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Model of Mapping Priority for Post-Disaster Infrastructure Rehabilitation and Reconstruction in Palu City

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Abstract:- In September 2018, a magnitude 5.2 earthquake struck Palu City – Central Sulawesi Province, Indonesia. The earthquake caused a destructive tsunami and a liquefaction which paralyzed activities in the region and the surrounding. This disaster occurred shortly after the cataclysmic earthquake in Lombok – NTB in July of the same year. Furthermore, the handling of infrastructure in the aftermath of the Palu City disaster demands for very precise and efficient approaches due to lack of resources. To facilitate the handling of rehabilitation and reconstruction, this study utilizes priority mapping models using geographic information systems (GIS). Two indicators of spatial data are used which consist of 10 infrastructure components, including infrastructures (roads / transportation, clean water, waste, irrigation, and housing) and facilities (health, economy, education, public administration, and worship places). Before making a mapping model, the Analytical Hierarchy Process (AHP) is used to obtain weighting data based on the priorities of the infrastructure indicators. Furthermore, the data is analyzed using algorithm density to produce a priority mapping model of post-disaster infrastructure rehabilitation and reconstruction in Palu City. The results show that coastal areas with large amounts of infrastructure damage are the priority in handling the rehabilitation and reconstruction of Palu City followed by the area which encountered liquefaction.

Keywords:- *Density Algorithm, Analytical Hierarchy Process (AHP), Mapping Model, Infrastructure Rehabilitation and Reconstruction Priority, Geographic Information System (GIS).*

I. INTRODUCTION

Indonesia is on the most active earthquake and volcanic track in the world because it is on the Pacific Ring of Fire or better known as Ring of Fire (Pusgen, 2017). One of the regions in Indonesia that is vulnerable to earthquake natural disasters accompanied by tsunamis and liquefaction is the City of Palu (Pratomo, R.A, & Rudiarto I., 2013). Based on historical records, the City of Palu and its surroundings have a considerable potential for tsunamis which are mostly triggered by earthquakes (Abdullah, 2005). These earthquakes occurred due to the active Palu-Koro fault with quite high seismic activity that stretched across the City of Palu. The Palu-Koro fault is a system of large active fault zones extending from north-northwest to south-southeast on the Indonesian island of Sulawesi (Mudin, 2015).

In September 2018, Palu City encountered an earthquake natural disaster which was followed by a very destructive tsunami and liquefaction. This disaster occurred shortly after the earthquake in Lombok - NTB in July of the same year. This led to the handling of post-disaster rehabilitation and reconstruction of infrastructure in Palu City is lack of resources, because most of them have been mobilized for post-disaster handling in Lombok - NTB. In addition, the impact of the damage that occurred after the disaster in Palu City was also massive which paralyzed the economy of Palu City. Therefore, comprehensive management is needed in a planning, coordinating and integration to help policy makers in determining the steps to address post-disaster rehabilitation and reconstruction of infrastructure in Palu City. The policies must have the principles of right on time, right on quality, and appropriateness, especially in the allocation of available resources.

The use of priority mapping models using geographic information systems (GIS) is expected to accelerate and facilitate the handling of rehabilitation and reconstruction of infrastructure after the disaster in Palu City (Fathansyah, 1999). In addition, the use of spatial data in geographic information systems (GIS) can provide more detailed and accurate results in handling post-disaster infrastructure damage in the administrative area of Palu City (Curran, 1984). To support the processing of spatial data, an analysis using the Analytical Hierarchy Process (AHP) is carried out by officials or experts in the field of disaster management. The purpose of this study was to obtain a priority mapping model for infrastructure rehabilitation and reconstruction after the disaster in Palu City.

II. METHODOLOGY

Primary data in this study were obtained through survey methods carried out using questionnaires and interviews. The questionnaires and interviews are collected to assess the priority of infrastructure in post-disaster rehabilitation and reconstruction on the perceptions of expertises and experience respondents in handling disasters.

The respondents chosen were officials and / or experts in their respective fields related to the rehabilitation and reconstruction of infrastructure after the disaster. The questionnaire compiled is a combination of the pairwise comparison between indicators and also open entries on suggestions and recommendations. Suggestions and recommendations are included, so that respondents can provide unlimited input which may provide inputs for writers from several different perspectives. Inputs from respondents who are officials and experts in the field of disaster management can enrich this research.

