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Location Design of GIS-Based Temporary Evacuation Sites (TES) by Considering the COVID-19 Pandemic Situation: A Case Study in Padang City)

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ABSTRACT

Padang City is an area that is predicted to occur in the Mentawai Megathrust disaster. In dealing with these potential disasters, proper planning is needed to reduce the impact of disasters. The exact location of the Temporary Evacuation Sites (TES) will affect the safety level of the community. However, based on the current situation, the COVID-19 pandemic adds to the complexity of disaster management. Therefore, anticipatory steps are needed to prevent the spread of disease in the environment. This study aims to design a TES location-allocation to deal with the potential Mentawai Megathrust disaster in Padang City by adjust to physical distancing health protocols. Determination of the location-allocation in this study is using Network Analysis extension namely Maximum Capacitated Location Problem (MCLP) in Geographic Information Systems (GIS). In addition, this study uses an evacuation time scenario with an interval of 3-30 minutes consisting of two different scenarios involving the use of community response times to disasters. The location-allocation results consist of four results based on the scenario of evacuation time and the addition of Proposed TES. Based on the location-allocation results, with the addition of Proposed TES, the maximum number of people that can be accommodated is only around 34-39 percent in both evacuation scenarios. This shows that there is a need for further design related to both Existing TES and Proposed TES so that the percentage of the number of people who can be accommodated can increase.

1. INTRODUCTION

Indonesia is an area prone to natural disasters [1]. One of the areas in Indonesia that is prone to natural disasters is the city of Padang, West Sumatra. The Padang City is located in the Mentawai Megathrust zone which is predicted to experience earthquake shocks of 8.8 to 9 Magnitude and cause a tsunami as high as 5-11 meters [2], [3]. At least 55% of the population of the province of West Sumatra is domiciled in that area. At least 6 of the 11 urban villages in Padang City are predicted to be affected by the disaster. Therefore, it is necessary to plan strategies to deal with potential disasters that exist.

In planning a disaster management strategy, it is necessary to plan an appropriate disaster location in order to reduce the number of disaster victims. Temporary Evacuation Places (TES) or shelters are places of refuge used during a disaster. Padang City has several TES that utilize several existing facilities, namely school buildings, office buildings, hills, and residential areas that are considered safe to use. In the evacuation process, the interval for the arrival of a tsunami can reach 20-30 minutes, so residents must evacuate within 10-30 minutes [4]. The Padang City Government has prepared 73 TES by considering the space requirement of each person of 1.64 m2 [2]. Based on the short evacuation time, it is necessary to design mature shelter locations so that it can accommodate residents who have fled to the nearest TES location.

One of the challenges of disaster management is the existence of a disease called Coronavirus Diseases (COVID-19) which spreads globally and is able to infect everyone who comes into contact with each other. The government appeals to the public to maintain a minimum distance of one to two meters between people to avoid the spread of the virus [5]. The presence of this disease adds to the complexity of disaster management, especially in disaster-prone areas. This is due to the potential for other disasters that can occur simultaneously. Therefore, multi-disaster management needs serious attention.

In the context of disasters, the use of spatial technology such as Geographic Information Systems (GIS) has been carried out in various case studies, including mapping of disaster-prone areas, determining distribution routes and determining the location of emergency facilities. GIS provides convenience in determining a decision [6]. There are several researches that have been studied about disaster problems. In 2020, a paper discussed the application of GIS in a case study of emergency located facility locations in Nigeria. The author used the Maximum Capacitated Location Problem (MCLP) method in obtaining a solution to the problem. Based on this paper, the author focused on evaluating the optimization of existing facilities, selecting facilities based on predetermined facilities, and optimizing the number of new facilities. The author also considered the travel time from the center point of the community to the specified point in order to know the optimization of the facilities used. In addition, by using Network Analysis Extension in GIS using different driving times, it produces the mileage value that is used as the maximum distance traveled to the facility through the Djikstra Algorithm which functions to produce the shortest distance from one point to another. After that, the researcher ran the program repeatedly based on the addition of the number of new features to get optimal results [7].

In 2019, there were publications discussing the issue of location-allocation in emergency facilities in China. The author used a multi-level location model to distinguish shelters based on minimizing travel time, construction costs, and maximizing the coverage that could accommodate the community. The author used the Weighted Voronoi Diagram (WVD) model to limit the capacity of each shelter. Then, the author used GIS software to find out the results of the service coverage of each shelter in the Jianchuan area. In determining the location of the shelter, the author used the Analytic Hierarchy Process (AHP) method to evaluate the shelter based on several predetermined factors. In calculating shelter needs, the author used several parameters, such as the need for each person's shelter space obtained from local government regulations. This paper shows how crucial the design of shelter locations is in disaster management, considering that there are many factors involved in it [8].

