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Institutional role in analysis of installation of Tsunami Natural Disaster Detection Equipment using Analytical Hierarchy Process (AHP) and Cost Benefit Analysis Methods

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Abstract. The problem of natural disasters, such as tsunamis, tends to increase from year to year, mainly due to Indonesia's location in the Pacific Ring of Fire (Ring of Fire) and exacerbated by the lack of tools that can inform early for people if a geological disaster will occur and the lack of early warning for geological disasters installed according to local needs. The tsunami disaster will have a harmful and destructive impact on an area where the community suffers a significant material loss. Therefore, this study aims to determine the priority weight of each region in installing early warning tools to minimize the risk of geological disasters in Indonesia using the AHP (Analytical Hierarchy Process) and Cost-Benefit Analysis methods. This type of research is descriptive exploratory research, using qualitative data analysis methods—classifying regional criteria in Indonesia to determine the installation zone for early detection of natural disasters. The weighting and assessment are carried out on regional factors. Early detection tools for natural disasters are determined using the Analytical Hierarchy Process (AHP) method, which provides subjective calculations based on the hierarchical structure of regional components, namely Dense Settlements, Business Activities, Strategic Buildings Conservation Areas. The subjective calculation is combined with sub-criteria components from the area in coastal settlements, urban settlements, significant business activities, small business activities, important strategic buildings, historical strategic buildings, water conservation areas, and wildlife conservation areas. They support data taken directly through questionnaires and secondary data as comparison data. The data and results of AHP calculations are presented in the form of a parameter table based on the factor component of the regional component. The results of the analysis show that the detectors are divided into four types, namely CBT, Buy, Gauge, and ISDL

Keywords. natural tsunami disaster, early detection tool, risk management, AHP method, cost-benefit analysis

1. Introduction

Natural phenomena can threaten human survival, one of which is natural disasters. The occurrence of natural disasters can have a negative impact in the form of material and immaterial losses. These disasters can be described as floods, landslides, earthquakes, and non-natural disasters such as fires, technological failures, modernization failures, social conflicts between groups, and terrorism.

Given its nature as part of the phenomenon of human life, natural disasters cannot be known

with certainty when natural disasters will occur. The development of science developed by humans can only recognize early symptoms and predict their onset. The sophistication of artificial technology sometimes can only explain these early symptoms. Hence, the details of the disaster are only human guesses.

However, with the ability to recognize the early symptoms, the community can prepare for a disaster. The preparation stage includes preparation before a disaster occurs, during a disaster, and after a disaster occurs. That is, preparations can be made to recognize the early symptoms, level of risk, and more.

Located on the Pacific Ring of Fire (an area with high tectonic activity), Indonesia faces the constant risk of volcanic eruptions, earthquakes, floods, and tsunamis. On several occasions over the last 20 years, Indonesia has made global headlines due to devastating natural disasters that resulted in the deaths of hundreds of thousands of human and animal lives, coupled with their destructive effects on land areas (including infrastructure, and thus resulting in economic costs).

According to Law No. 24 of 2007 that a disaster is an event or series of events that threaten and disrupt people's lives and livelihoods caused, both by natural factors or non-natural factors as well as human factors, resulting in human casualties, environmental damage, property loss, and psychological impact.

Indonesia is a country with the most active volcano of all countries worldwide. The Eurasian Plate, Pacific Plate, and Indo-Australian Plate are three active tectonic plates that cause subduction zones that form these volcanoes. Indonesia is estimated to have 129 volcanoes, all closely monitored by the Center for Volcanology and Geological Hazard Mitigation. Many volcanoes in Indonesia exhibit continuous activity. In addition, it is estimated that more than five million people live (or work) within the volcano's "danger zone" (which people need to be evacuated immediately if activity increases significantly).

There is at least one significant volcanic eruption in Indonesia every year. However, they usually do not cause significant environmental damage or cause fatalities because most active volcanoes are in remote areas. Some of the famous volcanic eruptions in Indonesia's modern history are listed below. This list contains only significant eruptions that caused at least 20 deaths [1]

Underwater earthquakes or volcanic eruptions at sea can cause tsunami water waves that can devastatingly affect people and objects near the ocean. In 2004 much of the world was rocked by the Indian Ocean earthquake and subsequent tsunami, killing more than 167,000 people in Indonesia (mainly Aceh) alone and displacing more than half a million people as thousands of homes were washed away. Although large tsunamis such as the 2004 tsunami are rare, the Sumatra region is often shocked by offshore earthquakes that can trigger a tsunami.