No.	Population	Sample	Number of Respondents
1.	Officials, Experts and Researchers in the field of clean water, sanitation and waste networks	• Director of Research Center for Water Resources • Young Researcher of Research Center for Water Resources	2 people
2.	Officials, Experts and Researchers in the infrastructure and facilities of infrastructure, housing and settlements	• Director of Research Institute for human settlements • Head of Program and Evaluation Division, Research Institute for human settlements	2 people
3.	Officials, Experts and Researchers in the field of road / transportation networks	Head of Program and Evaluation Division, Agency for Research and Development Institute of Road Engineering	1 person
4.	Infrastructure Assets Officer and Expert	Head of State Asset Own Management Center, Secretariat General, Ministry of Public Works and Public Housing	1 person
5.	Officials and Experts in Disaster Response Data and Information	• Head of Sub-Division for Emergency Response, Center of Data Processing • Head of Rehabilitation and Reconstruction Sub-Sector, Center of Data Processing • Head of the Disaster Mitigation Sub-Sector, Center of Data Processing	3 person
TOTAL			9 people

Table 1:- Population and Sample Mapping

Every post-disaster infrastructure rehabilitation and reconstruction program must be carried out as soon as possible, according to the priorities and available resources and must fulfill certain indicators of achievement. So that, each component can function adequately to support the continuity of life, social and economic community in the disaster area.

In accordance with the Regulation of the Head of BNPB No.11 of 2008 (BNPB, 2008), indicators of post-disaster infrastructure rehabilitation and reconstruction are including:

No.	Indicator	Component
1.	Infrastructure	1. Road / Transportation
		2. Clean water
		3. Sanitation and Waste
		4. Irrigation
		5. Housing
2.	Facilities	1. Health Centers
		2. Economy
		3. Education
		4. Public Administration Offices
		5. Worship places

Table 2:- Indicator of Infrastructure of Rehabilitation and Reconstruction

There are several stages of obtaining a priority mapping model for post-disaster infrastructure rehabilitation and reconstruction in this study, such as:

A. Priority Determination using Analytical Hierarchy Process (AHP) Method

The Analytical Hierarchy Process (AHP) was first introduced and developed in the 1970s by Dr. Thomas L. Saaty from the Wharton School of Business to organize information and considerations in choosing alternatives that have a high priority level. In general, AHP aims to arrange the priorities of various alternative choices which are complex and multicriteria (Bourgeois, 2005).

The initial step of this research is to analyze using the AHP method to obtain weighting data based on the priorities of the indicators and components of post-disaster rehabilitation and reconstruction of infrastructure.

Pairwise comparison is one method of comparing several criteria derived from AHP. Pairwise comparison matrix compares each component in each paired indicators to assess which components of each indicator have the highest priority order.

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Pairwise comparisons are divided into 3 parts, including pairings between indicators of rehabilitation and reconstruction of infrastructure in the infrastructure sector, paired items between indicators of rehabilitation and reconstruction of infrastructure, facilities, and pairing between indicators of infrastructure and facilities. Each of these fields has the following questions:

1. From the indicators of the infrastructure sector below, (Table 3) which are more prioritized regarding the rehabilitation and reconstruction of post-disaster infrastructure?

Infrastructure	Road / Transportation	Clean water	Sanitation and Waste	Irrigation	Housing
Road / Transportation	X				
Clean water	X	X			
Sanitation and Waste	X	X	X		
Irrigation	X	X	X	X	
Housing	X	X	X	X	X

Table 3:- Pairing Fields between the Components of the Infrastructure of Rehabilitation and Reconstruction Indicator

2. From the component indicators of the facilities below, (Table 4) which are more prioritized regarding the rehabilitation and reconstruction of post-disaster infrastructure?

Facilities	Health	Economy	Education	Offices	Worship
Health	X				
Economy	X	X			
Education	X	X	X		
Offices	X	X	X	X	
Worship	X	X	X	X	X

Table 4:- Pairing Fields Among the Indicator Components of Infrastructure of Rehabilitation and Reconstruction in the Field of Facilities

3. From the indicators of the infrastructure and facilities below, (Table 5) which are more prioritized regarding the rehabilitation and reconstruction of post-disaster infrastructure?

X	Facilities
Infrastructure	

Table 5:- Pairing Fields between Indicators of Infrastructure Rehabilitation and Reconstruction for Infrastructure and Facilities

Respondents' assessment data from 3 sections in pairs for 2 indicators with each of the 5 components of infrastructure indicators for post-disaster rehabilitation and reconstruction are compiled into priority sequences for handling damage from infrastructure component indicators.

B. Modeling using Geographic Information Systems (GIS)

After obtaining respondent weighting data based on the priorities of the indicators and components of post-disaster infrastructure rehabilitation and reconstruction, the next step is to make a mapping model using geographic information systems (GIS) with ArcGIS 10.5 software applications.