Meanwhile, in 2019, there were publications regarding the determination of shelters in the city of Tunceli, Turkey. In his research, the author used the Capacitated Maximal Covering Location model which was a feature of location-allocations in GIS software. By using the limit of shelter capacity with the maximum number of people that could be allocated, the community's residence was considered as a demand that would be allocated to the nearest shelter node which was then resolved using GIS software. The author ran the program by using the distance between residents' locations and different shelters to find out how many residents had been successfully allocated [9].

This study aims to design the allocation of Temporary Evacuation Sites (TES) in Padang City that takes into account the health protocols in the evacuation area. In this study, the evacuation process will be used as a reference in the design of TES locations. The two evacuation scenarios are used by considering the use of community response time to disasters. Determination of community response time is considered based on community preparation in dealing with disasters. If the community does not know the characteristics of the disaster that will occur, then the community is considered to still need more time to evacuate, whereas if it is considered to have known and is considered ready to evacuate, the community can immediately evacuate. In addition to considering the community's response time to disasters, it is also necessary to take into account the arrival time of the tsunami to the settlements, which in this study uses a tsunami arrival time of 10-30 minutes. This study uses GIS software with the help of the existence of Network Analysis using the type of problem such as Maximize Capacitated Coverage Problem (MCCLP). GIS makes it easier for stakeholders to understand the related situation and facilitates decision-making.

2. RESEARCH METHODOLOGY

The solving problems in this study, the author uses GIS. The GIS is a complex system that can integrated with other systems. The GIS components are hardware such as personal computers (PCs), software consisting of program modules, geographic data, and management that operate the system [10]. One type of GIS software is ArcGIS. ArcGIS has an extension, namely Network Analysis. Network analysis is an analysis of the movement of resources from one point to another. The system is able to analyze the road network by finding the one with the fastest impedance number, so as to provide the fastest travel route [11]. The problem-solving in location allocation in ArcGIS is using Teitz and Bart heuristics (TBH) [12]. TBH is a settlement method by increasing the initial by substituting candidates with selected facilities in pairs and stopping when there are no further improvements [13].

In solving the problem, the researcher uses Network Analysis in the form of Maximize Capacitated Coverage Problem (MCCLP). MCCLP model is used to determine the location based on the number of facilities that have been determined by the decision maker. In addition, MCLP can be used when searching for facilities that are unlikely to be able to meet all requests, so that the demand that can be covered can be maximized [14]. The location-allocation problem can also be done by using the Maximize Capacitated Coverage Location Problem (MCCLP) model by considering the capacity of each facility. The following is the formula for the MCCLP [15]:

Notation

- i : index of demand i, where $i \in I$
- j : index of facility j, where $j \in$ J
- a_i : number of demands i, where $i \in I$
- p : number of facilities to be selected
- S : coverage distance
- d_{ij} : distance between demand location $i \in I$ and facility location $j \in J$
- c_j : the capacity of facility $j \in J$
- N_i : $\{j | dij \leq S\}$ facilities j that can meet demand i based on service coverage standards considerations

Decision Variable

$X_j = \begin{cases} 1 \\ 0 \end{cases}$ 1 if facility $j \in J$ is selected, 0 otherwise

$Y_{i \in I, j \in J} = \begin{cases} 1 \\ 0 \end{cases}$ 1 if request $i \in I$ is served by facility $j \in J$, 0 otherwise

Objective Function

Maximize	$\sum i \in I \sum j \in Ni \; aiYij$		(2.1)
Subject to	$\sum j \in Ni \; Yij \leq 1$	$\forall i \in I$	(2.2)
	$\sum j \in J \; Xj = p$	$\forall j \in J$	(2.3)
	$\sum j \in J \; aiYij \leq cjXj$	$\forall j \in J$	(2.4)
	$Xj \in \{0,1\}$	$\forall j \in J$	(2.5)
	$Yij \in \{0,1\}$	$\forall i \in I, \forall j \in J$	(2.6)

The objective function of the formulation in (2.1) is to maximize the number of requests served by the selected facility. Constraint (2.2) indicates that each request can be allocated to at least one facility. Constraint (2.3) indicates that the selected facility does not exceed the number of p. Constraint (2.4) indicates the number of requests at the point of the population does not exceed the capacity of the selected facility. Constraints (2.5) and (2.6) are non-negativity limits.

In this study, the first step that needs to be done is to calculate the new capacity of TES which takes into account space requirements in pandemic conditions. After that, the evacuation time is calculated based on five-time scenarios which are divided into two scenarios, namely using response time and no response time. The results of the calculation of the evacuation time resulted in the maximum distance of the population to TES. The two results of these calculations will be used as parameters in determining location-allocations using GIS, so that the results obtained show the number of people who can survive in a disaster which is divided into two different conditions and various evacuation times.

