PLANNING OF CARGO TRANSPORTATION FOR DISASTER MITIGATION

-Application to Hot Mud Flow Disaster in Indonesia-

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ABSTRACT

In the case that emergency logistic system fails to handles network disruption that follows disaster; question goes to disaster manager whether mitigation plan is ready for unexpected event. This paper explains developed mitigation steps and transport model for cargo distribution. It considers utilization of intermodal transportation to create alternative transport network under worst case condition with an objective to minimize total transport costs. In addition, projection of emission was calculated to show contribution of solution to the effort for reducing adverse impacts of climate change in sustainable freight distribution policies.

INTRODUCTION

Emergency management covers all process from planning until establishment of physical body affected by disaster including transportation system by the implementation of emergency logistic. Recognition to research in disaster management has increased where most of the research related to distribution of emergency relief for disaster (Altay et al. (2)). Less research conducted for business application such as mitigation planning for cargo distribution. This paper focuses on the following things:

1) Container cargo transportation with goal to minimize total transport costs
2) Mitigating unexpected event post disaster that may give adverse impact to transportation.
3) Applicable to case with complex choices in mode of transport, nodal points and routes.

There are modal and technological disparities between countries that will make mitigation treatment differ from one another.

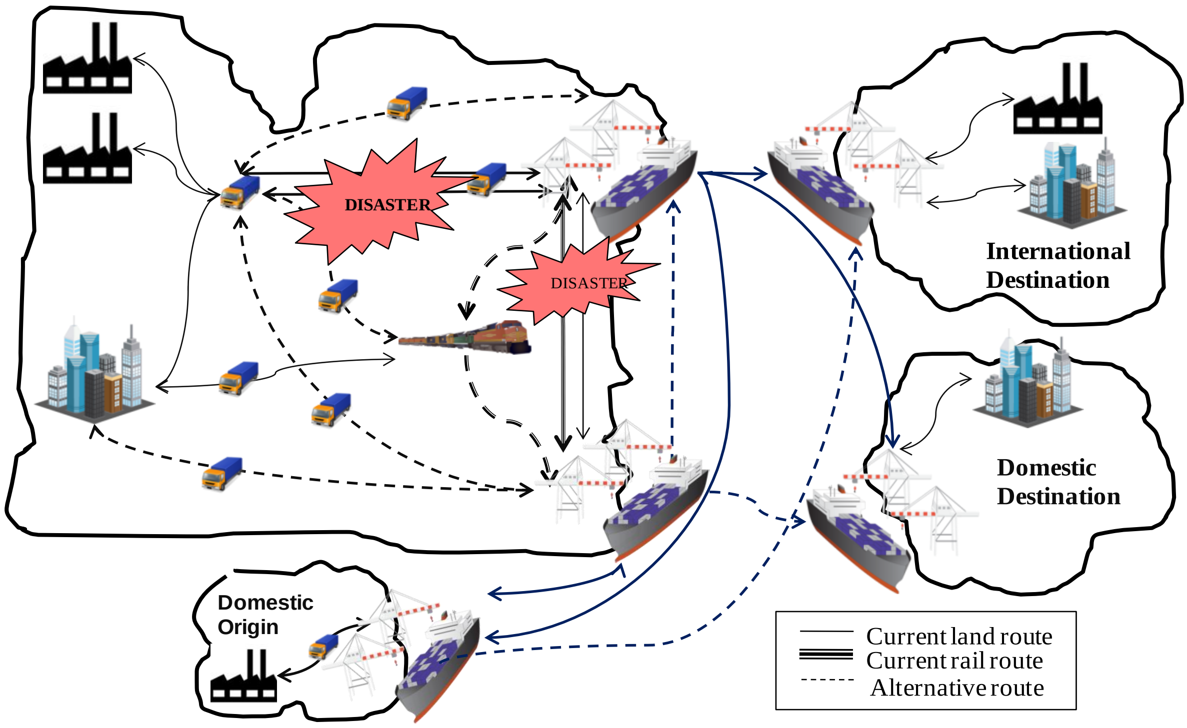

Figure 1 Concept of intermodal transportation system to disaster mitigation

To generalize the situation, mitigation steps in this paper was designed to provide solution that optimizes available infrastructures and alternative networks with without considering additional investment in new infrastructures. Figure 1 illustrated the concept for modeling redistribution of cargoes after network disruption upon disaster.

