AID GOODS ALLOCATION - DISTRIBUTION INTEGRATION PLANNING FOR NATURAL DISASTER RELIEF WITH DIRECT SHIPMENT

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The aid goods distribution for natural disaster relief involves activities for delivering aid goods from supply nodes to demand nodes. In this case, the supply nodes are the places whith surplus of commodity or aid goods and the demand nodes are the places where the disaster occurred. A well-planned integration of allocation-distribution system of aid goods is essential to support a prompt supply of aid goods for minimizing the casualties and restoring the productive activities in the disaster area.

This paper discusses a research on development of allocation and distribution model of aid goods for natural disaster relief. The objective function of the model is to minimize total unsatisfied demands for all necessary aid goods in all demand nodes throughout the planning horizon.

The model considered multi commodities, multi transportation modes, multi vehicles, and multi periods. The model is decomposed into two sub models. Sub model 1 deals with the allocation problem of aid goods, and sub model 2 concerns with the assignment problem of vehicle distributing aid goods where their compositions and amounts are to be specified by Sub model 1. Allocation of aid goods in Sub model 1 considered weighted of commodities, so the solution of the developed model in sub model 1 obtained with *Integer Linear Programming* (ILP).The sub model 2 developed in this research also adopts maximum weight and volume of consignment to define load capacities of vehicles used in delivering the aid goods. The pattern of distribution is direct shipment; one supply node will supply multi commodities for many demand nodes. The purpose of this paper is to determine allocation model for both type and amount of aid goods which will be distributed from supply node to demand node.

Keywords: Distribution System Planning, disaster logistics, transportation, Integer Linear Programming (ILP), direct shipment.

1. INTRODUCTION

Hoesada (2006), defined that disaster represents the sudden/unexpected interruption that breaks the continuity of daily activity or operations and having destructive effect to member of the community, clients as well as various other stakeholders of the said community. The interruption can cause community losing their productive and isolated from outsource supply resources. Moe (2006) defined that disaster management same with public project management, the difference is that disaster management disregards cost efficiency, while public project management is aimed at minimizing cost. In addition financing of disaster management came from governmental fund, non-government organization (NGO) and international organization fund, while financing of ordinary public project is to be provided only by the government. How ever, in case of disaster situation, a particular allocation system and aid goods distribution is to be designed in an emergency, responds circumstance involving delivery of goods like medical personnels as well as medicines, medical equipments, food and beverages to the affected areas.

Some researches have been conducted in the field of aid goods distribution for disaster. Ozdamar, Ekinci, and Kucukyazici (2004) have done research focusing on the development of mathematical model for natural disaster macro scale logistics planning. The model integrates the problem of multi-commodities flow network with the problem of routing vehicle having objective function of minimizing the total of unsatisfied demand of all commodities or aid goods in all demand nodes throughout the planning horizon. Another research conducted by Yi and Ozdamar (2007) tends to integrate the model of location and distribution to coordinated logistics support and evacuation process in emergency response circumstance and relief for natural disaster.

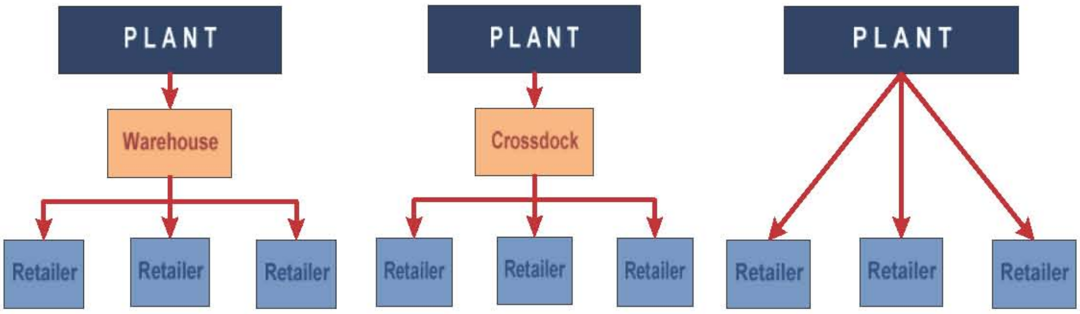
Solution of the model proposed by Ozdamar, Ekinci, and Kucukyazici (2004) is to decompose the model in two, i.e. model P1 deals with the allocation of aid goods or commodities, while model P2 concerns with the assignment of transportation mode or vehicle. However the said model for took into configuration the vehicle load capacity constraint only, while the volume limitation of the vehicle was disregarded. Volume constraints may impose primary limitation when we deal with light voluminous material such as temporary shelter materials for emergency.