Secondary data in this study are spatial data collected from government agencies that are directly related to disaster management in Palu City, such as Ministry of Public Works and Public Housing (PUPR), Ministry of Health, and the National Disaster Management Agency (BNPB).

The next stage of processing is to process spatial data using the density algorithm. The tool used in the ArcGIS 10.5 software application is tailored to the data type. Point data type would be processed using the point density tool. The data in the questions includes public infrastructure: clean water, waste, irrigation, and housing; and public facilities: health, economy, education, offices, and worship. Moreover, line type data would be processed using the line density tool. The data is the data on public road / connecting infrastructure.

The results of the density tool calculation are then used in raster calculations that include weighting. Each infrastructure raster is multiplied by the weighting value obtained from the AHP method. This calculation includes multiplication of weights according to expert perceptions of each indicator. So that, the priority mapping of infrastructure rehabilitation and reconstruction is obtained as the model developed in this study.

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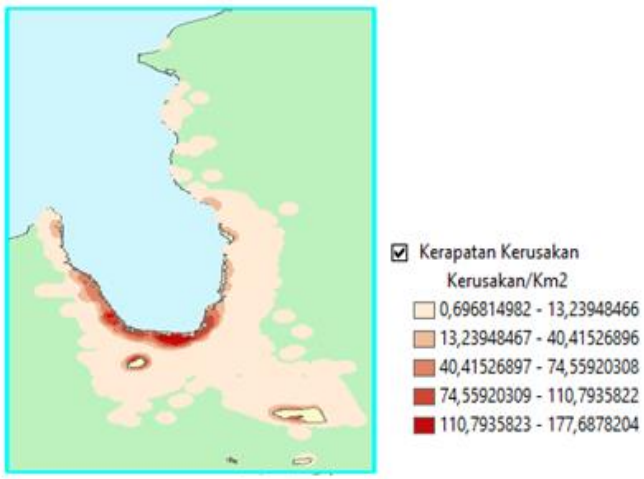

Fig. 1:- Map of Affected Area with Raster Calculation Results that Include Weighting

Fig.1 shows that coastal areas are the most affected by the disaster. Darker color areas indicate that the area has a higher priority handling level than the lighter colored area. From the figure, the priority area is dominated by the coastal area, and the other two points are more in the middle of the mainland.

III. RESULT AND DISSCUSSION

A. Results of Priority Determination Analysis using Analytical Hierarchy Process (AHP) Method

Based on Table 6, the assessment of experts chooses the clean water and road / transportation as the top two priorities weighing 37.7 and 24.8 respectively. Subsequently, they followed by waste infrastructure, housing, and irrigation with weights of 20.5, 11.5 and 5.5 respectively.

No.	Component	Weight	Ranking
1	Road / Transportation	24.8	2
2	Clean water	37.7	1
3	Sanitation and Waste	20.5	3
4	Irrigation	5.5	5
5	Housing	11.5	4

Table 6:- Results of Weighting Calculation of AHP Pairing Fields between Components of Indicators for Infrastructure Rehabilitation and Reconstruction in the Infrastructure Sector

Based on Table 7, the assessment of experts argues that health and education infrastructure as the main priority. Each component of the indicator has a weight of 43.7 and 20.3. The third sequence is filled by economic infrastructure with a weight of 15.2. Furthermore, it followed by worship infrastructure and offices weighing 11.6 and 9.1 respectively.

No.	Component	Weight	Ranking
1	Health	43.7	1
2	Economy	15.2	3
3	Education	20.3	2
4	Offices	9.1	5
5	Worship	11.6	4

Table 7:- Results of Weighting Calculation of AHP in Pairing Between Components of Indicators for Infrastructure Rehabilitation and Reconstruction for Facilities

Based on Table 8, Among all indicators of infrastructure rehabilitation and reconstruction in infrastructure and facilities, the experts who responded stated that infrastructure in the infrastructure sector was more prioritized than infrastructure in the field of facilities with a value of 73.6 for the infrastructure category and 26.4 for the facilities category.

No.	Component	Weight	Ranking
1	Infrastructure	73.6	1
2	Facilities	26.4	2

Table 8:- Results of Weighting Calculation of AHP Pairing Fields between Indicators of Infrastructure Rehabilitation and Reconstruction for Infrastructure and Facilities

Table 9 shows the calculation of all indicators weight of infrastructure rehabilitation and reconstruction without the separation of indicators. The calculation results show that the top five priorities are filled by four indicators of infrastructure and one infrastructure facility, including clean water (27.75), roads / links (18.25), waste (15.09), health (11.55), and housing (8.46). The five lowest ranking criteria are dominated by facilities with a weighting value below the average of 5, except education which is positioned in the sixth (overall) with a weighting value of 5.36.