3. THE CASE STUDY

Based on research conducted by LIPI and Nanyang Technological University Singapore, the estimated earthquake caused by the Mentawai Megathrust could reach 8.8 Magnitudes with a depth of 30 km originating from the southwest of Padang City. Regional Disaster Management Agency assumed that determining the evacuation time involved the arrival time of the tsunami and the response time of the community, where the evacuation time is the difference between the tsunami arrival time and the community response time [2]. The agency determined that the speed of refugees to TES is 0.751 m/s. The local government has also prepared 73 TES using the minimum TES space requirement of 1.64 m2/person.

In the conditions of the COVID-19 pandemic, the number of cases continues to grow. The COVID-19 Task Force urges the public to reduce mobility outside the home and maintain a minimum distance of one to two meters to prevent the reduction of transmission of the COVID-19 pandemic [5].

Population data were obtained from official documents belonging to the Central Statistics Agency (BPS) of Padang City in 2020. Based on this data, there are 104 sub-districts and 11 sub-districts in Padang City. However, there were 50 villages that were in the tsunami hazard zone [2]. The area that becomes the landmass of the tsunami can be seen in **Fig. 1** which is shown as the inundation area.

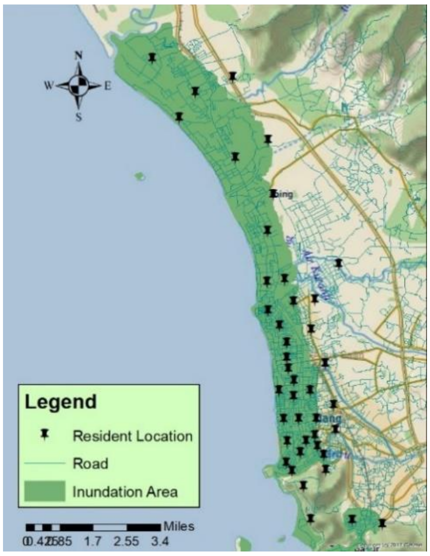

Fig. 1. Resident Location

Based on **Fig. 1**, the black dot symbol indicates the location of the centroid or the center of the population, which is based on the assumption that the population lives concentrated in the same point, so that when evacuating, they can find the closest way to TES.

In this research, two types of TES are used, namely the Existing TES and the Proposed TES. Both of TES data was obtained from the BPBD of West Sumatra Province as the party placed in disaster management in the area. The Existing TES is facilities that has been officially established by the local government, while the Proposed TES is an additional TES that is still a proposal. The use of the proposed TES is considered if the Existing TES is still considered unable to accommodate the entire population at risk of disaster.

In the conditions of the COVID-19 pandemic, there has been a decrease in the capacity of TES. During normal conditions, the space requirement used is 1.64 m2, while in pandemic conditions it changes to 4 m2 due to consideration of the COVID-19 Task Force regarding the rules for maintaining a distance of 2 meters [5]. The contrasting facility capacities under regular and pandemic circumstances are evident through the illustrative calculation of a specific TES in **Table 1**.

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Table 1. The Differences of Facility Capacity in Two Condition

Location	TES Area (m^2)	TES Capacity (people)		Gap
		Normal Condition	***Pandemic Condition***	
Gedung Asuransi Jasa Raharja	3,280	2,000	820	1,180

One of the TES capacity calculations can be seen as follows:

a. Capacity of Gedung Asuransi Jasa Raharja

$$= \frac{Area\ of\ TES}{The\ area\ needed\ for\ TES\ in\ pandemic\ situation} = \frac{3{,}280\ m^2}{4\ m^2/_{people}} = 820 \text{ people}$$

b. The difference in the number of people

= TES capacity under normal conditions – TES capacity under COVID-19 pandemic conditions

= 2,000 – 820 = 1,180 people

The evacuation process involves the time of tsunami arrival and community response time to the disaster. The tsunami arrival time is estimated to be 20-30 minutes after the earthquake occurred [4]. Therefore, in this study, five scenarios of tsunami arrival time were used, namely in intervals of 10-30 minutes with the speed of refugees heading to TES of 0.751 m/s. In addition, this study considers the condition of the community's preparedness in responding to disasters. Therefore, this study consists of two scenarios, namely by considering the response time if it is assumed that the community is ready to face a disaster and with conditions without response time if the community is considered unresponsive to the disaster, so it still takes time to understand the evacuation process. Determination of the community response time used without considering the variance of public awareness in responding to the tsunami disaster.