This paper discusses about model development for allocation and distribution of aid goods in natural disaster relief activities subject to load capacity and volume constraint of vehicle. The objective is to minimize the sum of unsatisfied demand for all commodities or aid goods throughout the planning horizon. The unsatisfied demand in this model is the shortage amount of all kind of commodity at all entire demand nodes during the planning horizon. Distribution of aid goods in this model concerns with the aid goods allocation from point of origin to point of destination and assignment of transportation mode or vehicle that will distribute the aid goods or commodities.

2. ANALYSIS OF PROBLEM

Model for distribution of aid goods from supply nodes to demand nodes (disaster location) previously studied by Ozdamar, Ekinci, and Kucukyazici (2004).

Distribution strategy can be divided in 3 patterns, is warehousing, cross docking (recognized also as distribution just-in-time) and direct shipment (Simchi-Levi et al., 2003). The schemes of the distribution strategy are presented in Picture 1.



(a) warehousing (a) cross docking (a) direct shipment

Figure 1. Scheme of distribution strategy.

All of the distribution patterns shown above can be used in aid goods distribution of emergency response for disaster. In this research, the direct shipment was used, with the distribution structure shown here bellow:

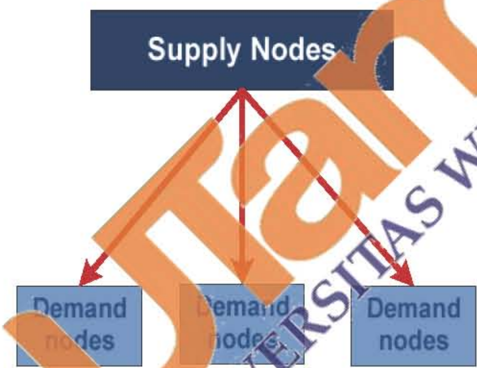


Figure 2. Structure of direct shipment aid goods distribution

The detail clarification for each node shown in the distribution structure is as follows:

1. Supply nodes are the points of origin, housing the resources (commodity and aid goods) to be delivered to demand nodes.
2. Demand nodes are points of destinations, with some shortage amount of demand for each resource (commodity and aid goods). The demand should be fulfilled by transporting the required resources from the supply nodes. In disaster cases, demand nodes are areas or locations affected by disaster.

The aid goods distribution presented model in this paper is basically decomposed into two sub models taking into account not only vehicle load capacity but also volume limitation as well wich was not considered in the aforementioned model (Ozdamar, Ekinci, and Kucukyazici, 2004). The solution both models is done sequentially in one model by using Integer Linear Programming (ILP) method and software Lingo 9.

There is some assumption, which is used in development of model; the assumption shall be as follows:

1. The model that developed in this paper do not consider the delivery cost of aid goods,

2. The delivery of aid goods conducted directly or using the direct shipment as structure of distribution from point of origin to point of destination.

