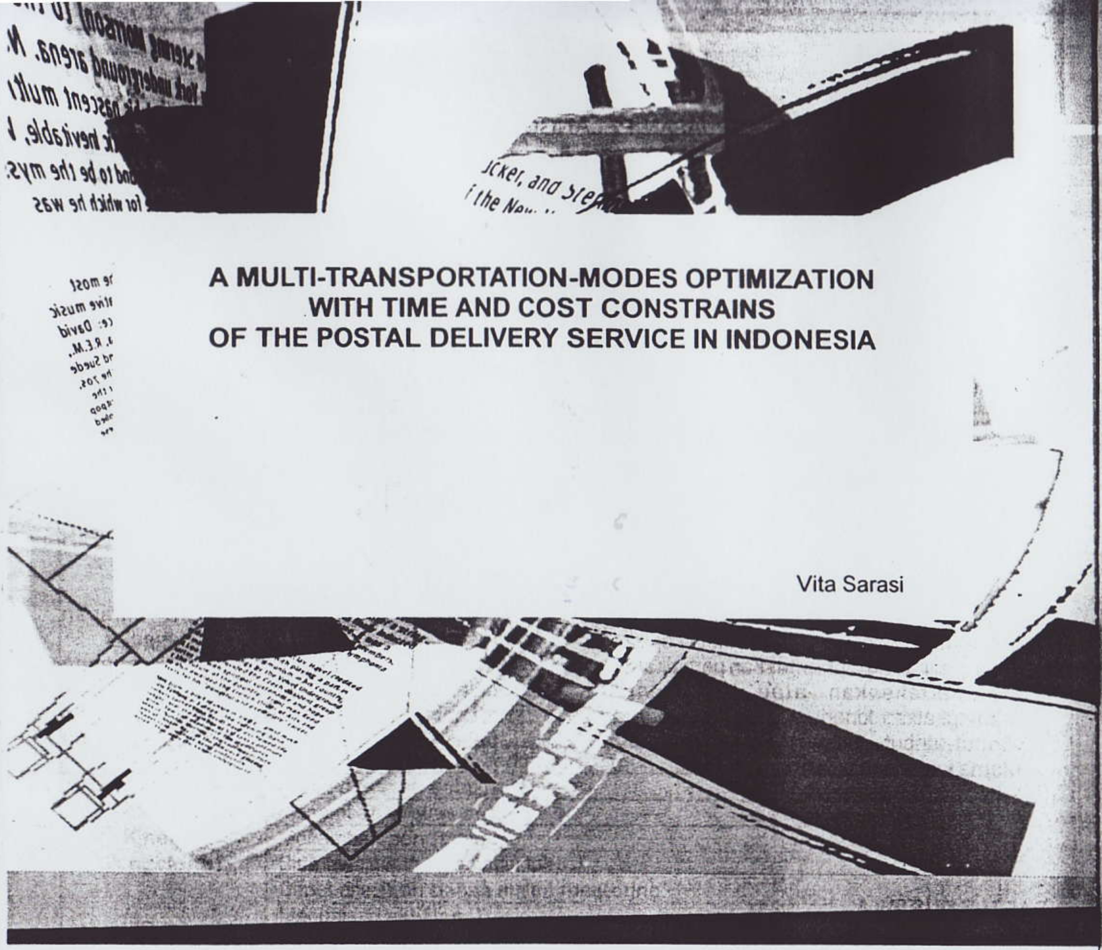


A MULTI-TRANSPORTATION-MODES OPTIMIZATION WITH TIME AND COST CONSTRAINS OF THE POSTAL DELIVERY SERVICE IN INDONESIA

Vita Sarasi

ABSTRACT

An optimization procedure with constraints of time and cost was applied to the postal delivery service in Indonesia involving third parties of transportation modes by using Triple Algorithm and Minimum Cost Network Flow Problem methods. Although it is nevertheless the initial stage, the optimization has showed its capability to satisfy the delivery time standard and to reduce the transportation cost simultaneously. The procedure has given a large impact on the cost effectiveness of 46.8% in this study by optimizing the choices of the transportation routes and the third parties involved. Invention of the consignment flow route and the modes selection will be useful for the network design, the third parties selection, and delivery monitoring and tracking, particularly by integrating it to the Geographical Information System. This information is especially suitable for a multifaceted archipelago and wide-area country such as Indonesia.