The following is one calculation of evacuation time with a response time scenario:

a.	Tsunami arrival time	= 30 minutes
b.	Evacuation Time	= Tsunami arrival time – Community response time
		= (30 – 7) x 60 seconds
		= 1,380 seconds
c.	Max. distance to reach TES	= Refugee speed to TES x Evacuation time
		= 0.751 meter/s x 1,380 s
		= 1,036.38 meters

The calculation above is a calculation when using a scenario with a response time. The calculation method for the scenario with no response time is the same, except that the evacuation time will be the same as the tsunami arrival time.

4. RESULTS AND DISCUSSION

After calculating the evacuation time, then determining the locations using ArcGIS software. Data processing is carried out through the Network Analysis feature in the form of locations-allocations in ArcGIS 10.8, using the type of trip in the form of Demand to Facility with the Maximize Capacitated Coverage Location Problem (MCCLP) problem type that can be seen in **Fig. 2**.

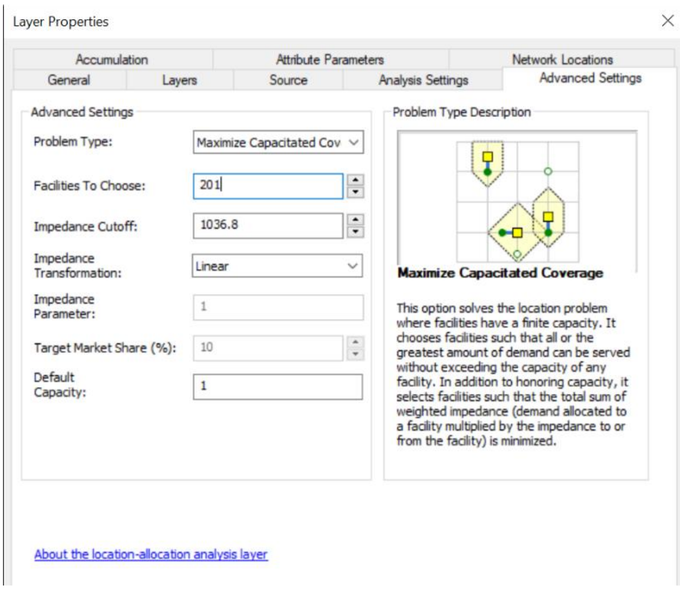

Fig. 2. Display of The Problem Type Selection Process in Network Analysis

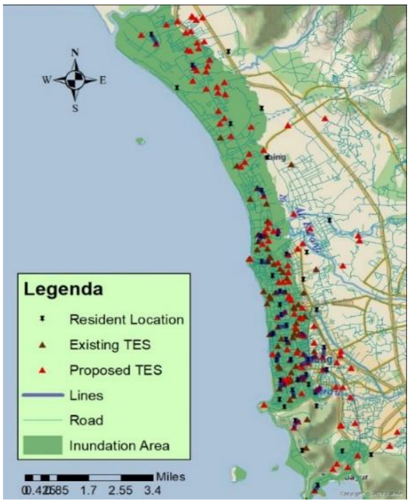

Fig. 3. Location-Allocation Results using an Evacuation Time of 10 Minutes

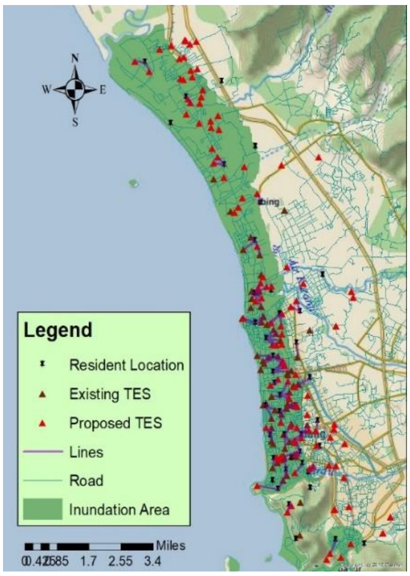

Fig. 4. Location-Allocation Results using an Evacuation Time of 20 Minutes

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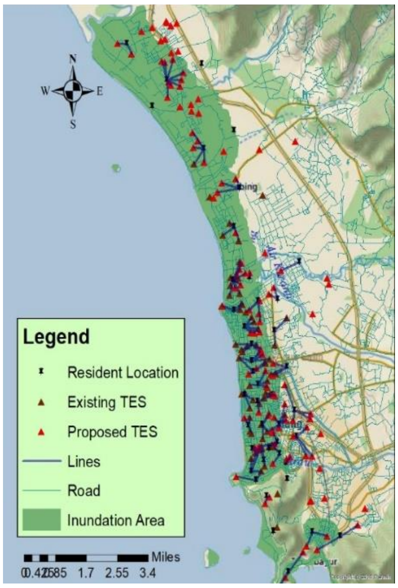

Fig. 5. Location-Allocation Results using an Evacuation Time of 30 Minutes

Fig. 3, **Fig. 4**, and **Fig. 5** show several location-allocation results when the maximum distance to TES are different, namely when the distance is 450.6 meters, 901.2 meters, and 1,351.8 meters. Some of these location-allocation results show that in some distance variants there are still unallocated residents. Location-allocation results will be discussed in the next section, while the recapitulation of location-allocation results can be seen in **Table 2** and **Table 3**.

