INTEGRATED DISTRIBUTION SYSTEM OF STATE-OWNED COMPANIES

Prof. Dr. Ir. Sutanto Soehodho, MEng.
Professor in Transportation
Dept of Civil Engineering,
Faculty of Engineering,University of Indonesia
Kampus UI Depok 16424. Ph: 021-7270029
Email : ssoehodho@yahoo.com

Ir. Nahry, M.T.
Doctoral Candidate
Dept of Civil Engineering,
Faculty of Engineering,University of Indonesia
Kampus UI Depok 16424. Ph: 021-7270029
Email : nahry@eng.ui.ac.id

ABSTRACT

The proposed model is aimed to optimize distribution system of Public Service Obligation State-Owned Company (PSO-SOC). The particular issue considered in the proposed model is related to the split of the demand into public (subsidized) demand and commercial one. Hence, the term ‘ multi-commodity ‘ in this model refers to types of product and types of users of the product as well. In the context of user satisfaction, both types of user are treated differently. Subsidized demands have to be fully satisfied, while the commercial ones are satisfied in case of excess plant capacity exists.

The other issue is the integration of distribution sub-systems of the affiliated companies into one system. It is intended to maximize profit of the system, rather than that of each affiliated company as a sub system.

In order to integrate the system, we propose the total capacity on main resource (raw material) of all plants as the upper limit of the production capacity of the system, and the amount of main resource which could be supplied by each plant as the upper limit of aggregate production capacity on each plant. Disaggregate capacity of each plant, that is the capacity with respect to the type of product, now is becoming a decision variable. Furthermore, the variables which are involved in our proposed model are production cost , transportation cost, warehouse cost, as well as negative revenue. The objective of the model is to minimize all such costs.

Solution of the model is approached by network representation. Some dummy links and nodes are added to the physical distribution network to represent all the variables of the model. In order to guarantee the equivalency of total supply and total demand, we add either Excess Supply Control Sub Network or Excess Demand Control one into our basic network representation, depending on which condition exists at the beginning of the optimization process. Primal-dual algorithm is utilized to solve the minimum cost flow problem of such network representation.

Keywords: Public Service Obligation State-Owned Company, multi-commodity, integrated distribution system

INTRODUCTION

State-owned company is defined as a legal entity created by a government to exercise some of the powers of the government. Some state-owned companies may resemble a not-for-profit company as they have no need or goal of satisfying the shareholders with return on their investment through price increase or dividends, while others are established as for-profit businesses.
A state-owned company is owned partly or wholly by national, regional or local government and it involves in the public sector. In Indonesia, the State-Owned Company (SOC) is classified into Public Service Obligation (PSO) SOC and Business Oriented SOC. PSO SOC has the obligation to serve the entire demand on “public (subsidized)” commodities or services regardless of the their sizes, locations and infrastructure condition, while at the same time they are assigned to gain profit from the “commercial” product when the excess capacity exists. In order to satisfy the public need, usually government controls the selling price of the products. As the aim of PSO is to secure the supply, the production target is maximizing the production capacity meanwhile the economic principles and efficiency are still being its concern.
In contrast, Business Oriented SOC has an objective to maximize its profit or minimize the cost then its objective in production is to optimize (rather than maximize) the operational capacity. At certain condition, the increasing of production volume will not come up to the increasing of the profit thus the company should create initiatives to utilize the excess capacity that may occur as a consequence of the plant not operates in full capacity.
Previous researches on freight distribution system concern mostly on private companies, in which their concern is merely on profit maximization (Bhutta *et al*, 2003) or cost minimization (Sun,2006 and Dupont,2008). Most of the researchs on distribution of public needs are related to the public services (such as school, police station, hospital, etc) rather than public goods. Savas (Savas,1978) focus his research on the equity in providing public services, while Ross (Ross, G.T. *et al*., 1980) propose model with multicriteria to select sites of public facilities. Regarding the variables included, most of the researchs concern to the transportation cost, while some of them deals with some other variables , such as production cost, fixed cost of facility, inventory holding cost, and others variables which are relevant to the special problem they face (Yan *et al.*, 2005, Harkness *et al.*, 2003 ,Bhutta *et al.*, 2003, Iakovou,2001). These facts bring the notion to enhance the earlier distribution models for the purpose of taking into account such special role of state-owned company.