HOT MUD FLOW DISASTER (LUSI)

Motivation for this research dates back to 2006 where Hot Mud Flow (LUSI) started in Porong district of East Java, Indonesia as depicted in Figure 2. It was natural gas explosion in an exploration well and a tragic event to be sure that brought crisis to its nearly surrounding area and Indonesia as well. LUSI disaster is categorized as technological disaster by drilling failure and major catastrophe compared to similar cases in the world, as shown in Table 1. Direct impact of LUSI has been felt by more than 17,000 citizens. Houses and factories have been buried in more than 6 square kilometers under 20 meters deep of mud covering nine villages in Sidoarjo area. LUSI disaster effect to transportation system was disruption of important highway for container transportation. Some alternative routes post disaster as shown in Figure 3, became source of congestion while the other is occasionally inundated by the mud. It affected container traffic from various hinterlands to Port of Tanjung Perak in Surabaya City, the second largest port in Indonesia. It has been served as important gateway for both domestic and international cargo distributions. Surabaya Container Terminal (TPS) and Berlian Jasa Terminal Indonesia (BJTI) are two terminals sophisticated to handle domestic and international containers that averagely handled 1.5 million TEU per year.

Source : Badan penanggulangan lumpur sidoarjo

Figure 2 LUSI disaster in Porong District, East Java, Indonesia

Figure 3 Transportation network condition after LUSI disaster

Table 1 Comparison of LUSI disaster with similar phenomena in the world

Characteristic	Lokbatan (Azerbaijan, 2001)	Koturdag (Azerbaijan, 1950 - present)	Piparo (Trinidad,2011)	LUSI (Indonesia, 2006)
Volume (km3)	0.0003	0.00045	0.025	0.012
Duration	30 minutes	19.660 days	1 day	1460 days **
Area km2	0.098	0.3	2.5	6
Average Rate*	0.0144	0.000000025	0.025	0.00007 - 0.0015
Estimated thickness of the mud layer (Feb 2007)				10m - 18 m
Estimated number of displaced people				11,000 - 50,000

* Cubic km/days ** As of February 2010

There are ongoing debates between experts on the cause of LUSI about uncertainties in spreading rate of volcano and long term effect to environment, urban areas and infrastructure and many forecasted that it can last for a very long time, averagely within 30 years. (Davies et al. (3) and McMichael (5)). Under the LUSI disaster case, application of mitigation plan had conducted for hazard of losing total connection in container distribution in and out Port of Tanjung Perak, Surabaya. Mitigation steps and transport modeling were combined for creation of alternative networks that can be used soon after unexpected event occurred in the future.

Table 2 Forecasted containerized cargo that flow around examined network

No.	Region	Domestic Cargoes			International Cargoes		Forecasted Cargoes (TEU/day)
		A	B	C	D	E	
1	Bali	Handcraft, Art Craft	Handcraft, Art Craft	Raw Materials	Handcraft, Art Craft	Electronics, G.C.	998
2	NTB	Agriculture	Agriculture, Natural	Raw Materials	Natural Resources	Electronics, G.C.	925
3	Banyuwangi	Agriculture	Agriculture, G.C.	Raw Materials	Fishery products	Electronics, G.C.	262
4	Pasuruan	Electronics, Cigarrate	Electronics, Cigarrate	Plywood	Wooden Furniture,	Electronics, G.C.	766
5	Probolinggo	Agriculture, Fishery	Agriculture, Fishery	Raw Materials	Fishery products	Electronics, G.C.	216
6	Malang	General Cargo	G.C.	Raw Materials	Wooden Furniture	Electronics, G.C.	390
7	Surabaya	General Cargo	Electronics, G.C.	Raw Materials	Semi processed materials	Electronics, G.C.	1044

Notes :
A : Bound for Surabaya and Western East Java
B : Shipped to other domestic port
C : Shipped from other domestic port
D : International Exports
E : International Imports

