Efficient Transportation of Disaster Waste in Jetis Region, Bantul Regency, Yogyakarta

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Abstract

Bantul Regency had Yogyakarta Earthquake in 27th May, 2006. Jetis region in Bantul Regency had severe damages due to this earthquake. After this experience, Bantul government needed to have the assessment of earlier disaster waste disposal for a next supposed earthquake. Therefore, this study sets two purposes as, 1) to find a disposal location of disaster waste in Jetis region, 2) to find an efficient transportation that considers both time and cost.

This study revealed that the total volume of waste generated under a supposed earthquake in Jetis region is 92.883,2 tons. This volume required a disposal area with 80.111,76 m^2, and Karang Semut, which has 9 ha, was proposed in this study. This study set 3 scenarios to evaluate the fastest road network to disaster waste disposal using Djikastra algorithm. This study also set another 4 scenarios, to investigate efficient tranportation of disaster waste with considering both time and cost by using Hauled Container System. As a result, the time for disaster waste disposal in Jetis takes 20 to 22 days with using 60 trucks, and for 8 to 9 days with 150 trucks. The trucks are allocated simultaneously in each village, it takes more days for waste disposal. The total cost is estimated from Rp.715,020.678.23 to Rp.787,828,088.07 depending on the senario.

Keywords: Disaster waste, Optimum Transportation, Djikstra Algorithm, Hauled Container System

1. INTRODUCTION

Earthquake is a major natural disaster in Indonesia. One of the examples is Yogyakarta Earthquake that occurred on May 27, 2006, and the magnitude was 5.9 in Ritcher scale. Damages in Bantul Regency, the research area of this study, were about 4,143 casualties and 78,622 heavily house damage. The total volume of disaster waste was estimated 2,900,000 tons, and also 950,000 tons in Bantul Regency [1].

Jetis is a region in Bantul Regency. 70% of houses in this region were destroyed by this earthquake. Each village in Jetis region had a different damage, and generated a different volume of disaster waste. From this event, the local government understood the importance of a disaster waste management.

In the management of disaster waste in Indonesia[2], local governments need to clear the methods for handling disaster waste as, 1) securing a temporary or final disposal location, 2) transporting the wastes to the disposal place, 3) monitoring the proper disposal. In addition to these items, the recycling of waste is an important policy in disaster waste problems.

An earthquake disaster often damages the road network. The network damage sometimes causes a difficulty in disaster recovery. For example, it prolongs the disaster recovery and expand a recovery budget. In order to realize an earlier recovery from disaster damages in Jetis region, it is important to assess the disaster waste management from the viewpoint of the availability of road network and the cost of the waste transportation.

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From above background, this study set the following two objectives. 1) to show an appropriate disposal place in Jetis region. 2) to assess an efficient waste transportation with regarding transportation distance, time, and cost.

2. EVALUATION METHOD

2.1 Configurations of study area

The location of Jetis region is shown in Figure 1. Jetis is one of 17 sub-districts in Bantul Regency. Jetis area is 2,447ha, and is divided into four villages. The northern part consists of Sumberagung Village and Trimulyo Village, while in the southern part consists of Patalan Village and Canden Village. Jetis locates near Opak Fault and the region has a higher earthquake potential as shown in Figure 2.

Figure 1. Location of research area, Jetis region in Bantul Regency

Table 1 shows the number of damaged houses by Yogyakarta Earthquake in 2006[2]. In this earthquake, Bantul area had the largest damage. The heavy damaged houses were 78.622, and the light damaged houses were 69.818. From those damages, the total disaster waste was estimated 950,000 tons[3].