This study is part of a serial research on distribution system of state-owned companies (Sutanto, 2009). The primary objectives of the main research are to develop the optimization model of distribution systems of a state-owned company. We focus on Indonesia's state-owned company which deals with the production and distribution of public commodities. Such commodities are widely used in most parts of the country as the vital substance on productivity. The current research is focusing on proposing optimization model that basically is based on the principle of integrated system among the affiliated companies of holding company under consideration. It is more likely intended to simulate the advantage of the proposed optimization model (through the simple exercise) rather than dealing with the real world application.

DISTRIBUTION SYSTEM OF THE COMPANY UNDER CONSIDERATION AND APPLICATION OF THE MODEL

The company under consideration is a group of companies that consists of 1 (one) holding company and 5 (five) affiliated companies. Each of companies (included the holding itself) carries out the operational of its plant and its distribution process independently. Those companies are managed separately and there is no regulation that integrates those companies in their logistical process. The operating holding company carries out task to assign the 'public' demand to each affiliated companies, included the holding itself. It also holds responsibility in distribution and marketing of subsidized products.

Each company deals with their own retailers (as end consumers) which are determined by the principle of clustering. The holding cluster the retailers based on the principle of "least cost of distribution" and production capacity of each plant. Furthermore, the holding assigns the demands to each plant to be satisfied.

The SOC under consideration produces four kinds of products where each product comprises of subsidized and non-subsidized (commercial) products. In order to meet the demand of final consumers, the SOC is assigned to fulfil all the national demands on subsidized products while the government fixes the selling price as the Highest Retail Price (HET). As the excess capacity takes place, the producers may utilize the capacity of the plant by selling the product as a commercial item, either for local/national demand or export commodities. Naturally, commercial price is greater than subsidized price and therefore these two prices could be a trade-off to attain the maximum profit of the companies.

The products of SOC under consideration are composed mainly of natural resource, that is natural gas. Such material covers 60% of production cost, while the remaining cost contains the overhead cost. Each of four kinds of products consumes different composition on natural gas. Production cost is various among the plants.

It is concluded from the preliminary stage of main research that the distribution system of company under consideration is lack of efficiency, in term of "system" level. The optimization is carried out by each company (as a subsystem) exclusively and there is no integration exists in the level of Holding Company. The concept of price/demand differentiation (subsidized vs commercial product) as well as the problem of utilization of excess capacity and sharing utilization of logistics facilities raises the notion to enhance the distribution systems of PSO State-owned Company. Such notion should be seen as the optimization in the level of Holding Company as a system (rather than each company as a sub-system) where the Holding Company has an authority to integrate the management and operation of the affiliated companies.

Basically , the proposed model is addressed for building up a holding company of the existing affiliated companies, and due to consequent integrated financing system the upstream resources, such as natural gas, can be reallocated optimally through more efficient optimal gas distribution.

As the implication of this idea, we propose to exploit total capacity of all plants on resource (i.e. natural gas) to be used as control variable in production assignment of each plant, rather than making use of capacity of each plant on each product, as used in practice by the company under consideration. We refer this as "resource-based assignment" in contrast with "product-based assignment" which bases its assignment process on the "total volume of end product".

In product-based assignment, capacity of each plant (in term of product) is set as a control variable while in resource-based assignment it becomes decision variable of the optimization. Moreover, in product-based assignment , the assignment of each product is carried out independently to each other, while in resource-based assignment it is done simultaneously for all products and all plants.

Through the resource-based assignment, it is expected that the holding company could manage its resources more efficiently.

Network Representation approach, as a chosen technique of solving the proposed model , has possibly made such application easy and manageable since all possible scenarios are materialized within the analysis through addition of dummy nodes and links. The rest of analysis is handled by any network optimization network, as described in the next sections.

THE PROPOSED MODEL FORMULATION

In order to cope with the problem of distribution system of PSO-SOC, which are, as described above, characterized mainly by the product/demand differentiation and integrated system, we propose a mathematical model which is used in the optimization of the production assignment. Such model is in association to the following distribution network.