MITIGATION FOR CARGO TRANSPORTATION POST LUSI

MITIGATION STEPS

Mitigation focused on unexpected event post LUSI disaster that may have adverse impact to container cargo distributions. Alternatives for solution were clearly depicted in mitigation steps that integrated transport modeling. Steps in providing solution to mitigate worst case scenario of LUSI were as follows:

1) Cargo Forecasting

   Time series forecast was conducted in earlier research by Achmadi et al. (1) and used in this paper, with detail cargo composition in Table 2. Forecasted containerized cargos that flow around the network were 4600 TEUS/day in total.

2) Consolidation point generation

   Figure 4 shows selected consolidation points that were used, notably marine ports and dry port. Cargo consolidation policy reduces the unit transport cost by advantages gained from economic of scale. It also minimizes the individual risk of transporting the cargoes individually by transferring it into larger scale means of transport.

3) Routes generation

   24 alternatives routes were created in this process through intermodal transportation by utilization of nodal points that connect hinterlands to delivery point.

4) Solution generation

   Movement of cargo was simulated computationally with mathematical model explained in next section. In addition, projected emission of solution were calculated

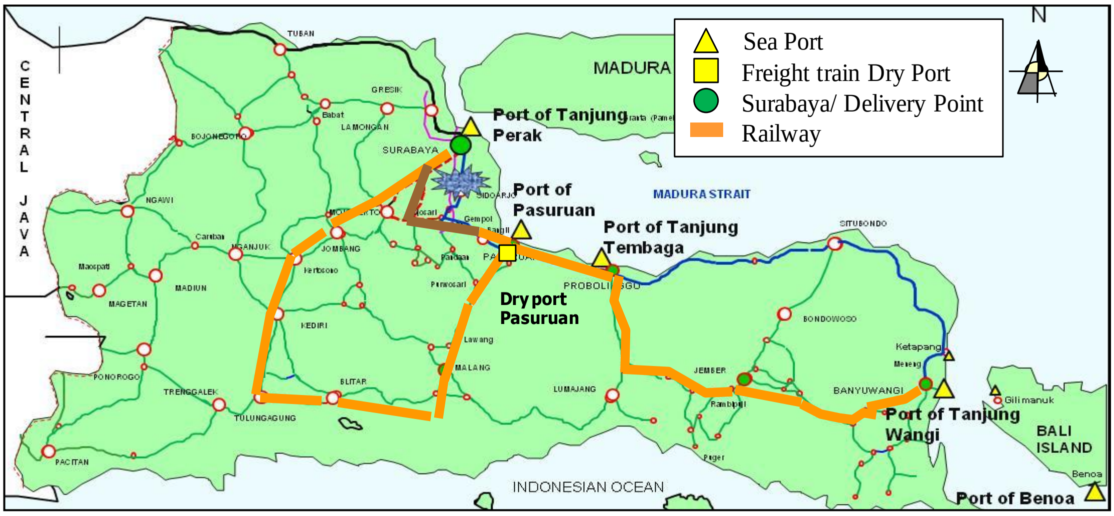

Figure 4 Consolidation point along disrupted network

Table 3 Notation of assumption in modeling

Notation	Index	Explanation
i_1	$i_1 = 1 .... n_1$	Number of hinterland as the source of containerized cargo
i_2	$i_2 = 1 .... n_2$	Number of delivery point for containerized cargo
i_3	$i_3 = 1 .... n_3$	Modes of transport choice that can be utilized for container transportation
i_4	$i_4 = 1 .... n_4$	Restrictions for cargo quantity for each mode of transport
s		Quantity of containerized cargoes that can be captured by delivery point
d		Quantity of containerized cargoes need to be distributed from hinterlands

TRANSPORT MODELING

The transportation network formally defined as distribution of container cargo in TEU from set of hinterlands to delivery point. The model is designed to provide solution after mitigation steps are conducted. It based on the principal of balanced transportation that is mathematically expressed with the following objective function.