Keywords: Postal delivery network, transportation cost, delivery time, transportation modes, optimization

1. Introduction

Until recently public postal service operational in Indonesia has many typical handicaps regarding to the wideness of the nation of about 1.9 million square miles and the lacking of the transportation facility at numerous remote areas in the 18,108 islands. Although the service has claimed to have 31,086 service points and roughly 28,000 personnel that are distributed at almost entire the country, in the reality one has only 1,975 units of long-distance road transport (trucks, buses, cars, and boats) which are insufficient in relation to the coverage area (PT. Pos Indonesia, 2001). The condition influences the fulfillment of delivery time standard of postal consignment as a major measure for the customer satisfaction. Until today many customers have complained concerning lateness or, even, unaccepted of the consignment, which might not comfortable to the public postal institution related to the competition with other private services.

The postal service, moreover, needs cooperation with private airlines, maritime, and road transport companies to support the transportation modes. The involvement forms include liberated transporting, contracts of baggage packet, or truck shipments. However, there are further problems on additional transportation cost and time of which the third parties to be followed.

This contribution of third parties could be viewed as managed resources by the postal service. Hence, it is possible and necessary to optimize the uses of the transportation modes in such to fulfill the time standard and to minimize the total transportation cost. However, this study approaches it with a cost minimization (Jablonsky, J., Lauber, J., 1999) with time restriction (Bartels, H.G., 2003 and Ohse, D., 1996) which is applied to multi transportation modes.

2. Governing the Optimization Procedure

2.1 Scopes

Since 1987, the operational of Indonesian postal service had been following a network based on the concept of Postal Processing Center (PPC) (Post and Giro Public Enterprise Center Office, 1993). It is a main office coveringa region such a province which laying Main Postal Offices (MPOs) and secondary network (Figure 1). A PPC has tasks of collecting the consignment supplies from sender MPOs, then processing and transporting the postal consignment in the inter region (primary or backbone) network, and finally delivering the postal demands to the destination MPO.

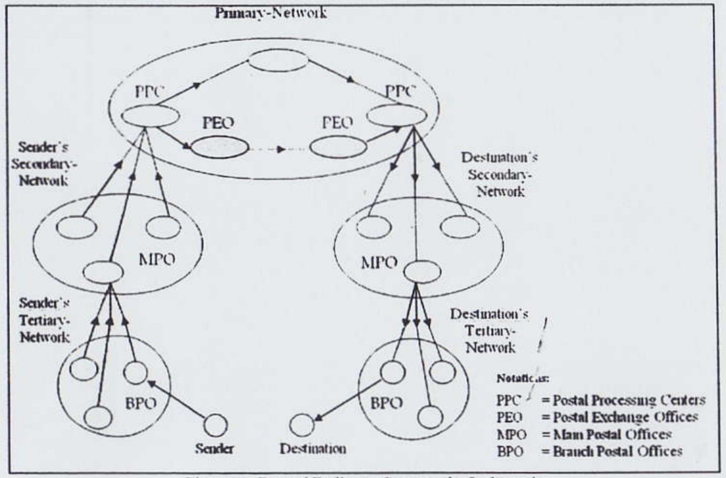


Figure 1. Postal Delivery System in Indonesia

In the primary network PPCs will manage the transport of the postal incoming and outgoing by their own trucks and/or by exchanging the consignments with the private's transportation modes, i.e., airplanes, ships, and/or trucks. The exchanges are done through the Postal Exchange Office (PEO) at airports, harbors, and/or truck terminals, respectively (Figure 2). The tasks should consider the work schedules, however ones does not be included in the study.