3. MATHEMATICAL FORMULATION

The mathematical formulation of the problem and the corresponding notations are given here below. The notations fall into 3 groups which stand for set notations, parameter notations and decision variable notations, with the details are the followings:

a. Set notations

T : length of the planning horizon,
C : set of all nodes,
CD : set of demand nodes,
CS : set of supply nodes
A : set of commodities,
M : set of transportation modes, (ex. ground, rail way, marine, air)
V_m : set of vehicle types defined for each transportation mode m,

b. Parameter notations

f_{opvm} : the maximum traveling frequency that can be done to traverse arc *(o, p)*, with in one periode of delivery time by vehicle v and transportation mode m, f_{opvm} is zero for non-existent links,
o : point of origin
p : point of destination
h_a : the weight of commodity a (kg),
i_a : the length of commodity a (m),
j_a : the width of commodity a (m),
k_a : the height of commodity a (m),
q_{vm} : the maximum load capacity of vehicle v and transportation modes m (kg),
l_{vm} : the length of vehicle v and transportation modes m (m),
b_{vm} : the width of vehicle v and transportation modes m (m),
n_{vm} : the height of vehicle v and transportation modes m (m),
d_{aot} : amount of commodity a demanded or supplied at node o at time t (unit), positive for supply and negative for demand,
av_{ovmt} : number of vehicles of type v – transportation mode m at node o *added* to the fleet at time t ,

c. Decision variables notations

R_{aopvmt}	:	Amount of commodity a that allocated at arc (o,p) using vehicle v and transportation mode m at time t (unit).
dev_{aot}	:	Amount of unsatisfied demand for commodity a in demand node o at time t (unit).
X_{opmvt}	:	integer number of vehicle of type v – transportation mode m traversing the arc (o, p) at time t ,
Z_{ovmt}	:	integer number of vehicle of type v – transportation mode m *not*-traversing the arc (o, p) at time t ,

The objective function for this model is minimizing the sum of unsatisfied demand for all commodities or aid goods at all the demand nodes throughout the planning horizon. The objective function can be expressed in mathematical statement as follows:

$$\text{minimize} \sum_{a\in A}\sum_{o\in CD}\sum_{t\in T} dev_{aot} \qquad (1)$$

Subject to:

$$\sum_{m\in M}\sum_{v\in V_m}\left[-\sum_{p\in C} R_{apovmt} + \sum_{p\in C} R_{aopvmt}\right] - dev_{aot} = d_{aot}, \quad (\forall a\in A, o\in CD, t\in T), \qquad (2)$$

$$\sum_{m\in M}\sum_{v\in V_m}\left[-\sum_{p\in C} R_{apovmt} + \sum_{p\in C} R_{aopvmt}\right] \le d_{aot}, \quad (\forall a\in A, o\in CS, t\in T), \qquad (3)$$

$$\sum_{p\in C} X_{opvmt} + Z_{ovmt} \le av_{ovmt}, \quad \forall o\in C, v\in V, m\in M, t\in T \qquad (4)$$

$$\sum_{a\in A} h_a \times R_{aopvmt} \le \sum_{v\in V_m} X_{opvmt} \times q_v \times f_{opvm}, \quad (\forall\{o,p\}\subseteq C, m\in M, t\in T) \qquad (5)$$

$$\sum_{a\in A}(i_a \times j_a \times k_a)\times R_{aopvmt} \le \sum_{v\in V_m} X_{opvmt} \times (l_{vm}\times b_{vm}\times n_{vm})\times f_{opvm}, \qquad (6)$$

$$(\forall\{o,p\}\subseteq C, m\in M, t\in T)$$

$$R_{aopvmt} \ge 0 \qquad (7)$$

$$dev_{aot} \ge 0; \qquad (8)$$

$$X_{opvmt} \ge 0 \text{ and integer} \qquad (9)$$

$$Z_{ovmt} \geq 0 \text{ and integer,} \tag{10}$$

Constraint set (2) balances material flow between demand nodes and supply nodes and explicitly reports the quantity of unsatisfied demand, dev_{aot}, in each period. Constraint set (3) material flow balance on supply nodes, this constraint makes sure that the amount of aid goods delivered to demand nodes does not exceed the available amount at the supply nodes. Constraint set (4) ensures that the number of vehicles delivering the aid goods from supply nodes to demand nodes does not exceed the number of vehicles available at the supply nodes. If the number of vehicles available at the supply nodes is bigger than the number of vehicle delivering the aid goods, there will be excess idle vehicles. Constraint set (5) makes sure that the total weight of the entire commodity, delivered using any vehicle does not exceed the total load capacity of the said vehicle. Constraint set (6) implies that the total volume of all transported aid goods does not exceed the total volume capacity of vehicle. Constraint set (7) until (10) are non-negative constraint, indicating that the minimum value for all decision variables is 0 (zero)