Minimize $$Z = \sum_{i_1,i_2,i_3,i_4=1}^{n_1,n_2,n_3,n_4} \left(x_{i_1,i_2,i_3,i_4} \, c_{i_1,i_2,i_3,i_4} \right) \qquad \text{(Eq.1)}$$

Subject to

$$\sum_{i_1,i_2,i_3,i_4=1}^{n_1,n_2,n_3,n_4} x_{i_1,i_2,i_3,i_4} \geq d \qquad \text{(Eq.2)}$$

$$\sum_{i_1,i_2,i_3,i_4=1}^{n_1,n_2,n_3,n_4} x_{i_1,i_2,i_3,i_4} \leq s \qquad \text{(Eq.3)}$$

$$\sum_{i_1=1}^{n_1} d \leq \sum_{i_2=1}^{n_2} s \qquad \text{(Eq.4)}$$

In Eq.1, total transport cost is minimized by optimizing production of transportation in the form of distributed cargo winthin the network, under notation $x_{i1,i2,i3,i4}$, times the transport cost that arises, denoted as $c_{i1,i2,i3,i4}$. Here, notation $_{i1,i2,i3,i4}$ represents the restrain condition in finding optimal solution. Eq.2 ensures that each delivery point d_{i1} receives the requested quantity of cargo and in the same manner Eq.3 ensures that each hinterlands s_{i2} distribute not to exceed its delivering capacity. Eq. 4 ensures the quantity of cargo available in the hinterland is sufficient enough to cover the demand in the delivery point. All employed notations are summarized in Table 3. Earlier research result from Achmadi et al. (1) provided capacity assumptions for modes of transport that are used in modeling i.e. 300 TEU shallow draft ship, 70 TEU freight train, and normal container trailer. In addition, projected emission was calculated. Standards from INFRAS/IWW (4) were used due to lack of emission standard in Indonesia.

Table 4 Example of cargo movement in modeling solution

No	Destination \ Origin	INTERNATIONAL CARGO SURABAYA: Banyuwangi ● L	Banyuwangi ● S	Direct to Surabaya L	Direct to Surabaya S	Direct to Surabaya S-L	DOMESTIC CARGO SURABAYA: Banyuwangi ● S-L	Banyuwangi ● S-S	Direct to Surabaya L	Direct to Surabaya S	Bali ● S-L-S-L	Demand
1	Bali	-	**630**	⇠	-	**630**	**368**	⇢ **368**	-	-	-	998
2	NTB	-	**488**	⇠	**488**	-	-	**437**	⇠		**437**	925
3	Banyuwangi	**101**	⇠	**101**	-	-	-	-	**161**	⇢ **161**	-	262
4	Pasuruan	-	-	**329**	-	-	-	-	**437**	-	-	766
5	Probolinggo	**101**	⇠ -	**101**	-	-	-	-	**115**	-	-	216
6	Malang	-	-	**160**	-	-	-	-	**230**	-	-	390
7	Surabaya	-	-	**491**	-	-	-	-	**552**	-	-	1,043
	Supply	202	1,118	980	-	-	-	805	1,334	161	-	
				2300					2300			**4,600**

Notes :

L = Land transport
S = Sea transport
S-L = Combination of sea & land transport
⇢ = Difference in way of transport ;current situation and modeling
● = Cargo consolidation point
S-S = Combination of 2 port in sea transport