This investigation focuses on the transportation process held among six PPCs in Java and Kalimantan Islands (Surabaya, Yogyakarta, Jakarta, Balikpapan, Banjarmasin, and Pontianak) that now become major concern of improvement of the service operational (PT. Pos Indonesia, 2001; PT. Pos Indonesia, 2002). The PPCs serve notably potential needs of postal service as many government, business, and household activities. Optimization will select which modes and routes are optimally suitable for transporting postal consignments

2.2. Time Restriction

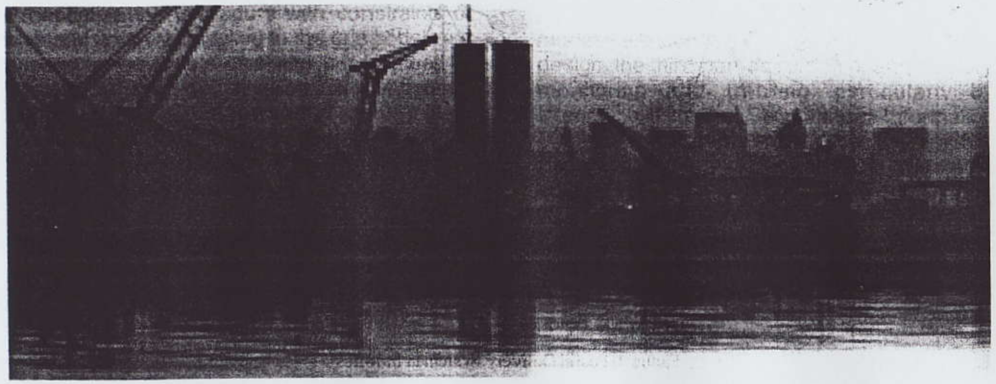
As complexity of the model it is now decided not to combine delivery time with cost in the objective function directly (Jablonsky, J., Lauber, J., 1999). The time restriction refers to the delivery time standard which must be estimated prior to the cost optimization procedure. The standard could be modeled as the minimum travel time which can be calculated over all nodes simultaneously using Triple Algorithm (Bartels, H.G., 2003 and Ohse, D., 1996):

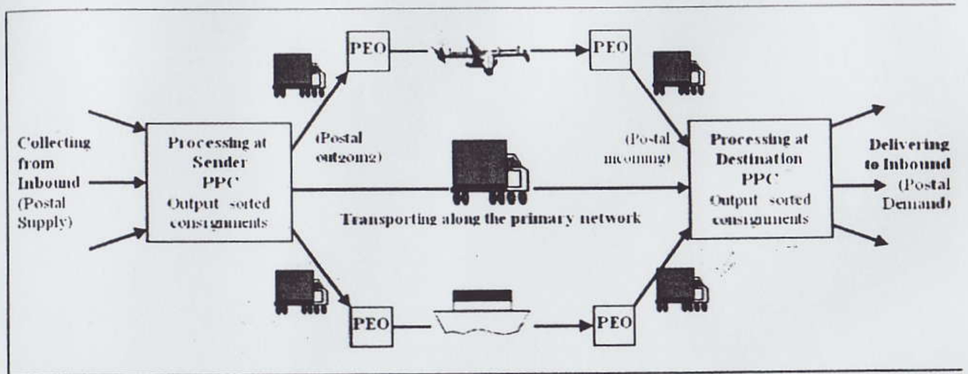
$$T_{ij} = \min\left(t_{ij}, t_{iU} + t_{Uj}\right) \quad \text{for all i and j. but U?i and U?j} \qquad (1)$$

where T_{ij} is the delivery time standard of the route from node-i to node-j, T_{ij} and $t_{iU} + t_{Uj}$ expresses the maximum travel time of direct and indirect (i.e., through transshipment node-U) routes, respectively.
The maximum travel time is calculated among the available transportation modes (t_{ijl}) as follows:

$$t_{ij} = \max_l\left(t_{ijl}\right) \qquad \text{for all i, j. and l} \qquad (2)$$

where t_{ijl} is the travel time of a transportation mode-l of the route. The time standard is then, in return, used for assessing the travel times in order to decide the possibilities of the mode-l to transport the consignment in the route. These possibilities will be evaluated again by using the cost minimization.