Considering the 2004 tsunami, which is estimated to be the most severe, the loss is also relatively high. People who live in villages or towns close to the coast flee to the hills (located further inland) after an earthquake occurs because they are afraid of becoming tsunami victims (although it is usually a false alarm). On average, every five years, a significant tsunami occurs in Indonesia, mainly on the islands of Sumatra and Java. In general, the damage to infrastructure outweighs the loss of life. There are warning systems installed in many coastal areas. However, there are reports that not all of these systems are functioning correctly.

The natural disasters in Indonesia are earthquakes and tsunamis and active volcanoes (volcanic eruptions). On the other hand, Indonesia is also located in a wet tropical area with high rainfall, with two distinct seasons and rugged terrain, which can cause floods, landslides, droughts, and forest fires. [2] From the Indonesian Disaster Information and Data (DIBI), the

highest and most frequent natural disaster in Indonesia is flooding, which will increase every year. Floods require special attention because of the various adverse effects caused by floods, such as the number of diseases and health problems caused by floods and exposure to floods.

Based on Law No. 24 of 2007 concerning disaster management, disasters have been classified into three types, namely natural disasters, non-natural disasters, and social disasters, which Indonesia itself has three types of disasters. Natural disasters that occur in Indonesia include earthquakes, tsunamis, volcanoes, land movements, floods, droughts, erosion, abrasion, and extreme weather and extreme waves. Non-natural disasters include technological failures, epidemics, and disease outbreaks. Meanwhile, social disasters include social conflicts and terrorism.

As a natural disaster that often occurs in Indonesia, earthquakes, and tsunamis have been recorded to have claimed many lives in Indonesia. After the Aceh Tsunami in 2004, which resulted in the death toll being estimated at up to 120,000 people and devastating all infrastructure, Indonesia has also developed mitigations to anticipate the same natural disaster. This was marked by the preparation of the 2006-2009 National Action Plan for Disaster Risk Management which stated that three main factors were causing the slow response to disasters, both natural and artificial disasters, namely, first, the low capacity of various components at the community level, infrastructure, and internal elements. [3]

However, in reality, Indonesia's mitigation plan was tested in 2018 when the tsunami occurred in the Palu area of Central Sulawesi. Based on statistical data, it was noted that more than 2,000 fatalities were found. [4] However, considering that many residential areas were washed away by the tsunami and liquefaction materials, and there are still many buried people who have not been found, it is difficult to know with certainty the number of victims of the Palu Tsunami. Not yet finished the disaster in Palu. The same Tsunami disaster occurred in Banten, precisely in the Sunda Strait, on December 28, 2018. This incident was shocking because it took place at night that hit the west coast of Banten and South Lampung. The cause is thought to be caused by the activity of the Anak Krakatau volcano. The tsunami caused by this is very unusual. Based on historical records, the last tsunami caused by a volcanic eruption occurred in 1883, namely a tsunami caused by the eruptive activity of Mount Krakatau, which later formed Mount Anak Krakatau. [5] The natural tsunami disaster impacted social life, both victims and material losses. Indonesia has a high incidence of natural disasters such as earthquakes, floods, landslides, tsunamis, etc. Disaster is something that causes distress, loss, or suffering. When the Tsunami disaster occurred, the Indonesian government did not immediately receive foreign aid. Like the tsunami disaster in Palu, the President finally decided to accept international assistance a few days later, after the damage in Central Sulawesi was recorded far exceeding estimates. Several countries offer assistance in cash or kind. The UK, US, Australia, and New Zealand collectively assisted a few days later. [6] The government built temporary shelters during the emergency transition period (huntara). A shelter to accommodate refugees whose houses were heavily and lightly damaged. The goal is to minimize social unrest and anticipate the rainy season so that refugees will be more comfortable. In constructing shelters, the local government needs to submit ready-to-use funds to BNPB to construct shelters. Physical work by the TNI. The local government allocates a budget for repairs to repair lightly damaged houses. Repairs for heavily and moderately damaged houses will be proposed through a rehabilitation and reconstruction grant to BNPB. [7] Data from BNPB infographics from year to year show an increase in the number of disasters in Indonesia, especially in the last decade experiencing an increasing trend. As of December 31, 2019, there have been 3,814 disasters. Floods, landslides, and hurricanes still dominate disasters. [8]