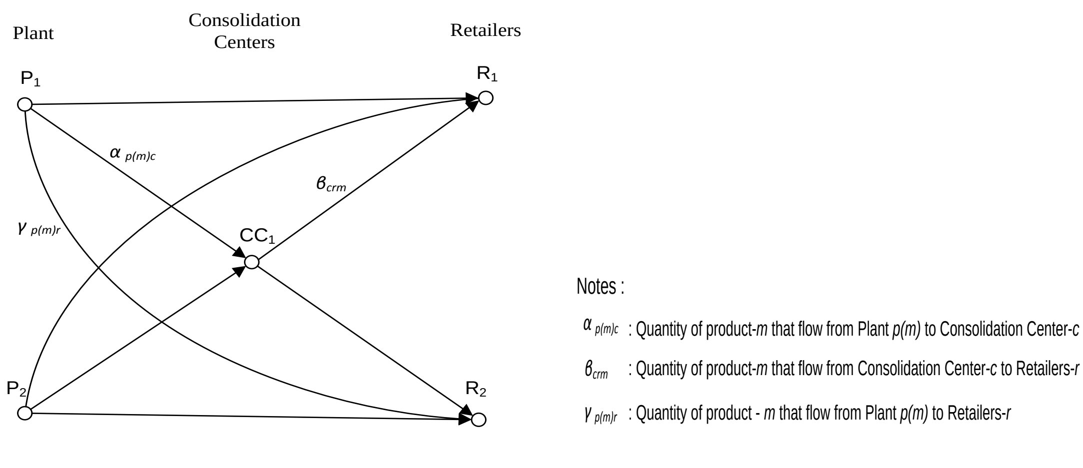


Figure 1. An example of physical distribution network

The proposed mathematical model is as follows:

$$\min Z\ (\alpha_{p(m)c}, \beta_{crm}, \gamma_{p(m)r}) =$$
$$\sum_{p\in P}\sum_{c\in C}\sum_{m\in M} u_{pc}.\alpha_{p(m)c} + \sum_{c\in C}\sum_{r\in R}\sum_{m\in M} v_{cr}\ \ \beta_{crm}. + \sum_{p\in P}\sum_{r\in R}\sum_{m\in M} z_{pr}.\ \gamma_{p(m)r} + \sum_{p\in P}\sum_{c\in C}\sum_{m\in M} w_{cm}.\alpha_{p(m)c}$$
$$\sum_{p\in P}\sum_{m\in M}\left(\sum_{c\in C}\alpha_{p(m)c} + \sum_{r\in R}\gamma_{p(m)r}\right).\ \eta_{p(m)} - \sum_{r\in R}\sum_{m\in M}\left(\sum_{c\in C}\beta_{crm} + \sum_{p\in P}\gamma_{p(m)r}\right).\rho_{rm} \qquad (1)$$

subject to

$$\sum_{p\in P}\alpha_{p(m)c} = \sum_{r\in R}\beta_{crm}\ , \qquad \forall c\in C, \forall m\in M \qquad (2)$$
$$\sum_{c\in C}\beta_{crm} + \sum_{p\in P}\gamma_{p(m)r} = \lambda_{rm}\ , \qquad \forall r\in R, \forall m\in M^{s} \qquad (3)$$
$$\sum_{c\in C}\beta_{crm} + \sum_{p\in P}\gamma_{p(m)r} \le \lambda_{rm}\ , \qquad \forall r\in R, \forall m\in M^{c} \qquad (4)$$
$$\left(\sum_{c\in C}\sum_{m\in M}\alpha_{p(m)c} + \sum_{r\in R}\sum_{m\in M}\gamma_{p(m)r}\right)\mu_m \le Cp_p\ , \forall p\in P \qquad (5)$$
$$\alpha_{p(m)c} \ge 0\ , \qquad \forall p\in P, \forall c\in C, \forall m\in M \qquad (6)$$
$$\beta_{crm} \ge 0\ , \qquad \forall c\in C, \forall r\in R, \forall m\in M \qquad (7)$$
$$\gamma_{p(m)r} \ge 0\ , \qquad \forall p\in P, \forall r\in R, \forall m\in M \qquad (8)$$