4. ALGORITHM SOLUTION

The algorithm of solution model performed within development of aid goods distribution model at this research can be resume as follows:

1. Define the objective function,
2. Determine the time horizon planning,
3. Define the matrix sets and parameters,
4. Run the program for t = 1,
5. Obtain the minimized shortage solution for sub model 1, defining the amount of aid goods or commodity to be delivered to a specific destination by particular vehicle and transportation mode at any scheduled time t, R_{aopvmt}.
6. From the solution of sub model 1, check if there is still unsatisfied demand.
   a. If NO, than all of the demands 100% are fulfilled
   b. If YES, than read the unsatisfied demand as $dev_{aot,}$
7. Based on the solution of sub model 1, next iterate the sub model 2, to define the assignment for each vehicle, X_{opvmt} which will minimize.
8. From the solution of sub model 2, check if there is still the idle vehicle.
   a. If NO, than all of the number vehicle that distributed the commodity is was 100%,
   b. If YES, than read the idle vehicles as $Z_{ovmt.}$
9. Save the R_{aopvmt}, dev_{aot}, X_{opvmt}, and Z_{ovmt} as optimal solution at t=1,
10. Calculate the objective function for t=1,
11. Check, $t = T$?
    a. If NO, go to step 12,
    b. If YES, jump to step 15,
12. Revise all of the sets and parameters for t+1,
    a. Revise sum or number or type for commodity and number or type of vehicle if necessary,
    b. Parameter d_{aot} became $d_{aot} + dev_{aot-1}$
13. Run the program and calculate the decision variables for $t = t$+1,
14. Repeat step 5 until step 13, and $t = T$,

15. Compile the report of optimal solution.

5. NUMERICAL EXAMPLE

Numerical example conducted to obtain and to analyze solution of the model. The assumptions used in the numerical example shall be as follows:

1. Amount of demand for each commodity in the first period (day-1) at demand nodes is known.
2. Amount of demand for each commodity at demand nodes for next period (after day-1 until at the end of the horizon planning) conducted by forecasting and added with unsatisfied demand at previous period. In this case, demand for day-2 until the end of the horizon planning is assumed increase 10%.
3. Amount of supply capacities for each commodity in the first period (day-1) at supply nodes is known.
4. Amount of supply capacities for each commodity at supply nodes for next period (after day-1 until at the end of the horizon planning) conducted by forecasting. In this case, demand for day-2 until the end of the horizon planning is assumed increase 20%.
5. Horizon planning in this case is six periods.

Demand nodes in this case are consisting of six nodes, are Bantul, Sleman, Yogya, Kulon Progo, Gunung Kidul, and Klaten. Supply nodes consist of 28 nodes, that shown at Tables 1. Commodity, which is considered in this case, is rice, instant noodles, mineral water, white sugar, clothes, and medicines. Amount of demand and supply capacities for each commodity at every nodes, and dimension each commodity are shown at Tables 1. Vehicle that involved in this case consist of four modes that is ground, railway, marine and air. Amount of each vehicles at every nodes and dimension capacities and volume capacities for each vehicle shown at Tables 2.