One of the main factors that cause an increase in vulnerability is the failure of early detection tools to provide early warning of disasters to the community. This increased vulnerability will be further exacerbated if the government apparatus and the community are entirely unaware and responsive to the potential for natural disasters in their area. Experience shows that natural disasters have caused much loss and suffering due to the combination of natural hazards and the complexity of other problems. For example, the Palu Tsunami and the Sunda Strait Tsunami caused many casualties. [9]

As stated in an open letter addressed to President Joko Widodo by a postgraduate lecturer at the Faculty of Engineering, Gadjah Mada University, Yogyakarta, Bagas Pujilaksono Widyakanigara, who stated that the high number of deaths and injuries caused by the Sunda Strait tsunami was the result of the failure of the Meteorology, Climatology, and Geophysics (BMKG) in providing disaster early warnings to the community, thus leading to pressure to remodel. BMKG remembers that this is not the first time BMKG has failed to give early warnings.

The Palu tsunami and the recent Sunda Strait tsunami have made Indonesians aware of the vulnerability and vulnerability of natural tsunami disasters. Natural disasters in Palu City occurred in three types disasters, the first earthquake, the second tsunami, and finally liquefaction. Liquefaction is a phenomenon of loss of soil strength due to earthquake vibrations. [10] A tectonic earthquake occurred in Donggala Regency, Central Sulawesi on Friday, September 28, 2018, at 17.02.44 WIB with M 7.7, Location 0.18 South Latitude and 119.85 East Longitude and a distance of 26 km from North Donggala, Central Sulawesi, with a depth of 10 km. Natural disasters that occurred in Palu City occurred in three types of disasters, the first earthquake, the second tsunami and finally liquefaction. Liquefaction is a phenomenon of loss of soil strength due to earthquake vibrations. Minor tremors occurred throughout the day, but the 7.4-magnitude earthquake occurred when the Palu Koro Fault that crossed the city of Palu shifted about 10 kilometers underground. Since then, there have been at least 500 aftershocks in Palu, most of which residents have not felt. [11]

This incident made us aware of the need for a disaster management method that is carried out based on the needs of Indonesia proactively and comprehensively within the community. Especially input for all stakeholders as decision-makers to make decisions on geological disaster management in Indonesia.

One of them is the need to optimize the calculation of natural disaster early detection tools, significantly improve geological risk management capabilities, and pay special attention to which areas are vulnerable to geological disasters The method can determine the installation of early detection tools for natural disasters in Indonesia. One of which is the Analytic Hierarchy Process (AHP) developed by Thomas L. Saaty in 1970 as a decision-making tool. [12]

2. Materials and methods

Based on this background the purpose of this research is to conduct an analysis in determining the installation of an early detection tool for natural disasters in Indonesia with the help of the Analytic Hierarchy Process (AHP) and Cost and Benefit Analysis methods. While the purpose of this study is to provide information on early detection tools for natural disasters that are following Indonesia's needs to all parties and are expected to be a decision-making tool for installing early detection tools for natural disasters in Indonesia.

2.1 Risk Management

With the frequent occurrence of natural disasters in Indonesia, disaster risk management is needed for better and systematic handling of disaster relief. The problem that arises is that many Indonesian people still do not know and understand what a disaster is, how to anticipate and deal with a disaster, so that the risks arising from the disaster can be minimized, and who is responsible for the disaster. According to Herman Darmawi, risk management aims to identify, analyze, and control risks in every company activity to improve effectiveness and efficiency. Alternatively, a logical and systematic method for identifying, measuring, determining attitudes, determining solutions, and monitoring and reporting risks that occur in each activity or process. So it can be concluded that risk management is an effort to control risks that occur by applying systematic ways so that losses can be avoided or minimized. [13]. A Disaster Risk Management Assembly (DRM) is an analytical tool conceptualized as emerging from different human and disaster geography strands. Recent disaster risk terminology adopted by the United Nations. [14] DRM begins by first exploring the emergence of flat ontologies concerning debates about the nature of scale, causality, and agency in human geography. [15] A greater focus on the future can help address the question of "nature" that common criticisms of the thinking of geographical thinkers raise.