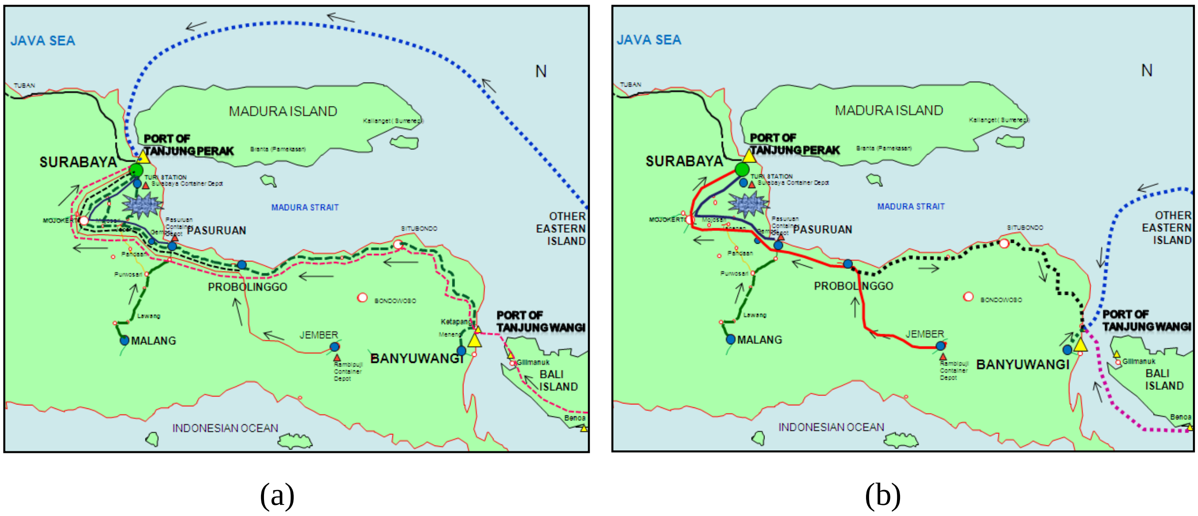

Figure 5 Illustrated cargo flows for current situation (AD) and modeling result

MODELING RESULTS

Each cargo from every hinterland is provided with choice to utilize available mode for node-to-node travel until it reaches the final delivery point. Simulation result showed changed in distribution pattern compared to current network situation. Change of cargo movement from current condition after LUSI disaster occurred (AD) to modeling solution is shown in Table 4. For more understanding, Figure 5(a) illustrates the distribution pattern of AD, and Figure 5(b) illustrates the pattern change of modeling solution. Significant flow pattern change has occurred, notably for cargo from other eastern island, particularly NTB region, either for domestic or international cargo. In AD condition, international cargo from this region was directly transported by ship to Port of Tanjung Perak (PTP), denoted as S in Table 4, while its domestic cargo was transported by sea halfway journey and then utilized Port of Tanjung Wangi (PTW) as transit point for modal split into smaller mode of transport i.e. container trucking, denoted as S-L-S-L in Table 4. On the other hand, modeling result employed PTW for both kind of cargo as consolidation point and transferring the cargo into larger modes of transport, i.e. container ship. Cargoes from another region, notably from Bali, Banyuwangi, and Probolinggo region show similar pattern with the explanation above. In brief explanation, different between AD condition and modeling solution is that cargoes from some hinterlands is consolidated in a nodal point before it distributed to delivery point by larger sized means of transport.

Analysis of result

Important points are obtained by applying proposed mitigation steps and simulating the cargo movement, as follow:

1) Port of Tanjung Wangi (PTW) in Banyuwangi region act as feeder port that consolidated 40% of hinterlands cargoes before transported by ship to Port of Tanjung Perak (PTP) in Surabaya. Cargo from eastern part of East Java i.e. Bali Island, NTB Island bear lesser transport cost by consolidating in PTW than direct transport to PTP. Meanwhile, cargos from western part of East Java Island are still maintaining similar pattern with AD.
2) As the implication, total transport cost of network and projection of emission that generated by modeling were lower than network condition before and after LUSI disaster, as shown in Table 5. In aggregate, total cost can be reduced up to US$ 182,626 from US$ 370,374. Noted that, the total cost compared here is aggregate total cost for daily cargo flow which means by consolidating some cargoes in PTW, the network can be 51% more efficient in each day operation. Interestingly, average unit transport cost for domestic cargo of modeling solution is become higher than that of AD and BD condition. This anomaly resulted because of much lower reduction for total traveled distance of modeling solution than the reduction, while some additional cost adds up, most notably handling cost in terminal.

3) Efficiency in transport cost is impacted also by utilization ratio between land and marine modes of transport, which changed from 90-10 ratios during AD condition, to 40-60 ratios. In term of distance production, this change in mode utilization ratio resulted in 35% reduction of total traveled distance for combined land and sea transport.
4) Projected emission in Figure 6 shows the contribution of solution in reducing emission than that of modeled network after disaster (AD) and modeled network before disaster (BD). Larger reduction of land based mode of transport emissions by 28.9 ton offset the raises in marine based mode emissions by 6.2 ton compared to AD condition. While total emission cost can be reduced by 37% compared to AD condition.