Table 1. Quantity of Supply and Demand at each Node

No.	Nodes		Quantity of Comodity					
			Rice	Instant Noodles	Mineral Water	White Sugar	Medicines	Clothes
			A	B	C	D	E	F
1	**Bantul**	**BTL**	**-1664**	**-10277**	**-21411**	**-206**	**-20**	**-50**
2	**Sleman**	**SLM**	**-1910**	**-11938**	**-24872**	**-239**	**-20**	**-50**
3	**Yogya**	**JOG**	**-464**	**-2900**	**-6042**	**-58**	**-10**	**-30**
4	**Kulon Progo**	**KLP**	**-673**	**-4204**	**-8758**	**-84**	**-15**	**-40**
5	**Gunung Kidul**	**GKL**	**-835**	**-5218**	**-10871**	**-104**	**-10**	**-30**
6	Banjarnegara	BJN	18	90	90	18	18	36
7	Banyumas	BYM	27	135	135	27	27	54
8	Batang	BTG	12	60	60	12	12	24
9	Blora	BLR	16	80	80	16	16	32
10	Boyolali	BYL	19	95	95	19	19	38
11	Brebes	BRB	17	85	85	17	17	34
12	Cilacap	CLC	23	115	115	23	23	46
13	Demak	DMK	14	70	70	14	14	28
14	Grobogan	GBG	19	95	95	19	19	38
15	Jepara	JPR	14	70	70	14	14	28
16	Karanganyar	KRG	17	85	85	17	17	34
17	Kebumen	KBM	26	130	130	26	26	52
18	Kendal	KDL	19	95	95	19	19	38
19	**Klaten**	**KLT**	**-2275**	**-14218**	**-29622**	**-284**	**-22**	**-50**
20	Kudus	KDS	9	45	45	9	9	18
21	Magelang	MGL	21	105	105	21	21	42
22	Pati	PAT	21	105	105	21	21	42
23	Pekalongan	PKL	19	95	95	19	19	38
24	Pemalang	PML	14	70	70	14	14	28
25	Purbalingga	PBL	18	90	90	18	18	36
26	Purworejo	PWJ	16	80	80	16	16	32
27	Rembang	RBG	14	70	70	14	14	28
28	Semarang	SMG	18	90	90	18	18	36
29	Sragen	SRG	20	100	100	20	20	40
30	Sukoharjo	SKH	12	60	60	12	12	24
31	Tegal	TGL	18	90	90	18	18	36
32	Temanggung	TMG	20	100	100	20	20	40
33	Wonogiri	WNG	25	125	125	25	25	50
34	Wonosobo	WNS	15	75	75	15	15	30
Dimension each comodity								
Weight (kg)			25	3.2	12.2	20.5	5	10
Volume (m3)			0.2442	0.0168	0.0185	0.0272	0.0380	0.0380

Source: http://www.bakornaspbp.go.id/new/ (Agustus 2007), http://infogempa.jogja.go.id/ (Agustus 2007), http://www.sphereproject.org/ (Agustus 2007), dan http://jateng.bps.go.id/

The result which is obtained from numerical example shown at Tables 3. Pursuant to the tables, can be seen that amount of unsatisfied demand ever greater for every periods, this matter happened caused by accumulation of unsatisfied demand. unsatisfied demand in period 1 will be added with demand in period 2 and so on. At period 1, the total of unsatisfied demand for all commodity in all demand nodes is equal to 153,096 and this number is increase for next period.

