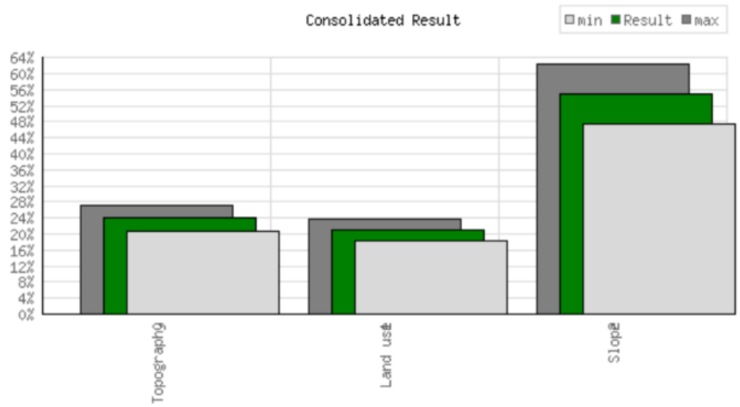

Figure 6 Weight of environmental sub-criteria

The geographical condition of the Mandalika coastal area which directly faces the Lombok Sea makes this area prone to abrasion, although this condition is slower than the coastal areas on the island of Java, especially along the south coast. The criterion that is ranked second (See Figure 7) is coastal threat with the sub-criterion that is ranked first which influences vulnerability, namely tectonic process with a weight of 0.55.

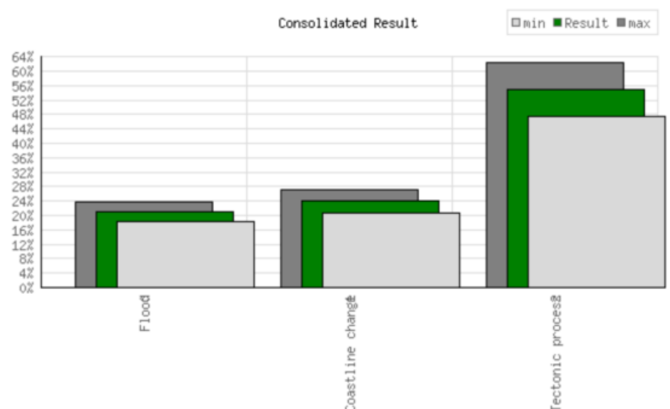

Figure 7 Weight of coastal threat sub-criteria

These results are in accordance with research by Mawardin (2018) which states that Indonesia's areas vulnerable to tsunamis are located on the west coast of Sumatra, the south coast of Java, Bali and Nusa Tenggara, as well as the north coast of Sulawesi-Maluku and the north coast of Papua. This is because Indonesia is located at the meeting point of three tectonic plates, namely the Eurasian Plate, the Indo-Australian Plate and the Pacific Ocean Plate. Therefore, from the identification of these vulnerabilities, policy alternatives are recommended to overcome these problems. The alternative result that is the highest choice (See Figure 8) is persistent action.

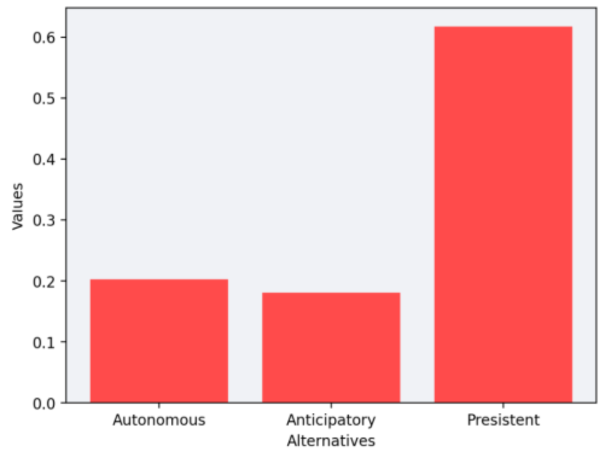

Figure 8. Alternative Evaluation Of Coastal Tourism Vulnerability In The Mandalika

The persistent approach considered to be the most effective for protecting this area is to use embankments and revetments. Furthermore, evidence indicates that beaches shielded by dikes and revetments remain unaffected by erosion in inclement weather; nevertheless, sections of the beach located mere meters from erosion control structures suffered significant erosion.

4. Conclussion

This study also introduces different policy frameworks applied in the Mandalika Region for the selection of significant sustainable weights from criteria and sub-criteria. The findings of the study indicate that human activity holds the highest weight as a criterion affecting tourism vulnerability in the Mandalika region. Sub-criteria associated with road construction play a role in influencing tourism vulnerability in the coastal area of Mandalika. Moreover, the preferred alternative for addressing vulnerability issues is continuous adaptation measures. As a result, it is anticipated that this study will help address vulnerability challenges stemming from climate change, particularly in the tourism industry, by fostering collaboration among all stakeholders through policy suggestions.

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