Table 2. Recapitulation of Location-Allocation Results of The Population to The Existing TES

Evacuation Time Scenario	Evacuation Time (minute)	Impedance Distance (meter)	Allocated Residents (people)
With Response Time	3	135.18	3,280
	8	360.48	12,295
	13	585.78	34,714
	18	811.08	59,100
	23	1,036.38	68,685
No Response Time	10	450.6	20,350
	15	675.9	44,750
	20	901.2	64,784
	25	1,126.50	70,725
	30	1,351.80	74,005

Table 3. Recapitulation of Location-Allocation Results of The Population Based on The Addition of Proposed TES

Evacuation Time Scenario	Evacuation Time (minute)	Impedance Distance (meter)	Allocated Residents (people)
With Response Time	3	135.18	6,708
	8	360.48	30,935
	13	585.78	67,037
	18	811.08	106,293

Evacuation Time Scenario	Evacuation Time (minute)	Impedance Distance (meter)	Allocated Residents (people)
	23	1,036.38	130,150
No Response Time	10	450.6	41,918
	15	675.9	84,319
	20	901.2	115,180
	25	1,126.50	138,950
	30	1,351.80	151,120

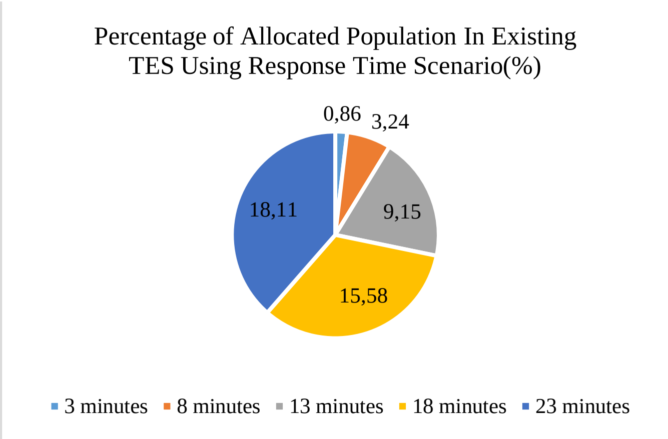

Fig. 6. Percentage of Allocated Population in Existing TES Using Response Time Scenario

Based on **Fig. 6**, there has been a change in the allocation for each of the scenarios set. In a scenario with a response time, with a distance impedance of 135.18 meters and a minimum evacuation time of 3 minutes, the percentage allocated is only 3,280 people or 0.86% of the total population potentially affected by the tsunami disaster. Meanwhile, by using a maximum evacuation time of 23 minutes, the percentage that can be accommodated by the Existing TES reaches 68.685 people or 18.11%. This shows that with a longer evacuation time, more people will be able to save themselves to the nearest TES.

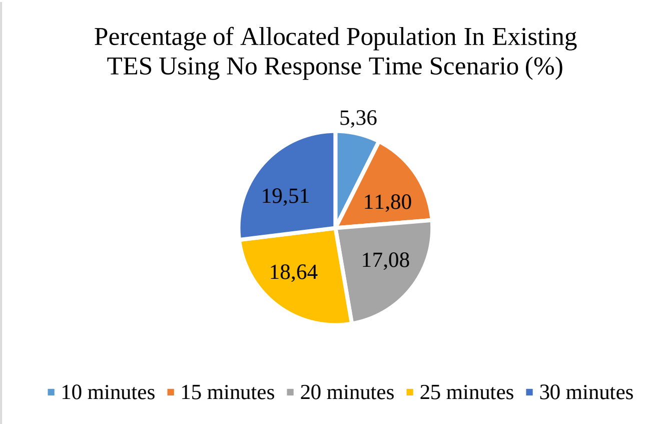

Fig. 7. Percentage of Allocated Population in Existing TES Using No Response Time Scenario

Fig. 7 shows an increase in the number of people allocated. In response time, with a minimum distance impedance of 450.6 meters and a waiting time of 10 minutes, the percentage that occurred only reached 20,350 people or 5.36% of the total tsunami disaster incident. Meanwhile, by using 30 minutes, the percentage that can be accommodated by the Existing TES reaches 74,005 people or 19.51%. When viewed from the results of locations with response times, the percentage in scenarios without response times increased. This is because the length of time required to evacuate is longer, resulting in an increase in the number of people who have been successfully allocated to the Existing TES.