There are six components of Donovan's [16] (2017) DRM Assemblages that can be explored in-depth, where they can be used to help researchers frame their analysis of disaster risk and its management in all its complexities:

1. governance and governance in disasters;
2. expert advice, strengths, and uncertainties;
3. values, ideology, and social empowerment;
4. vulnerability and imbalance of wealth, resources, and scale;
5. disasters and geopolitical risks; and
6. hazard and risk assessment under uncertainty or uncertainty. [17]

National DRM systems and institutions are the driving force for planning, implementing, monitoring, and evaluating DRM processes and products within a country and ensuring coordination among all stakeholders involved in each phase of DRM. In addition, they play an essential role in integrating DRR efforts into development policies and programs to reduce the vulnerability of rural livelihoods to natural hazards. National DRM institutions develop policy frameworks, disaster management plans, and codes of ethics in aid and development; they guide and assist in developing early warning systems, declare states/phases of emergency during disasters; and lead communications with the general public sectoral bodies at different levels. The existence (as an essential requirement) and a coordinating role of DRM agencies are essential, though not sufficient, to ensure that the DRM system is functioning and operational. Equally important are formal links with sectoral line agencies that have complementary sectoral responsibilities for DRR and thus need to integrate aspects of DRR into their regular development work. Although there is a growing emphasis on disaster risk reduction in most developing countries, the mandate of national DRM agencies typically focuses on coordinating and advocating for prevention and mitigation strategies. However, the final implementation of prevention and mitigation measures and direct responsibility for emergency response remains the task of sectoral line agencies. Therefore, depending on the entry point of the assessment topic, relevant sectoral agencies should be included in the analysis. Agriculture is used to illustrate sector-specific issues, questions, demands, and challenges in the context of DRR.

The objectives of the national level institutional assessment are to:

- a. provide insights, guidance, and checklists to assist DRM practitioners to understand better the strengths and weaknesses of existing DRM policies, legal frameworks, codes of conduct, institutional structures, and coordination mechanisms among them, including national DRM focal point ministries, other relevant sectoral ministries, research organizations and NGOs and CSOs; assess the availability, suitability and effectiveness of crucial DRM instruments, the extent to which they are being used/promoted by institutions at the national level, and how DRM programs and services are communicated and promoted at the decentralized level;
- b. undertake a deeper assessment of technical capacity in countries undergoing organizational restructuring processes to support better the shift from reactive emergency relief operations to longer-term disaster risk prevention, mitigation and preparedness strategies;
- c. contribute to the development of effective and coherent national DRM policies to guide the development of complementary district and local DRM strategies and plans; and
- d. identify tangible institutional attributes (policies, mandates, and organizational structures, and supporting instruments such as finance, logistical support, technology) and intangible attributes (attitudes, perceptions, and underlying drivers) that determine the success of a DRM program [18]
- e. The success of any institutional assessment depends on the "right" institutional entry point. Therefore, it is crucial to identify the national focal point that will host the assessment process and the most relevant partner organizations. In most cases, the entry point is likely to be the National Disaster Management Office (NDMO), if one exists, or the lead agency with a mandate for DRM. The agency responsible for developing, interpreting, and disseminating early warning information should also be involved from the outset of the assessment. In the next step, selected sectoral ministries such as the Ministry of Agriculture, Water, Environment or Health and selected multi-sectoral ministries/agencies such as the Ministry of Rural or Regional Development, Finance, and Planning should be involved.

Understanding each step in disaster risk management is critical. The effectiveness of disaster risk management is limited to activities during the handling of disaster relief. However, it also includes all actions as in the 4 (four) phases of the disaster risk management model:

- a. The government's preparedness stage needs to ensure a sense of security and safety of the people's lives in disaster areas. An integrated and comprehensive implementation of disaster risk management is required. In addition, understanding disaster in the community is an important part of this phase. At this stage, communities need to understand their responsibilities and actions in the event of a disaster.
- b. The mitigation stage of disaster risk management is an emergency activity that focuses on minimizing the negative consequences of disasters. Key responses during the mitigation period include policies on economic development, land-use policies, planning for infrastructures such as roads and public facilities, and identifying resources to support investment.
- c. The response stage demands good coordination from various parties. Coordination enables the provision of assistance to disaster-affected communities to take place quickly, accurately, and effectively.
- d. Recovery stage is the evaluation and rehabilitation of disaster damage. In this phase, the focus is on the process of distributing aid. The method includes determining and monitoring assistance to disaster-affected communities. [19]

The success of disaster risk management cannot be separated from various parties such as volunteers, the community, Non-Governmental Organizations (NGOs) or Non-Governmental Organizations (NGOs), the government, and even the international community. The cooperation of various parties will accelerate the handling of various disaster problems and minimize the impact of risks posed by disasters quickly and effectively, both in the short and long term, in disaster-affected areas.