PPCs at Java Island					
	Collecting	Processing	Transporting	Processing	Delivering
Ph. 1	00.00-02.00	02.00-05.00	05.00-10.00	10.00-14.00	14.00-16.00
Ph. 2	08.00-10.00	10.00-14.00	14.00-19.00	19.00-22.00	
Ph. 3	17.00-19.00	19.00-22.00	22.00-02.00	02.00-05.00	10.00-12.00
PPCs at other Islands					
	Collecting	Processing	Transporting	Processing	Delivering
Ph.1	07.00-09.00	09.00 13.00	13.00 18.00	18.00 21.00	09.00-11.00
Ph. 2	16.00-18.00	18.00-21.00	21.00-09.00	09.00-13.00	13.00-15.00

Figure 2. Principle of procedure in the primary network and work schedule of the PPC

2.3 Cost Minimization

The optimization applies an adjusted Minimum Cost Network Flow Problem (Winston, W.L., 1991) which also appears as specific cases such as Assignment, Transshipment, Shortest Path, Maximum Flow, and Critical Path Method (Bartels, H.G., 2003 and Ohse, D., 1996). This method represents the PPCs as six nodes laying in a network system whereas the inbound postal offices act as an environment. A node plays as a sender in case of putting consignment supplies into the system, while one performs as a destination in situation of sinking consignment demands out. In case of overall incoming to a node (say, Node-D), the others acts as senders and transshipments at once. The problem can, hence, be viewed as six cases.

An objective function executes the overall transportation cost minimization as follows:

$$\text{minimize} \sum_{l=1}^{3}\sum_{k=1}^{6}\sum_{j=1}^{6}\sum_{i=1}^{6} c_{ijkl}\, x_{ijkl} \qquad (3)$$

subject to the balances of consignment flow at a node as follows:

$$\sum_{l=1}^{3}\sum_{i=1}^{6} x_{iDDl} = \sum_{i=1}^{6} d_{iD} \qquad \text{for all D} \qquad (4)$$

$$\sum_{l=1}^{3}\sum_{j=1}^{6} x_{ijkl} = \sum_{l=1}^{3}\sum_{j=1}^{6} x_{jikl} + s_{iD} \qquad \text{for all i but i=D=k} \qquad (5)$$

where: x_{ijkl} is the postal consignment variable (e.g., ton) to be transported through the route of node-i to node-j to be ended at node-k by using transportation mode-l, c_{ijkl} is the unit cost of the transportation which is assumed to depend merely on the consignment weight (e.g., Euro/ton), d_{iD} and s_{iD} are postal demand and supply from node-i to node-D, respectively.

In addition, it is assumed that there is no outgoing from Node-D and no internal transport in all nodes. It is also supposed that transport cost of away is same as one of return direction. The others are non-negative variables, and no costs of exchanges and non operational. The general programming software of Matlab applies this procedure (Lindfield, G., Penny, J., 1995) with key function of Linprog.

3. Results and Discussion

The basic data essentially include direct travel time, unit cost of each transportation mode, destination-specified postal supplies from each sender PPC, and the delivery time standard of each route. This study, however, applied synthetic data as a test of the procedures but were attempted to be as realistic as possible (Post and Giro Public Enterprise Center Office, 1993, Postal Enterprise Region IX Kalimantan, 2002, PT. Pos Indonesia, 2001). Both travel time and unit cost data were supposed to be derived linearly from the direct distance of each route based on the geographical map (Table 1). The travel times were designed by assuming the average velocities of airplane, ship, and truck of 400, 30, and 50 km/h, respectively. The unit costs of airplane, ship, and truck cargos were modeled by € 1.0, 0.6 and 0.3 per ton for each km, correspondingly. The postal supply data were set according to the assumed growth level of development and population (Table 2). Some data were adjusted as the impossibility of access, in particular, a route between the islands and the road at Kalimantan Island.

The time standards were calculated according to (1) and (2). Due to presumption, direct travel time by ship reached maximum at almost all routes except the routes connecting to PPC Yogyakarta as there was no harbor (Table 3). However, it is necessary to adjust the extremely values with an allowable time limit to open then possibility for transporting by the ship mode. The time limit is chosen as 14 hours according to the time availability between two phases of the work schedule of PPCs. As a result, the time standards (Table 4) can accommodate the choices of the three transportation modes alternatives.