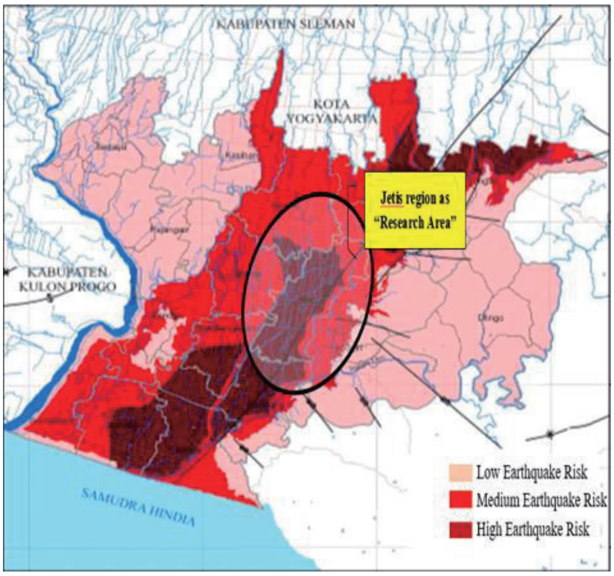

Figure 2. Earthquake hazard map in Bantul Regency.

Beside Bantul area, Kulon Progo, Gunungkidul, Sleman and Yogyakarta city had the earthquake damages. Based on these damages, Maryono[4] estimated the total volume of disaster waste as 2,900,000 tons.

Jetis area also had a large impact by Yogyakarta Earthquake in 2006. Table 2 shows the number of damaged houses in each village in Jetis area. This research evaluates the location of the disaster waste disposal area in Jetis region. The location accepts the disaster wastes from each village, when an earthquake produces the amount of disaster waste.

Table 1. Number of house damages due to Yogyakarta Earthquake in 2006[5]

Regency	House damages (unit)	
	Heavy Damage	Light Damage
Kulon Progo	4,009	5,134
Bantul	78,622	69,818
Gunungkidul	2,957	5,783
Sleman	6,186	16,065
Yogyakarta	4,129	10,219
Total	95,903	107,019

This research employs trucks with a capacity of 10 tons. This size is commonly available in Indonesia. Bantul Regency can provide 60 trucks by itself. In addition to this number, there is a possibility to increase the number of tracks up to 150 by the support from Yogyakarta Province.

Table 2. House damages due to Yogyakarta earthquake in 2006

No	Village in Jetis Region	Level of Damage		
		Totally Damage	Heavy Damage	Light Damage
1	Patalan	2.799	392	82
2	Sumberagung	2.263	1.218	221
3	Canden	3.008	116	13
4	Trimulyo	3.286	884	348
	Total	11.356	2.610	664

Source: *Recapitulation data of earthquake natural disaster (Jetis Region office,2006)*

2.2 Location of disaster waste disposal place and road network

Figure 3 shows the disposal place of disaster waste and road network in Jetis region. The disposal place is located in Karang Semut, where this location has a area of 9ha. This locatian is selecteed by considering the total volume of disaster waste, proximity from each village and availability of open space in Jetis region.

This study uses Dijkstra's Algorithm[6] to find a suitable place for disaster waste disposal. This is a transportation modeling which finds the fastest path from an origin to a destination with using a directional graph. The algorithm finds a path from a current node to an optimal node at each step. This study sets some scenarios, which are mentioned in next subsection, and assesses an efficient route for the disaster waste disposal.

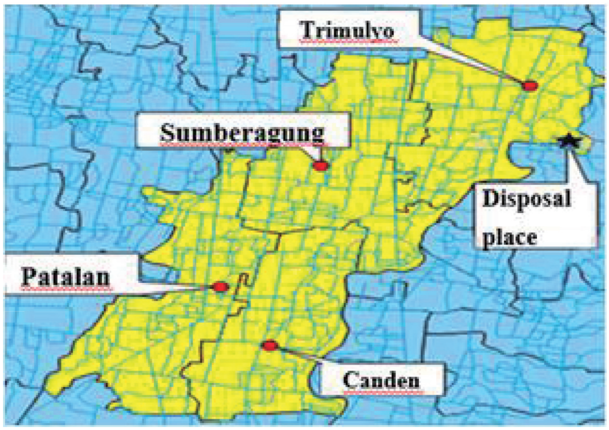

Figure 3. Proposed disposal location and road network in Karang Semut, Jetis

2.3 Estimation of disaster wastes

Based on the estimation by Indonesian National Board for Disaster Management, BNPB, the total number of damaged houses in Bantul is estimated 148,480[5]. According to the previous study by Boen T.[7], the average number of disaster waste generated by a damaged house is accounted 6.4 tons. This study used this number to estimate the volume of disaster waste in each village.