2.2 Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) was developed by Dr. Thomas L. Saaty, a mathematician from Pittsburgh, the United States, in the 1970s. AHP is a way of determining decision-making by decomposing complex multi-factor or multi-criteria problems into a hierarchy, which Thomas L. Saaty developed in 1993[20]. Saaty defines a *hierarchy* as representing a complex problem in a multi-level structure where the first level is the goal, followed by the level of factors, criteria, sub-criteria, Etc. AHP is often used as a problem-solving method compared to other methods for the following reasons:

1. Hierarchical structure, as a consequence of the selected criteria, to the deepest sub-criteria.
2. Considering the validity up to the tolerance limit for the inconsistency of various criteria and alternatives chosen by the decision-maker.
3. Taking into account the durability of the decision-making sensitivity analysis output.

2.3 Cost Benefit Analysis

Cost-benefit analysis (CBA) is widely used, and the methods must be properly understood. The purpose of CBA analysis is to provide a consistent procedure for evaluating decisions in terms of their consequences. This may seem an obvious and reasonable way to proceed. However, it is not the only one (examples of alternative procedures are majority voting, collective bargaining, the exercise of power, or assertion of rights). As described, CBA analysis covers a vast field.

CBA is a tool that supports the policy process and political decision-making on policy measures or policy alternatives by presenting information about their effects, risks, and uncertainties, their consequences for costs and benefits and social welfare, and information about who benefits and who experiences side effects.

The essence of CBA is that different projects or policy alternatives can be assessed by comparing their impact on society's overall well-being: economic and social costs and benefits. CBA is firmly entrenched in economic welfare analysis [21] where all relevant advantages and disadvantages of a policy measure are identified and measured as far as possible. Expressing these gains and losses in monetary terms whenever possible (monetization) makes them comparable and allows them to be added and subtracted. The result is a direct data set that can weigh the advantages and disadvantages of a measure. This information also includes the costs and benefits of non-market-priced effects, such as environmental impacts and safety implications. The balance of benefits and costs indicates whether a measure increases total well-being or not. In essence, CBA indicates the economic efficiency of action: do the benefits outweigh the costs? CBA also provides insight into the effectiveness of an action (to what extent does it solve the problem and are there other effects?) and into the legitimacy of government intervention (is government intervention necessary and justified?).

CBA provides politicians and stakeholders with the information they can use to help them reach balanced decisions, making CBA an essential input in the decision-making process. CBA can be used in almost all policy areas for almost any type of action to investigate whether an

action is cost-effective from a welfare economic point of view, compare different alternatives, and reveal the implications of decisions to be taken on the action. CBA is mainly used towards the end of the decision-making process. It can also be used in the early stages of the decision-making process to investigate how a problem can be addressed and improve steps to address the problem. Although at this stage, little empirical information is available regarding the expected effects of the measurements, the principles of the CBA methodology can be used to structure the decision process, identify potential solutions and determine what practical information will be needed in future decisions making. Process for evaluating policy measures.

As summarized by Romjin and Renes [22], the CBA stage includes eight (8) steps as follows: 1) Problem Analysis, 2) Establish the baseline alternative, 3) Define Policy Alternatives, 4) Determine effects and benefits, 5) Determine costs, 6) Analyze variants and risks, 7) Overview of costs and benefits, and 8) Presentation of results.

The steps for preparing the CBA were chosen to run more or less in parallel with the policy-making process. In practice, they are often used in this way and have proven compatible with policy preparation. This is no coincidence. During the policy preparation process, decision-makers are provided with the information they need to consider options, and the CBA can help them develop arguments. This applies to all stages of policy formulation. Therefore, it makes sense to use the CBA expertise available at all stages of the policy preparation process, even if this does not lead directly to CBA preparation. The steps also open up all relevant aspects of CBA for discussion.

The order of the main steps is also logical, although it doesn't always have to be done in a strictly linear order. Sometimes it is necessary to go back and review the previous step after completing the next step, for example, because circumstances have changed or new insights have been revealed. Steps 4 through 7 are usually considered the heart of CBA. However, it is possible to create technically perfect CLAs for specific measures that do not answer the relevant policy questions or do not consider relevant alternatives. Such a CBA will usually be of little use and questioned or criticized.