Table 1. Geographical distance of PPCs (km)

From to	*1.Sby*	*2.Ygy*	*3.Jkt*	*4.Bpn*	*5.Bjm*	*6.Ptk*
1.Sby	0.0	250.0	650.0	900.0	400.0	850.0
2.Ygy	250.0	0.0	375.0	1000.0	550.0	750.0
3.Jkt	650.0	375.0	0.0	1250.0	850.0	650.0
4.Bpn	900.0	1000.0	1250.0	0.0	500.0	850.0
5.Bjm	400.0	550.0	850.0	500.0	0.0	625.0
6.Ptk	850.0	750.0	650.0	850.0	625.0	0.0

Table 2. Postal supply data (ton)

from to	*1.Sby*	*2.Ygy*	*3.Jkt*	*4.Bpn*	*5.Bjm*	*6.Ptk*
1.Sby	0.0	50.0	50.0	50.0	50.0	50.0
2.Ygy	100.0	0.0	100.0	100.0	100.0	100.0
3.Jkt	150.0	150.0	0.0	150.0	150.0	150.0
4.Bpn	125.0	125.0	125.0	0.0	125.0	125.0
5.Bjm	100.0	100.0	100.0	100.0	0.0	100.0
6.Ptk	75.0	75.0	75.0	75.0	75.0	0.0

Table 3. Maximum direct travel time (hours)

From to	*1.Sby*	*2.Ygy*	*3.Jkt*	*4.Bpn*	*5.Bjm*	*6.Ptk*
1.Sby	0.00	5.00	**21.67**	**30.00**	**13.33**	**28.33**
2.Ygy	5.00	0.00	7.50	2.50	1.38	1.88
3.Jkt	**21.67**	7.50	0.00	**41.67**	**28.33**	**21.67**
4.Bpn	**30.00**	2.50	**41.67**	0.00	**16.67**	**28.33**
5.Bjm	**13.33**	1.38	**28.33**	**16.67**	0.00	**20.83**
6.Ptk	**28.33**	1.88	**21.67**	**28.33**	**20.83**	0.00

Table 4. Delivery time standard (hours)

from to	*1.Sby*	*2.Ygy*	*3.Jkt*	*4.Bpn*	*5.Bjm*	*6.Ptk*
1.Sby	0.00	**14.00**	21.67	28.00	14.00	28.00
2.Ygy	**14.00**	0.00	**14.00**	**14.00**	**14.00**	**14.00**
3.Jkt	21.67	**14.00**	0.00	28.00	28.00	21.67
4.Bpn	28.00	**14.00**	28.00	0.00	16.67	28.00
5.Bjm	14.00	**14.00**	28.00	16.67	0.00	20.83
6.Ptk	28.00	**14.00**	21.67	28.00	20.83	0.00

Aiming to investigate its effectiveness, the cost optimization was simulated in four scenarios that described the conditions of direct transport (no optimization), transport using single mode, and multi modes without and with the time restriction.

A Multi-Transportation-Modes...

Results of overall incoming case to PPC Surabaya and PPC Balikpapan will be explained (Figure 3 and 4). The single mode scenario showed that there are indirect transports to Surabaya through Yogyakarta and Banjarmasin as well as to Balikpapan through Banjarmasin in order to reduce the overall costs. The indirect transport was more frequently in scenario of multi transportation modes, especially through the two transshipment-acted PPCs. In case of incoming to PPC Surabaya, it was cheaper to flow the consignment using truck transport along the routes in two islands. The time restriction causes change of the direct ship transportation of postal supply from Pontianak into the indirect routes of ship transport through Jakarta followed by truck transport through Yogyakarta.

The similar pattern was also performed in the incoming case to Balikpapan. It is cheaper to transport the consignment through Surabaya as transshipment from Java Island, meanwhile consignments from Pontianak and Banjarmasin were directly transported by ship and truck, respectively. The time restriction caused the consignments from Pontianak was firstly sent through Banjarmasin. In this case, PPC Banjarmasin became transshipment from all other nodes which would be sent to PPC Balikpapan.

It is essential to assess capability of the optimization by measure its effectiveness for reducing the overall cost regarding to the direct transportation cost (in this study, € 2,145,625). The choice of single airplane mode reduced the overall cost of only € 5,000 or 0.23%. The optimization was more effective for the multi modes situation which had largely reduced the cost of € 1,015,000 or 47.3%. This result was comparable to the lowness of the unit cost of truck and ship cargo as alternatives. The time restriction just affected similar to the previous of only € 1,003,562.50 or 46.8%.