This study estimates the volume of solidified waste with using following equation (1).

$$V = A \times E \quad (1)$$

where *V* is solid waste volume, *A* is a volume of waste, *and E* is a compaction rate assumed 1.5 ton/m^3 [8].

In Patalan village, the total number of damage houses is estimated 3,273, and the waste can be estimated 20,947.2 ton. In Sumberagung village, the damage houses are 3,702 and the wastes are 22,944 tons. In Canden village, the houses are 3,137 and the wastes are 20,076.8 tons. In Trimulyo village, the houses are 4,518 houses and the wastes are 28,915.2 ton. The total wastes in Jetis are 92,883.2 tons.

The area of disposal place was calculated by the following equation (2).

$$L = \frac{V}{T} \times r \quad (2)$$

where *L* is the area of disposal place, *T* is a landfilled height (2m in this study), *r* is a margin factor, 1.15.

From equation (1), the total volume of solid waste in Jetis region is estimated 139,324.8 m^3. Also from equation (2), the area for disposal place is estimated 80,111.76 m^2. Regarding the available open space in Jetis region, the study set Karang Semut, which has 9 ha, as the disaster waste disposal place in Jetis region

2.4 Scenarios set in this study

This study firstly set three scenarios to discuss the influence of network damages on time that is needed to complete the waste disposal in Jetis region.

In scenario 1, all road networks are available without any damages. In scenario 2, only the wider roads more than 7 m capacity can be used for the waste transportation. In scenario 3, only the narrow roads less than 4 m and wider roads away from residential house can be used.

Secondly, this study also set four scenarios to investigate the efficient tranportation of disaster waste with considering both time and cost. In scenario 4, 60 trucks are used for transportation of waste, and 150 trucks in scenario 5. The transportation is carried out in both scenario by allocating all trucks to each village in turn. In scenario 6, 15 trucks are allocated simultaneously to each village, total is 60 trucks. In scenario 7, a total of 150 trucks are also allocated to Canden 37, 38 to Sumberagung, 37 to Patalan and 38 to Trimulyo, simultaneously.

2.5 Evaluation of transportation time and cost

This study calculate the number of trips with equation (3), that is based on Hauled Container System, HCS, method[9].

$$N_d = \frac{(1-W)H-(t1+t2)}{(pc+ac+dbc)+(s+a+bx)} \quad (3)$$

where N_d is the number of trip per day, *W* is an off route factor, *H* is a length of working day (*hour/day*), *t1* is a time from origin area to disposal place, *t2* is a time from disposal place to origin area, *pc* is a pick-up time per trip (*hour/trip*), *ac* is a time required to unload empty container, (*hour/trip*), *dbc* is an average time spent driving between container locations (*hour/trip*), *s* is a at-site time per trip (*hour/trip*), *a* is an empirical haul constant (*hour/trip*), *b* is also an empirical haul constant (*hour/km*), and *x* is a round-trip haul distance (*km/trip*).

In this study, time for pick up loaded and deposit empty container, *pc+ac*, was assumed 1.5 hour, and the time at the site, *s,* was also assumed 30 minutes. The trucks run with a constant speed as 30 km/h

This study assumed the use of truck with 10tons capacity, and the cost for renting a truck, including the cost for driver and fuel, is supposed Rp.587.650.74.

3. RESULTS AND DISCUSSIONS

3.1 The fastest transportation network

In Canden village, the fastest route from the origin “A” disposal location “K” is A - B1 - C 1- D1 - E1 - F1 - K in scenario 1 as shown in figure 4. The distance from A to K is 7.7 km and the time of transportation is 17 minutes. In scenario 2, the route is A - B3 - D3 - D1 - E3 - I2 - J1 - K, the distance is 8.9 km and the time is 17 minutes 48 seconds. In scenario 3, the route is A – B1- C1 - D1- E2 - F1 - I1 - K, the distance is 8,2 km, and the time is 18 minutes 24 seconds.