Since the CBA must provide answers to the right questions and provide the best possible input for policy development, this guide provides a clear overview of the early stages of CPD. This preliminary phase consists of steps 1, 2, and 3 – problem analysis, determination of basic alternatives, and definition of policy responses – and these steps should be appropriate responses to the policy questions at hand. Finally, however good an analysis maybe, if the report is not up to par, the policy preparation process may not benefit from the insights gleaned from the CBA. Therefore, step 8 is as essential as the previous seven steps. [23]

3. Results and discussion

3.1 Risk Management

Risk management is used to predict the hazards faced with accurate calculations and careful consideration of various initial information to avoid losses. In handling the natural tsunami disaster in Indonesia, it is necessary to carry out comprehensive risk management. Based on the four stages of risk management, the first stage, namely government preparedness, is the stage that the Indonesian government needs to emphasize in ensuring the safety of the lives of the Indonesian people from the threat of a natural tsunami disaster. Implement a policy of installing early detection tools for natural tsunami disasters. To support risk management decision-making, researchers use the AHP method to support policy-making for the Indonesian government, where primary data is obtained through questionnaires distributed to respondents in stages. In the first stage of the questionnaire, respondents only filled in the criteria for installing early detection equipment and sub-criteria for installing early detection equipment.

After that, in the second stage of the questionnaire, respondents were asked to compare the X variable to the Y variable or vice versa by giving the influence value of 1 (one) variable on the other variables.

Based on a questionnaire with a pairwise comparison matrix (pairwise comparison) with questionnaire questions the following criteria:

- Which is more important Dense Settlement compared to Business Activities
- Which is more important Dense Settlement compared to Strategic Building
- Which is more important Dense Settlement compared to Conservation Area
- Which is more important business activity compared to Strategic Building
- Which is more important business activity compared to Conservation Area
- Which is more important Strategic Building compared to Conservation Area

Based on the questionnaire results, a pairwise comparison matrix was made.

- Dense Settlement Is the First Most Important Criterion
- Business Activity Is the Second Most Important Criterion
- Strategic Building Is the Third Most Important Criterion
- Protected Areas Are the Fourth Most Important Criterion

The priority of the calculation results on the sub-criteria is stated in the following table 1:

Table 1. Priority Sub-criteria Criteria

Kriteria	Prioritas	Pesisir	Kota
Penduduk Padat	0.581	0.833	0.167
Kriteria	Prioritas	Besar	Kecil
Aktivitas Usaha	0.255	0.875	0.125
Kriteria	Prioritas	Historis	Vital
Bangunan Strategis	0.114	0.100	0.900
Kriteria	Prioritas	Air	Suaka Margasatwa
Area Konservasi	0.050	0.875	0.125

Source: Results of data analysis, 2021.

After knowing the value of the criteria and sub-criteria predictions, the results are entered into the AHP calculation. Where there are four alternative types of tsunami early detection tools. The final result is obtained from the multiplication of priority criteria and priority sub-criteria. Table 13 shows the multiplication of priority criteria and sub-criteria in each row.

Table 2. Priority Ordering Results of Early Detection Equipment Installation

	Pemukiman Padat	Aktivitas Usaha	Bangunan Strategis	Area Konservasi	Total	Alternatif
CBT	0.484	0.223	0.103	0.040	0.849	Pertama
BUOY	0.097	0.032	0.103	0.040	0.271	Kedua
GAUGE	0.484	0.223	0.103	0.040	0.849	Pertama
ISDL	0.484	0.032	0.103	0.040	0.658	Ketiga

Source: Results of data analysis, 2021.

This total value is used to rank the alternative installation of early warning tools.

Based on the results in table 13 related to 4 alternative early detection tools that can be used to follow up risk management in tsunami early warning, it is found that CBT and Gauge are the first choices, making CBT and Tide Gauge the main choice for installing tsunami early warning tools for Indonesia.