Subscripts:
p : indicate the Plants
c : indicate the Consolidation Centers
r : indicate the Retailers
m : indicate the Products
p(m) : indicate the plant $p \in P$ that produces product-*m*

Sets :
P : Set of plants
C : Set of consolidation centers
R : Set of retailers
M : Set of products
$M^{s} \in M$: Set of subsidized (public) products
$M^{c} \in M$: Set of commercial products

Decision Variables:
$\alpha_{p(m)c}$ is quantity of product-*m* that flow from Plant *p(m)* to Consolidation Center-*c*
β_{crm} is quantity of product-*m* that flow from Consolidation Center-*c* to Retailers-*r*
$\gamma_{p(m)r}$ is quantity of product - *m* that flow from Plant *p(m)* to Retailers-*r*

Input Parameters:

ρ_{rm} : selling price of the product-*m* at retailer- *r*	w_{cm} : unit warehouse cost to handle product-*m* in Consolidation Center-*c*
u_{pc} : unit transportation cost from Plant-*p* to Consolidation Center-*c*	$\eta_{p(m)}$: unit cost for producing product-*m* in plant-*p*
v_{cr} : unit transportation cost from Consolidation Center-*c* to Retailer-r	Cp : resource capacity of plant-*p* to produce all product
z_{pr} : unit transportation cost from Plant	μ_m : Resource Conversion Coefficient
p(m) to Retailer-r	λ_{rm} : demand of product-*m* in Retailer-*r*

Equation (1) denotes the objective function of our model, that is actually to maximize the profit, in which profit is represented by revenue minus cost. Surely, this objective function can be replaced by minimization of cost minus revenue.

Profit maximization is chosen rather than cost minimization since we are dealing with multi products with different prices and also concerning to the various production cost of all plants, as well as transportation and warehouse cost. There will be trade-off between those variables to attain the optimal solution.

The first three fractions of equation (1) represent transportation cost, the fourth is associated to warehouse cost . The fifth part represents production cost and the last part concerns to revenue. Surely, due to the opposite characteristic of cost and revenue, we put minus sign before revenue.

Equation (2) denotes that total inflow minus total outflow in consolidation centers is set as zero since those nodes are set as intermediate nodes.

Equation (3) and (4) are related to demand satisfaction. Equation (3) is related to subsidized products, hence the equal sign is used in order to guarantee that such products must be fully satisfied. Whereas, in equation (4) less than/ equal to sign is used since commercial product should not be fully satisfied.

Equation (5) implies that total amount of resource (raw material) used to produce all kinds of products by each plant should not be more than its capacity. Resource conversion coefficient (μ_m) is the amount of raw material used to produce one unit of product-*m*.

Equation (6)~(8) are non negative flow constraints.

THE USE OF NETWORK REPRESENTATION TO SOLVE THE MODEL

Product Sub Network Representation (P-SNR)

Network Representation (NR) is a technique to solve model by representing mathematical model as network flow-based formulation (Glover *et al.* ,1992). It is characterized by the use of diagrams that have emerged, by progressive elaboration, from those used traditionally in network flow and graph theory.

From equation (1)~(8), it is implied that our proposed model takes form of Minimum Cost Multi-commodity Flow (MCMF) problem. In order to cope with the multi-commodity problem, we develop NR that consists of some Sub Network Representation which is named "Product Sub Network Representation (P-SNR)" in which each of P-SNR represents NR of certain product. Figure 2 denotes an example of P-SNR of product-1 of the MCMF problem of physical network on figure 1.

Links between node $P_{i\text{-}m}$ and P_i are designed as production cost link. Those links represent cost to produce product-*m* in plant-*i*. Each of those links is characterized as product-exclusive link, that is each link is devoted to certain product.

Links between P_i - CC_i , P_i - R_i , and $CC_i^{'}$ - R_i are designed as transportation cost link, and they represent transportation cost between two distribution facilities. Hence, each link of transportation links is characterized by a certain unit cost of transportation. It is assumed that unit cost to transport any type of product in certain link is similar.

Links between $CC_i{}'$ - CC_i are representations of warehouse cost that is cost of handling inventory in consolidation center.