The result of the fastest tanspotation network in each village is summarized in Table 3.

From Table 3, scenario 1 provides the fastest route to disposal place from Canden, Patalan, Trimulyo village. While in Sumberagung village, the fastest route to the disposal place is in scenario 2.

3.2 Evaluation of time and cost

This subchapter evaluates the time and cost for waste transportation depending on the allocation of the trucks in each transportation network discussed in previous subchapter 3.1.

In Canden village, it takes 20 days for the waste transportation in scenario 4, that allocates 60 trucks for each village in oder under the transportation network of scenario 1. It also takes 21 days for the waste transportation under the transportation network

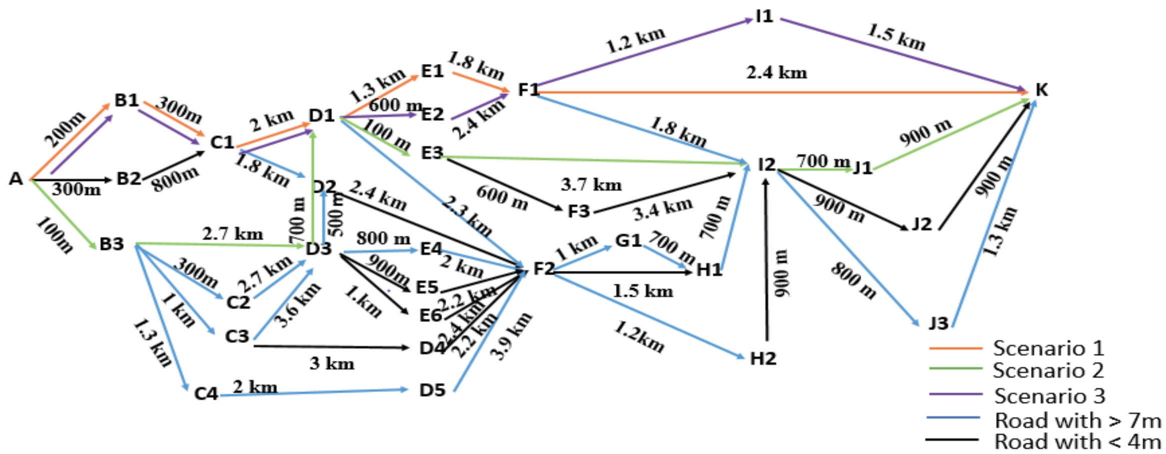

Figure. 4. Transportation network in Canden village

of scenario 2 and scenario 3. The total cost for the waste transportation at Canden village is Rp. 715,020,678.23 in scenario 1, Rp. 729,917,946.99 in scenario 2, and Rp. 743,922,139.13 in scenario 3.

Table 3. Result of the fastest network of each village in Jetis region

Villages	Scenario	Route	Length (km)	Time
Canden	1	A-B1-C1-D1-E1-F1-K	7,7	17 min 0 sec
	2	A-B3-D3-D1-E3-I2-J1-K	8,9	17 min 48 sec
	3	A-B1-C1-D1-E2-F1-I1-K	8,2	18 min 24 sec
Sumber agung	1	A-B1-D2-E3-H1-I2-J	5,25	11 min 30 sec
	2	A-B2-D1-E1-F1-G1-H1-I2-J	5,4	10 min 54 sec
	3	A-B1-D2-E2-G1-H1-I3-J	5,55	12 min 41 sec
Patalan	1	A-B2-D3-E4-F2-H2-I2-J1-K	7,9	16 min 12 sec
	2	A-B1-C1-D1-E1-F1-K	8,7	18 min 34 sec
	3	A-B2-D3-E5-F2-H2-I2-J2-K	8,4	19 min 10 sec
Trimulyo	1	A-B1-D2-E2-F	1,65	3 min 24 sec
	2	A-B2-C2-D2-E2-F	1,8	4 min 0 sec
	3	A-B3-C2-D2-E3-F	1,9	4 min 41 sec

Table 4 summarizes the time and cost for the waste transportation at each village in scenario 4 under the network of scenario 1, scenario 2, and scenario 3.