3.2 Cost-benefit analysis of the results of the Analytical Hierarchy Process in determining the installation of tsunami early detection tools

Based on the AHP results obtained, it refers to 2 alternative installations of tsunami early warning tools, namely CBT and Gauge, as the first choice. Therefore, from these two tools, Indonesia still needs consideration regarding the installation of an early warning tool that suits Indonesia's needs through an approach using the Cost-benefit Analysis or CBA stages as follows:

a) Problem Analysis

Based on the results of the AHP in the previous discussion, it shows that Indonesia can use two alternative options, namely Cable Based Tsunameter (CBT) or tsunami observation cables planted on the seabed and Tide gauges or tsunami detectors installed in the waters to detect waves. However, Indonesia needs to reconsider considering the constraints in terms of financing, technology, and the scope of equipment placement.

b) Establish the baseline alternative

The existence of these two alternative early warning tools has their respective benefits. Where is the CBT in the sea equipped with sensors for data transmission? While the gauge measures changes in sea level mechanically and automatically through seawater tides, which allows detecting tsunamis quickly.

c) Define Policy Alternatives

As stated by the Agency for the Assessment and Application of Technology (BPPT), which has installed an optical and wireless or hybrid cable-based tsunami early warning system (CBT), it is claimed to be more efficient. [24] Meanwhile, the Geospatial Information Agency (BIG) ensures that as many as 136 tide gauges spread throughout Indonesia are functioning correctly. [25] The data sent by the tide gauge is also utilized by InaTEWS, which is managed by the Meteorology, Climatology, and Geophysics Agency. In addition, sea level data is also helpful for confirming the actual situation whether a tsunami did occur or not.

d) Determine effects and benefits,

An optical and wireless cable or hybrid cable-based tsunami early warning system is more efficient. Based on the functional mechanism, which utilizes fiber optics, the provision of information on indications of a tsunami can be more accurate and faster. Optical fiber can deliver real-time information related to changes in pressure or the occurrence of an earthquake so that the time required to provide an early warning of about 10 minutes can be achieved. Meanwhile, tide gauges installed in the area around the epicenter can record sudden changes in sea level. This information can be used as a warning sign for residents who are pretty far from the epicenter but can be affected by a tsunami.

e) Determine costs

Considering the type of mechanism and its character, CBT has a cost of financing that is more expensive than the Tide Gauge, with an estimated cost of up to trillions depending on a certain depth of cable placement.

f) Analyze variants and risks

From the variations, the coverage area for laying CBT is still limited, where currently only 7 km have been installed in the territory of Indonesia. This is because the installation of CBT which is still limited, cannot be evenly distributed to areas of Indonesia that are prone to tsunami disasters. Meanwhile, the gauge itself has been recorded to have been installed in 138 units placed at disaster-prone areas in Indonesia.

g) Overview of costs and benefits

Based on the comparison between the two alternative tsunami early detection tools, namely CBT and Tide Gauge, in terms of financing factors, technology, and the scope of placement of the tools, it shows that the Tide Gauge is the correct early detection tool for Indonesia in tsunami risk management.

h) Presentation of results.

So, based on the analysis, it refers that from the two best choices produced through the AHP mechanism, Indonesia needs to increase the use of the Tide Gauge based on the cost-benefit analysis.

Conclusions

The experience of 2 tsunami events in 2018 in Palu and Banten proves that the threat of a tsunami that is not caused by an earthquake (non-tectonic induced tsunami) is an extraordinary potential hazard, so it is necessary to be aware of and prepare early warnings and efforts to mitigate the potential risks properly. The AHP (Analytical Hierarchy Process) method approach can conclude according to the desired goals. Based on the results of the analysis obtained to determine the installation of early detection equipment for natural disasters in the Indonesian region with several criteria achieved by researchers, namely for determining the installation of early detection equipment for natural disasters, first, dense settlements are the first most essential criteria in determining the choice of installation of early warning devices. Second, based on the AHP mechanism, it shows that there are two alternative tools that Indonesia can use, namely Cable Base Tsunameter (CBT) and Tide Gauge. Of the two alternative tools used to follow up on the installation of an Early Warning Tool based on a cost-benefit analysis, the early warning tool that Indonesia needs is the Tide Gauge. Installing a tsunami early detection tool for the territory of Indonesia is not an easy and short task. This requires a process, and Indonesia itself will continue to develop to improve the capability of handling natural disaster management, especially in the case of natural tsunami disasters. On the other hand, the threat of a natural tsunami disaster may continue to increase. Making Indonesia need to work together

and coordination between agencies and stakeholders is very necessary for the success of the tide gauge as an early detection tool for natural tsunami disasters in Indonesia.

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