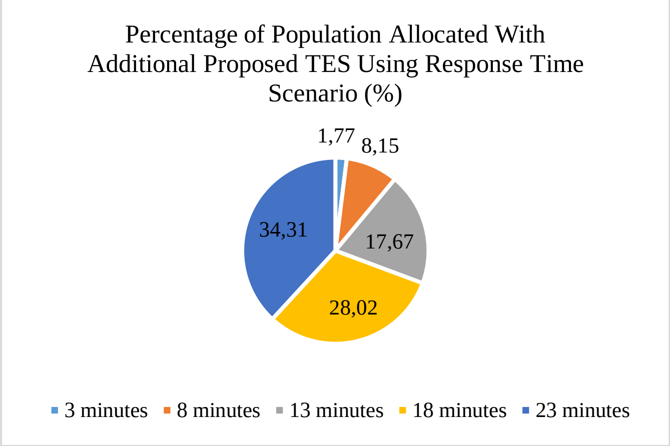

Fig. 8. Percentage of Population Allocated with Additional TES Proposed Using Response Time Scenario

After knowing the number of people who have been successfully allocated in the Existing TES, an additional allocation is made based on the Proposed TES data. Based on **Fig. 8** with an evacuation time of 3 minutes, the distance that refugees have to travel to TES is 135.18 meters with the percentage of refugees who are predicted to be successful in evacuating is 1.77% that reaches 6,708 people. Then, at an evacuation time of 23 minutes with a maximum distance to TES of 1,036.38 meters, the percentage allocated is 34.31% that are consist of 130,150 people.

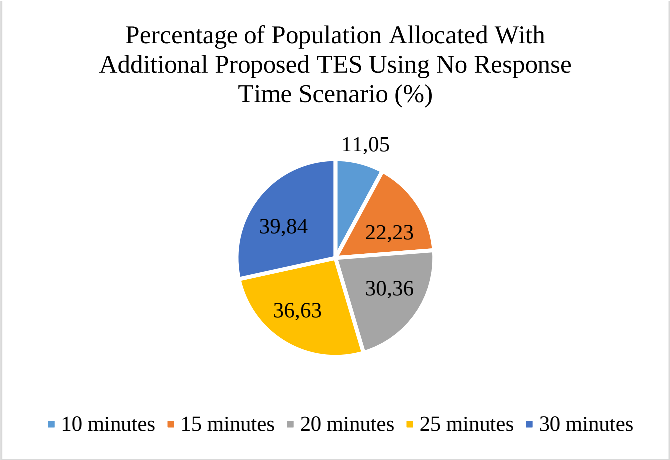

Fig. 9. Percentage of Population Allocated with Additional TES Proposed Using No Response Time Scenario

The percentage based on **Fig. 9** shows that at the time of evacuation for 10 minutes, the maximum distance that refugees can travel to the nearest TES is 450.6 meters with the percentage of the population predicted to be successful in evacuating is 11.05% that are consist of 41,918 people. Then, at 30 minutes of evacuation, the maximum distance that refugees can take to reach TES is 1,351.8 meters with the predicted percentage of residents who have successfully evacuated is 39.84 % that reaches 151,120 people.

Based on the results of the two locations-allocations, it is found that there is an increase in the population quantity that can be accommodated by TES based on a predetermined scenario. If using a scenario with response time, in the results of the Existing TES allocations, the percentage interval of the population that can be allocated is around 0.8-18.1 %. As for the results of the location-allocation with the addition of the Proposed TES, the interval of the percentage of the population that can be accommodated becomes 1.7-34.3%. Then, in the scenario without using response time, with Existing TES locations, the percentage interval of the population that can be allocated is 5.36-19.5%, while in the results of locations-allocations with additional TES Proposed the percentage becomes 11-39.8%.

This indicates an increase in the capacity of the allocation locations due to the addition of a number of Proposed TES which results in an increase in the number of people allocated to TES based on predetermined time parameters. Although the Proposed TES has been added, it turns out that the maximum number of residents that can be allocated can only reach 34.31% and 39.84% in the two scenarios used. This percentage shows that by using the Existing and Proposed TES in each predefined scenario, it has not been able to accommodate the entire population predicted to be affected by the disaster. Therefore, it is necessary to add another TES which can consider the maximum distance to the nearest TES based on the evacuation time.