Logistic disruption by LUSI resulted in much more transport demand than supply. Transport fares rises, leaving those willing to pay such a high price able to transport, and the rest will search for less costly transport alternative. The reason of modal shift from land transport to sea transport is that, though not the only one, since trucking fares are unstable because of disaster, containership slots are booked in advance at a locked price, discretionary travel may remain even when the system is disrupted, particularly when the disruption is over but the demand is still facing serious backlogs.

Table 5 Transport cost comparison between simulated conditions

Information	Measurement Base	Unit	Condition		
			Mitigation	AD	BD
Total Transport Cost	International Cargo	US$	182,626	370,374	339,400
	Domestic Cargo	US$	220,074	320,063	360,253
Avg Transport. Cost	International Cargo	US$/TEU	79	161	148
	Domestic Cargo	US$/TEU	96	139	157
Avg Unit Transport. Cost	International Cargo	US$/TEU/Km	0.00020	0.00024	0.00023
	Domestic Cargo	US$/TEU/Km	0.00032	0.00023	0.00025
Total Distance	Land	Km	272,789	807,721	725,427
	Sea	Km	550,472	467,636	346,332

Note : Mitigation = Achieved network condition after modeling mitigation plan for worst case scenario
BD = Modeled network condition before disaster occurred
AD = Modeled network condition after disaster occurred

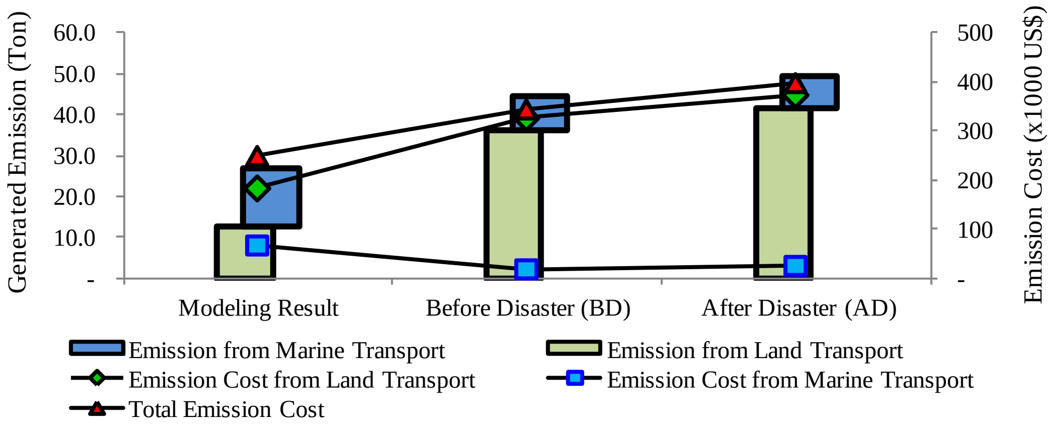

Figure 6 Comparison of emission production between modeled network condition

CONCLUSION

This paper investigated disaster combined mitigation plan and transport modeling for worst case scenario in cargo transportation and have applied in real case. Application of mitigation steps is provided more alternatives to solve distribution problem. Lesser total transport cost than current state condition was gained through cargo consolidation policy at some nodal points. In the applied case of mitigating transport disruption because of LUSI disaster in Indonesia, total transport cost for daily container cargo movement can be reduced by 51% while total traveled distance can be reduced by 35% from current condition. Another implication is in reduction of generated emission and emission cost of the network, thus the solution is optimum in economical and environmental measurement. Key points of successful mitigation plan for transport disruption are generalized as follows:

1) Cargo consolidation policy in one or more nodal points to minimize inefficient movement of cargo within the studied network, allowing modal shift from smaller to larger means of transport. It shows effect of economies of scale in reducing transport cost.
2) Employment of intermodal transportation which gave more choices in the way of transport, producing more alternative routes and combination of transport modes.

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