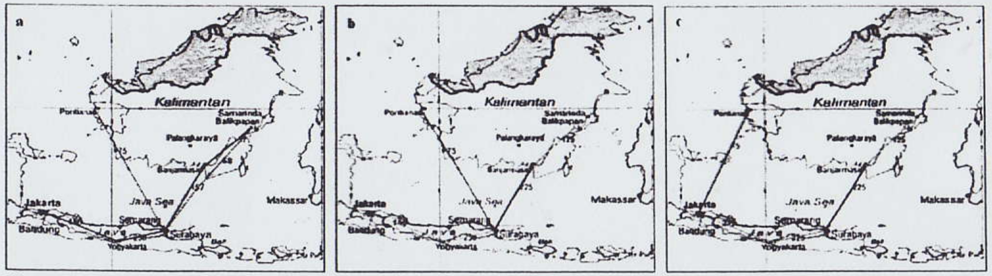


Figure 3.a, b, c. Consignment flows of the incoming case to PPC **Surabaya** by using single airplane mode and multi modes without and with time restriction (red, blue and green lines show the routes of airplane, ship and truck, respectively)

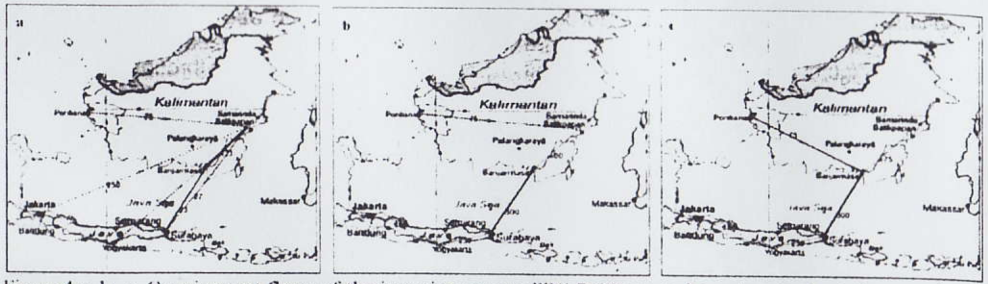


Figure 4.a, b, c. Consignment flows of the incoming case to PPC **Balikpapan** by using single airplane mode and multi modes without and with time restriction (red, blue and green lines show the routes of airplane, ship and truck, respectively)

4. Conclusions

Although it is nevertheless in the initial stage, the multi-transportation-modes optimization has showed its capability to satisfy the delivery time standard and to reduce the transportation cost simultaneously. The procedure has given a large impact on the cost effectiveness of 46.8% in this study by optimizing the choices of the transportation routes and the third parties involved. Invention of the consignment flow route and the mode selection are useful for network design, third parties selection, and delivery monitoring and tracking by integrating it to the Geographical Information System as performed by Deutsche Post AG (Engelhard, G., et.al., 1998, Grünert, T., et.al., 1999).

The future research will be directed to the multiple-objective optimization (Keeney, R.L. and H. Raiffa., 1976) which might be suitable for multiple aspects to be considered such as travel time, cost, and work and third parties' schedules. The development includes use of the real data, analysis of the model sensitivity, additional nodes, networks, and third parties, considering the probabilistic postal supply, and mode capacity. Optimization of the primary network could be integrated to one of the secondary (e.g., Putro, 2000).

Acknowledgement
Author wants to thank Prof. Dr. Hans G. Bartels and Prof. Dr. Dietrich Ohse from Johann Wolfgang Goethe-Universität Frankfurt am Main for their suggestions on transportation model and its expansion. Author would also appreciate to Mr. Endang Sunendar, SE., Mr. Agus Eko Putro, SE., MT, Mr. Ir. Nur Mustain, and Mr. Feri Sumarta, SE. from PT. Pos Indonesia for their helps on gathering some initial data and information. This research is performed by supporting of the scholarship from DAAD (Deutscher Akademischer Austauschdienst) Germany.

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