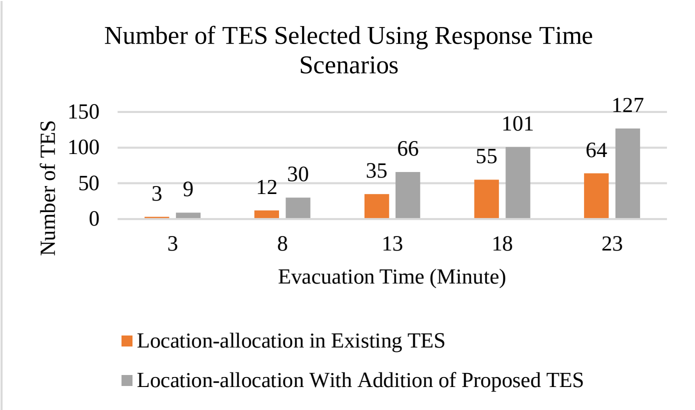

Fig. 10. Number of TES Selected Using Respone Time Scenarios

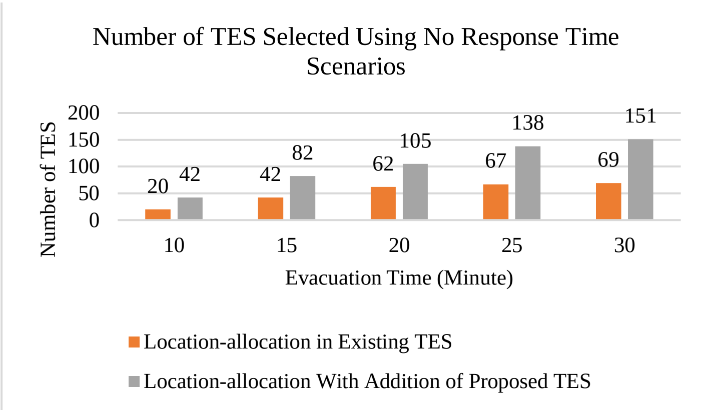

Fig. 11. Number of TES Selected Using No Response Time Scenarios

Fig. 10 and **Fig. 11** show that the use of TES has not been fully implemented. Overall, when using the response time scenario, the maximum TES selected was 4-87% on-site results based on Existing TES and 4-63% on site results based on additional Proposed TES. As for the scenario without response time, the results of location-allocation based on Existing TES with a maximum percentage are 27-94% and when the Proposed TES is added it reaches 20-75%. Changes that occur in the selection of TES are determined by the determination of the maximum limit of the community towards TES. If the TES location does not meet the predetermined criteria, then TES cannot be selected. This causes there are several TES that cannot be used, so that in determining the location of TES it is still necessary to evaluate and add a number of TES to complete these deficiencies.

Based on both scenarios at the 23rd and 30th minutes, there are still a number of TES that were not selected. At the evacuation time of 23 minutes, there were 6 TES that were not selected from the results of the Existing TES locations and 74 TES that were not selected as a result of the additional TES Proposed locations. At this time of 30 minutes, the number of TES that were not selected based on the results of the locations using the Existing TES reached 4 TES and 50 TES were not selected based on the addition of the Proposed TES. The number of unselected TES's is reduced in the no response time scenario. This is because the system continues to get results in the selection of TES that are selected based on the closest distance parameters and the capacity of TES, thus causing a number of TES that are not selected. As time increases, so does the distance travel. This will lead to more TES that can be achieved by the population. Therefore, the demands of TES time and capacity are very influential in the design of TES locations.

The location-allocation results demonstrate that the scenario without response time leads to a higher number of people being allocated to TES compared to the response time scenario. This is because a longer response time allows for more people to be evacuated, while a shorter response time leads to a reduction in evacuation time, potentially leaving some individuals unallocated to the nearest TES if they are located far away. Consequently, the level of public safety decreases when the time needed for evacuation is minimal. In contrast, a longer duration for evacuation maximizes public safety. To enhance public safety and response efficiency, community education plays a vital role in raising disaster awareness, ensuring that individuals are aware of the nearest TES locations, and ensuring that easily accessible TES facilities are available. These measures can help optimize evacuation processes and improve disaster management in the studied area. Additionally, the findings align with previous research highlighting the importance of considering community-specific factors and preparedness measures when designing TES locations to enhance disaster response capabilities and safeguard public safety.

5. CONCLUSION

This study shows the importance of designing TES facilities in reducing victims of the Mentawai Megathrust disaster in Padang City, especially in the conditions of the COVID-19 pandemic. By following the rules that have been determined by the local government, this study provides an overview of the allocation of the community to the nearest TES which of course has implemented health protocols.

In this study, the use of GIS is used to analyze and provide an overview of spatial information in the placement of people to the nearest TES. Determination of inundation areas is useful to make it easier to identify areas that are prone to disasters. This research uses the MCLP method on the Network Analyst feature in ArcGIS 10.8 which is able to provide an overview of location mapping and solutions to this problem. In this study also set two scenarios, namely the reporting scenario by setting the response time of the community to the disaster and the scenario without the response time by applying a time scenario of 3-30 minutes.