No	Component	Weight	Ranking
A	**Infrastructure**		
1	Road / Transportation	18.25	2
2	Clean water	27.75	1
3	Sanitation and Waste	15.09	3
4	Irrigation	4.05	7
5	Housing	8.46	5
B	**Facilities**		
1	Health	11.55	4
2	Economy	4.02	8
3	Education	5.36	6
4	Offices	2.40	10
5	Worship	3.07	9

Table 9:- Results of Weighting Calculation of Paired AHP Between All Indicators of Infrastructure Rehabilitation and Reconstruction for Infrastructure and Facilities

B. The results of the Modeling Analysis using Geographic Information Systems (GIS)

The analysis used in this study in determining the priority is the area with the highest level of damage density based on the model developed.

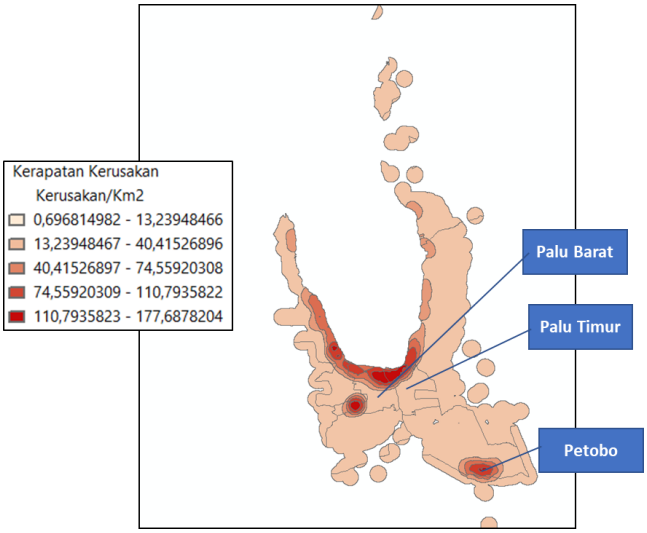

Fig. 2:- Results of Post-Disaster Infrastructure Rehabilitation and Reconstruction Priority Mapping Analysis

Based on the mapping of the modeling results in Fig. 2, the area that needs to be given the highest priority is the coastal area of Palu Timur District and West Palu District. These two sub-districts are part of the center of Palu City. This means that this area needs a fast-response and accurate handling which may restore community activities as usual. The dark red areas in these two sub-districts have relatively the same area, so the priority ranking of rehabilitation and reconstruction of infrastructure in these two sub-districts is prioritized.

The next area is the area in the West Palu District which is deeper inland. This area has a high damage density due to having a number of components of priority infrastructure indicators that have been damaged, including clean water infrastructure, sanitation and waste treatment infrastructure, and health facilities. As the results, the damage needs to be set as the top priority in the handling of rehabilitation and reconstruction of infrastructure to ensure adequate public services to the community.

The other area that has the highest damage density is Petobo Village. This area suffered fatal damage due to the liquefaction disaster. The disaster has caused all infrastructures on the surface to be damaged and sunk into the ground. Therefore, the damage to the infrastructure results in a huge loss. In the result, this area is part of the main priority in handling post-disaster rehabilitation and reconstruction in Palu City. However, taking into account the possibility of a recurrence of liquefaction and the statement of the relevant policy-making public official (statement from the Minister of Public Works and Housing, 2018) which will not develop Petobo Village due to the possibility of a similar disaster recurring; this study recommends that the area of Petobo Village not be included in the main priority in handling post-disaster rehabilitation and reconstruction in Palu City. This recommendation is part of disaster mitigation in Palu City.

IV. CONCLUSION

Indicators in determining the priority of post-disaster infrastructure rehabilitation and reconstruction consist of 2 indicators with 5 components for each, including infrastructure (roads / transportation, clean water, waste, irrigation, and housing) and facilities (health, economy, education, offices, and worship).

From the results of the analysis using the AHP method, the model for determining the weight of the priority indicator components of the post-disaster rehabilitation and reconstruction of the City of Palu resulting clean water as the top priority in 27.75 weighting value, and the rests are roads / transportation (18.25), waste (15.09), health (11 , 55), housing (8.46), education (5.36), irrigation (4.05), economy (4.02), worship (3.07) and offices (2.40).

Based on the mapping model built in this study, recommendations for priority areas for handling rehabilitation and reconstruction of infrastructure post-disaster in Palu City includes East Palu District, Palu Barat District and Petobo Village.

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