Links between node R_i and $R_{i\text{-}m}$ are designed as revenue link. Those links represent revenue from selling product-*m* in retailer-*r.* Initial *s* in $R_{i\text{-}m}{}^{S}$ stands for subsidized product, while c of $R_{i\text{-}m}{}^{C}$ stands for commercial one. Each of Revenue link is also designed as product-exclusive link. Links of P-SNR's are designed as uncapacitated links with respect to product flow.

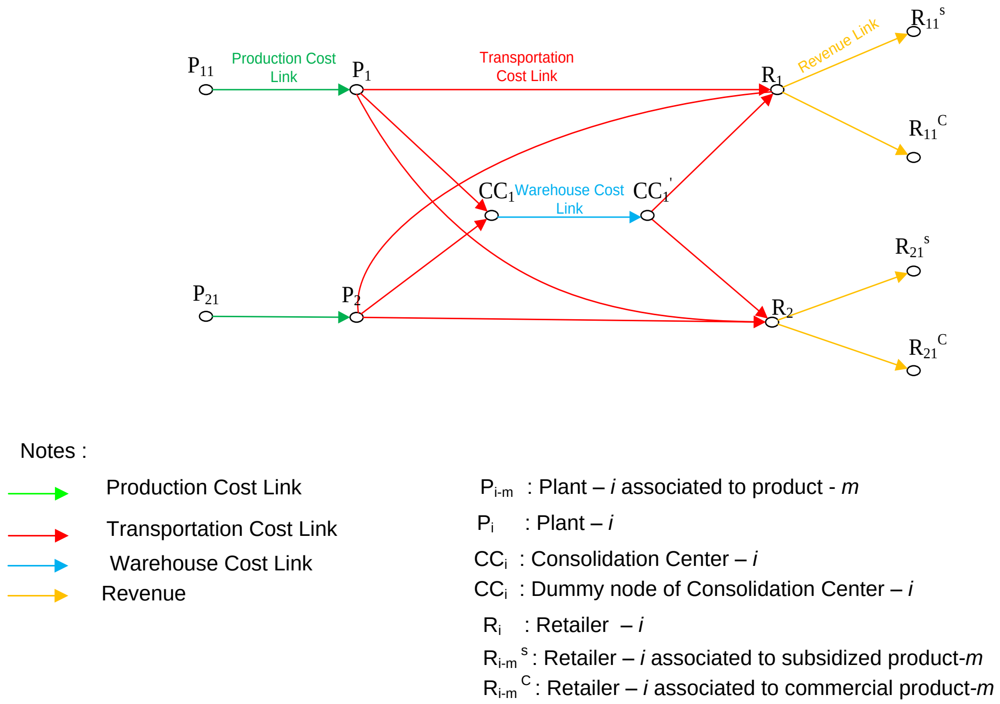


Figure 2. An axample of Product Sub Network Representation

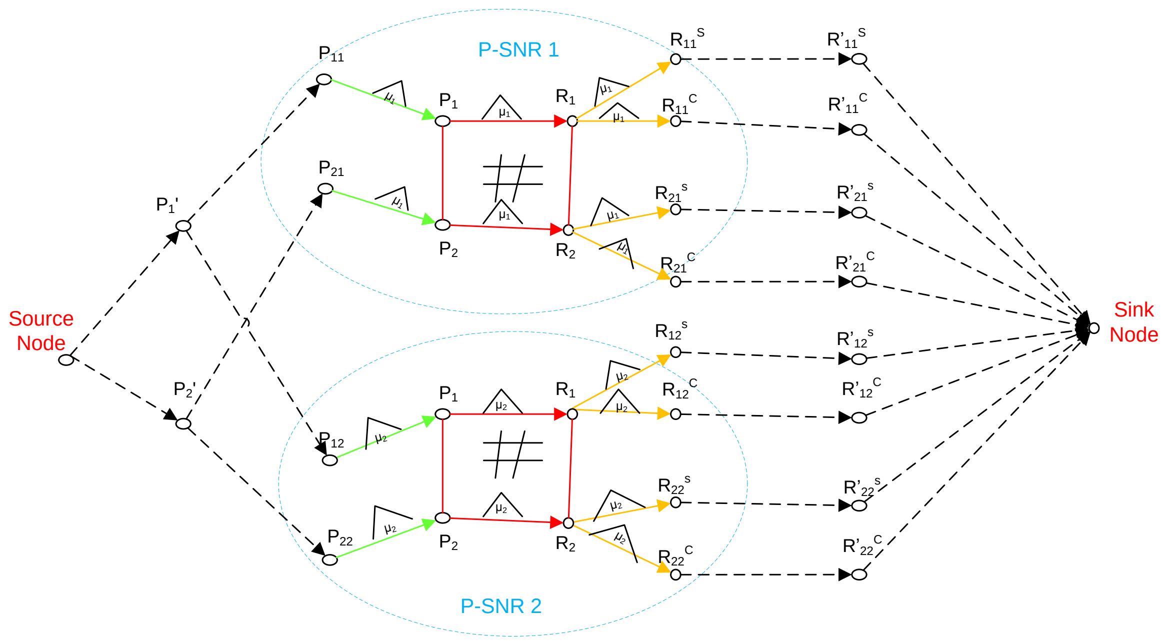
Transformed Sub Network Representation

In order to gather all the P-SNR's, we add Transformed Sub Network Representation which consists of some dummy nodes and dummy links to integrate all the P-SNR's into one NR. An example of Transformed Sub-NR and the modified NR is shown in figure 3.

Figure 3 denotes NR of the MCMF problem as formulated in equation (1)~(8). Since the case in the example is dealing with 2 (two) types of products, consequently the associated NR basically consists of 2 (two) P-SNR's. We simplify the figure of each P-SNR, especially in the parts that related to transportation cost links and warehouse cost ones.

We gather all the P-SNR's by introducing "resource-based" uncapacitated P_i'-P_{im} links. Flows on such links represents total amount of resource (raw material) of the associated plant which is used to produce the associated product. We categorize such magnitude as "resource-based unit" in contrast with "product-based unit". In product-based unit, flow refers to the flow of product.

From the example in figure 3, flow on link P_2'-P_{21} refers to the total resource that is used in plant 2 to produce certain amount of product 1.



Notes :

$P_{i\text{-}m}$: Plant – *i* associated to product - *m*

P_i : Plant – *i*