In addition, this study also shows the number of people who can be accommodated in the Existing TES and Proposed TES. Based on the location results, it shows that the Existing TES and Proposed TES that have been designed by the local government has not been able to accommodate all the people in the tsunami hazard inundation area in Padang City. location-allocation results, with the addition of the Proposed TES, the maximum number of people that can be accommodated is only around 34-39 percent in both scenarios based on scenarios. This shows that there is a need to design more closely related to both the Existing TES and the Proposed TES so that the percentage of the number of people who can be accommodated can increase. In this study, there are several limitations, including several places used, namely Temporary Evacuation Site and not using Final Evacuation Site. In addition, in community groups without considering age groups and without considering variations in the level of community response to disasters, it may be possible to produce more detailed results in further research.

REFERENCES

[1] R. A. Hadiguna and A. Wibowo, “Simulasi Sistim Logistik Bantuan Bencana Gempa – Tsunami : Studi Kasus Di Kota Padang,” no. 2008, 2011.

[2] BPBD, Rencana Kontijensi Menghadapi Bencana Tsunami Kota Padang, vol. 3. 2017.

[3] R. I. Liperda, A. R. Aulya, I. Sukarno, M. Lusiani, and N. Sirivongpaisal, “Geological Behavior (GBR) A Gis – Based Optimization For The Fuel Location-Allocation To Face The Probable Tsunami : Case Of Padang City,” vol. 5, no. 1, pp. 13–16, 2021, doi: 10.26480/gbr.01.2021.13.16.

[4] F. Ashar, D. Amaratunga, and R. Haigh, "The analysis of tsunami vertical shelter in Padang city," Procedia Economics and Finance, vol. 18, no. September, pp. 916–923, 2014, doi: 10.1016/S2212-5671(14)01018-1.

[5] Satgas, "Penyiapan Fasilitas Shelter Untuk Karantina Dan Isolasi Mandiri Berbasis Masyarakat Di Masa Pandemi Covid-19," pp. 1–7, 2020.

[6] L. R. Inca and S. Nikorn, "The Location-allocation Decision under The Dynamic Increment of Demand for Selecting The Local Distribution Centers to Face Sumatra Megathrust : Study Case of Padang City," vol. 9, no. 1, pp. 293–299, 2019.

[7] O. J. Taiwo, "Maximal Covering Location Problem (MCLP) for the identification of potential optimal COVID-19 testing facility sites in Nigeria," African Geographical Review, vol. 40, no. 4, pp. 395–411, Oct. 2021, doi: 10.1080/19376812.2020.1838306.

[8] Y. Shi, G. Zhai, L. Xu, Q. Zhu, and J. Deng, "Planning emergency shelters for urban disasters: A multi-level location-allocation modeling approach," Sustainability (Switzerland), vol. 11, no. 16, Aug. 2019, doi: 10.3390/su11164285.

[9] B. Özkan, S. Mete, E. Çelik, and E. Özceylan, "Gis-Based Maximum Covering Location Model In Times Of Disasters: The Case Of Tunceli," Beykoz Akademi Dergisi, pp. 100–111, Oct. 2019, doi: 10.14514/byk.m.26515393.2019.sp/100-111.

[10] K. M. Wibowo, I. Kanedi, and J. Jumadi, "Sistem Informasi Geografis (SIG) Menentukan Lokasi Pertambangan Batu Bara di Provinsi Bengkulu Berbasis Website," Jurnal Media Infotama, vol. 11, no. 1. pp. 51–60, 2015.

[11] A. Sahputra, R., Sutikno, S., & Sandhyavitri, "Mitigasi Bencana Kebakaran Lahan Gambut Berdasarkan Metode Network Analysis Berbasis GIS (Studi Kasus: Pulau Bengkalis)," 2017.

[12] ESRI, "Location-allocation analysis—ArcMap | Documentation," Esri. 2021. [Online]. Available: https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/location-allocation.htm

[13] A. T. Murray, J. Xu, Z. Wang, and R. L. Church, "Commercial GIS location analytics: capabilities and performance," International Journal of Geographical Information Science, vol. 33, no. 5, pp. 1106–1130, 2019, doi: 10.1080/13658816.2019.1572898.

[14] W. Xu, L. Qin, and X. Zhao, "Site Selection Models in Natural Disaster Shelters : A Review," pp. 1–24, 2019, doi: 10.3390/su11020399.

[15] J. Xu, A. Murray, Z. Wang, and R. Church, "Challenges in applying capacitated covering models," Transactions in GIS, vol. 24, no. 2, pp. 268–290, Apr. 2020, doi: https://doi.org/10.1111/tgis.12608.