Table 2. Amount of Vehicle at each Node

No.	Nodes		Amount of Vehicle					
			G1	G2	A1	A2	R	M
1	**Bantul**	**BTL**	**3**	**3**	**0**	**0**	**0**	**0**
2	**Sleman**	**SLM**	**3**	**3**	**0**	**0**	**0**	**0**
3	**Yogya**	**JOG**	**3**	**3**	**1**	**1**	**1**	**0**
4	**Kulon Progo**	**KLP**	**3**	**3**	**0**	**0**	**0**	**0**
5	**Gunung Kidul**	**GKL**	**3**	**3**	**0**	**0**	**0**	**0**
6	Banjarnegara	BJN	3	3	0	0	0	0
7	Banyumas	BYM	3	3	1	1	1	0
8	Batang	BTG	3	3	0	0	0	1
9	Blora	BLR	3	3	0	0	0	0
10	Boyolali	BYL	3	3	1	1	0	0
11	Brebes	BRB	3	3	0	0	0	1
12	Cilacap	CLC	3	3	1	1	1	1
13	Demak	DMK	3	3	0	0	0	0
14	Grobogan	GBG	3	3	0	0	0	0
15	Jepara	JPR	3	3	0	0	0	1
16	Karanganyar	KRG	3	3	0	0	0	0
17	Kebumen	KBM	3	3	0	0	0	0
18	Kendal	KDL	3	3	0	0	0	0
19	**Klaten**	**KLT**	**3**	**3**	**0**	**0**	**0**	**0**
20	Kudus	KDS	3	3	0	0	0	0
21	Magelang	MGL	3	3	0	0	0	0
22	Pati	PAT	3	3	0	0	0	1
23	Pekalongan	PKL	3	3	0	0	1	1
24	Pemalang	PML	3	3	0	0	0	0
25	Purbalingga	PBL	3	3	0	0	0	0
26	Purworejo	PWJ	3	3	0	0	1	0
27	Rembang	RBG	3	3	0	0	0	1
28	Semarang	SMG	3	3	1	1	1	1
29	Sragen	SRG	3	3	0	0	0	0
30	Sukoharjo	SKH	3	3	0	0	0	0
31	Tegal	TGL	3	3	0	0	1	1
32	Temanggung	TMG	3	3	0	0	0	0
33	Wonogiri	WNG	3	3	0	0	0	0
34	Wonosobo	WNS	3	3	0	0	0	0
Capacity of Vehicle								
Weight (kg)			26000	15000	5000	10000	90000	75000
Length (m)			8.84	7.52	8.48	10.50	23.00	23.00
Width (m)			2.45	2.45	2.45	2.50	3.20	3.20
Height (m)			2.70	2.70	2.70	2.70	3.00	3.00
Volume (m3)			58.48	49.74	56.10	70.88	220.80	220.80

G : Ground
A : Air
R : Railway
M : Marine

The average percentage of unsatisfied demand every period equal more than 90%: period-1 is equal to 96.01% , period-2 is equal to 97.69%, period-3 is equal to 98.47%, period-4 is equal to 98.86%, period-5 is equal to 99.09%, and period-6 is equal to 99.24%. Unsatisfied demand in every period caused by the existence of imbalances between capacity of supply and amount of demand, in this case, amount of supply capacities is smaller than amount of demand.