Table 5 also summarizes the time and cost in each village in scenario 5. Futrhermore, Table 6 and Table 7 shows the time and cost for the waste transportation in scenario 6 and scenario 7.

Judging from the comparison between Table 4 and Table 5, larger number of trucks make a waste disposal period shorter. This can be seen between Table 6 and Table 7. Of course, scenario 1 is faster than scenario 2 and scenario 3 due to the availability of the networks, though difference of disposal period seems smaller between scenario1, scenario2, and scenario 3.

Furthermore, as shown in Table 4 and Table 6, the waste disposal period in scenario 4 is faster than that in scenario 6. This means that all trucks should be allocated to each village in turn. Allocating the even number of trucks to each village seems disadvantage in earlier waste disposal. The same result can be seen between Table 5 and Table 7.

On the other hand, the total cost in scenario 1 shown in the tables from Table 4 to Table 7 is the same . This is because the total number of trucks used in the waste disposal period is the same in each scenario. The same result can be seen in scenario 2 and scenario 3. The total cost relates to the waste disposal period, and the cost in scenario 1 is lower than scenario 2 and scenario 3. This indicates the importance of keeping the networks availabe for completing the disaster waste disposal earlier after a huge earthquake event.

Table 4. Results of time and cost for waste transportation in scenario 4 with 60 trucks for each village

Villages	scenario	days	Total cost (Rp.)
Canden	1	20	715.020.678
	2	21	729.917.947
	3	21	743.922.139
Sumberagung	1	20	722.146.197
	2	21	723.333.990
	3	21	757.954.487
Patalan	1	21	734.363.336
	2	22	776.387.203
	3	22	787.546.016
Trimulyo	1	21	735.058.754
	2	21	747.495.928
	3	22	759.569.874

Table 5. Results of time and cost for waste transportation in scenario 5 with 150 for each village

Villages	scenario	days	Total cost (Rp.)
Canden	1	8	715.049.171
	2	8	729.947.033
	3	8	743.951.783
Sumberagung	1	8	722.146.197
	2	8	723.333.990
	3	9	757.954.487
Patalan	1	8	734.615.839
	2	9	776.654.155
	3	9	787.816.805
Trimulyo	1	8	735.058.754
	2	8	747.495.928
	3	9	759.569.874

Table 6. Results of time and cost for waste transportation in scenario 6

Villages	scenario	days	Total cost (Rp.)
Canden (15 trucks)	1	81	715.074.102
	2	83	729.972.484
	3	84	743.977.722
Sumberagung (15 trucks)	1	83	722.146.197
	2	83	723.333.990
	3	87	757.954.487
Patalan (15 trucks)	1	83	734.626.360
	2	88	776.665.278
	3	89	787.828.088
Trimulyo (15 trucks)	1	83	735.066.381
	2	85	747.503.683
	3	86	759.577.755

Table 7. Results of time and cost for waste transportation in scenario 7

Villages	scenario	days	Total cost (Rp.)
Canden (37 trucks)	1	33	715.027.801
	2	34	729.925.219
	3	34	743.929.550
Sumberagung (38 trucks)	1	32	722.158.787
	2	32	723.346.601
	3	34	757.967.701
Patalan (37 trucks)	1	34	734.563.234
	2	36	776.598.540
	3	36	787.760.391
Trimulyo (38 trucks)	1	33	735.033.333
	2	33	747.470.076
	3	34	759.543.606

4. CONCLUSIONS

The total volume of disaster waste in Jetis region is estimated 92,883.2 tons. This volume requires the area of 80,111.76 m^2. Regarding this area and an available open space in Jetis region, this study proposes Karang Semut, that has 9ha, as a waste disposal area.

The fastest transportation network from each village to the waste disposal area differs depending on the available network scenarios. Based on this result, this study evaluated the time and cost for the waste transportation by supposing the different allocation of trucks in each village.

The best scenario for the waste tranposportation in regarding the time and cost is allocating 150 trucks to each village in turn. On the other hand, the time for waste tranportation become longer in the case of allocating almost the same number of trucks, total is 150 trucks, simultaneously to each village depending on their waste volume.

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