CC_i : Consolidation Center – *i*

CC_i : Dummy node of Consolidation Center – *i*

R_i : Retailer – *i*

$R_{i\text{-}m}{}^{S}$: Retailer – *i* associated to subsidized product-*m*

$R_{i\text{-}m}{}^{C}$: Retailer – *i* associated to commercial product-*m*

$P_i{}'$: Dummy node of Plant – *i*

$R'_{i\text{-}m}{}^{S}$: Dummy Retailer – *i* associated to subsidized product-*m*

$R'_{i\text{-}m}{}^{C}$: Dummy Retailer – *i* associated to commercial product-*m*

- - -► Link of Transformed Sub NR

Figure 3. An Example of Network Representation

Since the flows on links P_{im} - P_i correspond to the total amount of product-*m* which is produced by plant-*i* (product-based flow), hence we require a means to describe how the magnitude of the flow alters as a result of the activity being performed. We make use of Resource Conversion Coefficient (μ_m) to change the magnitude of the flow. It refers to Multiplier Coefficient of Glover *et al*. (1992).

Furthermore, link flows of R_{im}-R'_{im} correspond to the total product of *m* that is supplied to retailer-*i,* in which they are already converted into the magnitude of resources.

Links between *Source node* – $P_i{}'$ and R'_{im} - *Sink node* are used to gather all the resource capacity in one system. The capacity of links between *Source* node and $P_i{}'$ are set as resource capacity of the associated plant. Links beyond the P-SNR's are cost as zero, except the links between R_{im}-R'_{im} . Such links which are connected to the commercial products, such as link $R_{12}{}^{c}$-$R'_{12}{}^{c}$ are cost extremely high, while the ones which are connected to subsidized products are cost as zero. This consensus is applied in order to make priority to satisfy the subsidized product more than to the commercial ones. Their capacities are set as the amount of associated demand to such links.