Table 3. Percentage of Unsatisfied Demand for Each Commodity

No.	Commodity	Amount of Supply	Amount of Demand	Satisfied Demand		Unsatisfied Demand	
				Unit	%	Unit	%
1	Rice	501	7,801	501	6.42	7,300	93.58
	Instant Noodles	2,505	48,756	2,505	5.14	46,251	94.86
	Mineral Water	2,505	101,575	2,505	2.47	99,070	97.53
	White Sugar	501	975	501	51.38	474	48.62
	Medicines	501	95	95	100.00	-	-
	Clothes	1,002	250	250	100.00	-	-
	TOTAL	**7,515**	**159,452**	**6,357**		**153,095**	
2	Rice	601	15,881	601	3.79	15,280	96.21
	Instant Noodles	3,006	99,883	3,006	3.01	96,877	96.99
	Mineral Water	3,006	210,803	3,006	1.43	207,797	98.57
	White Sugar	601	1,547	601	38.87	946	61.13
	Medicines	853	105	105	100.00	-	-
	Clothes	1,594	275	275	100.00	-	-
	TOTAL	**9,661**	**328,494**	**7,594**		**320,900**	
3	Rice	601	23,861	601	2.52	23,260	97.48
	Instant Noodles	3,006	150,509	3,006	2.00	147,503	98.00
	Mineral Water	3,006	319,530	3,006	0.94	316,524	99.06
	White Sugar	601	2,018	601	29.79	1,417	70.21
	Medicines	1,294	105	105	100.00	-	-
	Clothes	2,217	275	275	100.00	-	-
	TOTAL	**10,725**	**496,298**	**7,594**		**488,704**	
4	Rice	601	31,841	601	1.89	31,240	98.11
	Instant Noodles	3,006	201,135	3,006	1.49	198,129	98.51
	Mineral Water	3,006	428,257	3,006	0.70	425,251	99.30
	White Sugar	601	2,490	601	24.15	1,888	75.85
	Medicines	1,748	105	105	100.00	-	-
	Clothes	3,067	275	275	100.00	-	-
	TOTAL	**12,029**	**664,103**	**7,594**		**656,508**	
5	Rice	601	39,821	601	1.51	39,220	98.49
	Instant Noodles	3,006	251,760	3,006	1.19	248,754	98.81
	Mineral Water	3,006	536,984	3,006	0.56	533,978	99.44
	White Sugar	601	2,961	601	20.30	2,360	79.70
	Medicines	2,124	105	105	100.00	-	-
	Clothes	3,474	275	275	100.00	-	-
	TOTAL	**12,812**	**831,906**	**7,594**		**824,312**	
6	Rice	601	47,801	601	1.26	47,199	98.74
	Instant Noodles	3,006	302,386	3,006	0.99	299,380	99.01
	Mineral Water	3,006	645,711	3,006	0.47	642,705	99.53
	White Sugar	601	3,433	601	17.51	2,831	82.47
	Medicines	2,593	105	105	100.00	-	-
	Clothes	4,274	275	275	100.00	-	-
	TOTAL	**14,081**	**999,711**	**7,594**		**992,115**	

6. CONCLUSION

This research discusses about model development for allocation and distribution aid goods in natural disaster relief activities. The objective of this model is minimizing the sum of unsatisfied demand for all commodities or aid goods throughout the planning horizon. Solution of the model represent minimum amount of unsatisfied demand for all commodity type at entire all demand nodes during the planning horizon taking into account the vehicle load capacity constraint as well as volume limitation which has not been discussed in previous research. Distributions of aid goods in this model involve the problem of allocation from points of origin to points of destination, assignment for transportation mode, it is appropriate vehicles that will distribute the aid goods or commodities in terms of kind, and amount of goods, to it is corresponding destination. Actually, this model assist the process of distribution aid goods to affected location and to enforces that the aid goods will be received by disaster areas of the right time, as fast as it should be and at the right quantity of each commodities.

7. REFERENCES

1. Moe, Tun Lin. An Integrated Approach to Natural Disaster Management; Public Project Management and Its Critical Success Factors, *Disaster Prevention and Management*, Vol. 15 No. 3, pp. 396-413, 2006.
2. Hoesada, Jan (2006). Disaster Recovery Planning: Manajemen Bencana Administrasi dan Akuntansi. Sumber: http://www.ksap.org/Riset&Artikel/Art11.pdf (Juni 2007)
3. Ozdamar, Linet., Ekinci, Ediz., Kucukyazici, Beste, Emergency Logistics Planning in Natural Disasters, *Annals of Operations Research 129, 217–245*, 2004.
4. Yi, Wei., Ozdamar, Linet. A Dynamic Logistics Coordination Model for Evacuation And Support In Disaster Response Activities, *European Journal of Operational Research* 179 (2007) 1177–1193, 2007.
5. Simchi-Levi, D., Kaminsky, P., Simchi-Levi, E., *Designing and Managing the Supply Chain: concept, strategies, and case studies*, McGraw-Hill, 2003.
6. Website Badan Koordinasi Nasional Penanganan Bencana http://www.bakornaspbp.go.id/new/ (Agustus 2007).
7. Website Satlak Bencana Pemerintah Kota Yogyakarta http://infogempa.jogja.go.id/ (Mei 2008).
8. Website Project Sphere http://www.sphereproject.org/ (Agustus 2007).