Accordingly, unlike the practical side in the company under consideration, our proposed model makes use of total amount of product that is produced by each plant as a decision variable, not as capacity constraint any longer.

Flow Requirement of all nodes of the modified NR are set as zero except for the source and sink node. The flow requirements are set as total supply for Source Node and negative total demand for Sink Node.

Excess Supply/Demand Sub Network Representation

In certain condition, total demand (in this case, it is already converted into resource magnitude) is more than total supply (Excess Demand case). In such case, we add a dummy node that is called "Transformed-Source Node", as well as dummy links between such node and Source node and the one between Transformed-Source Node and Sink Node. Link capacity of the first dummy link is set as total resource capacity and for the second one is set as the difference between total demand and total supply. Those dummy links are cost as zero. All the flow requirements are set as zero except for Transformed-Source Node and Sink Node. The flow requirements are set as total demand and negative total demand for Transformed-Source Node and Sink Node, respectively. Figure 4 shows an example of NR for Excess Demand case.

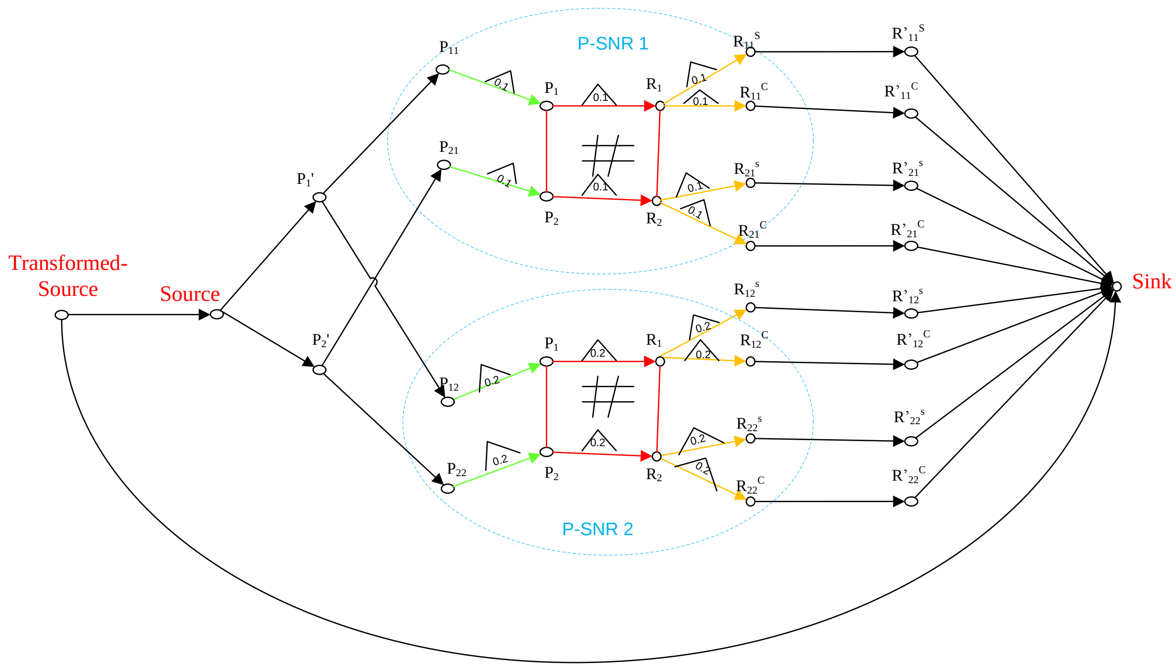


Figure 4. An Example of Network Representation for Excess Demand Case

In case of total supply is more than total demand (Excess Supply case), dummy Transformed-Sink Node is added to the NR, as well as dummy link between Sink Node and such node and the one between Source Node and Transformed-Source Node. Link capacity of the first dummy link is set as total demand and for the second one is set as the difference between total supply and total demand. Those dummy links are cost as zero. All the flow requirements are set as zero except for Source Node and Transformed-Sink Node. The flow requirements are set as total supply and negative total supply for Source Node and

Transformed-Sink Node, respectively. Figure 5 shows an example of NR for Excess Supply case.

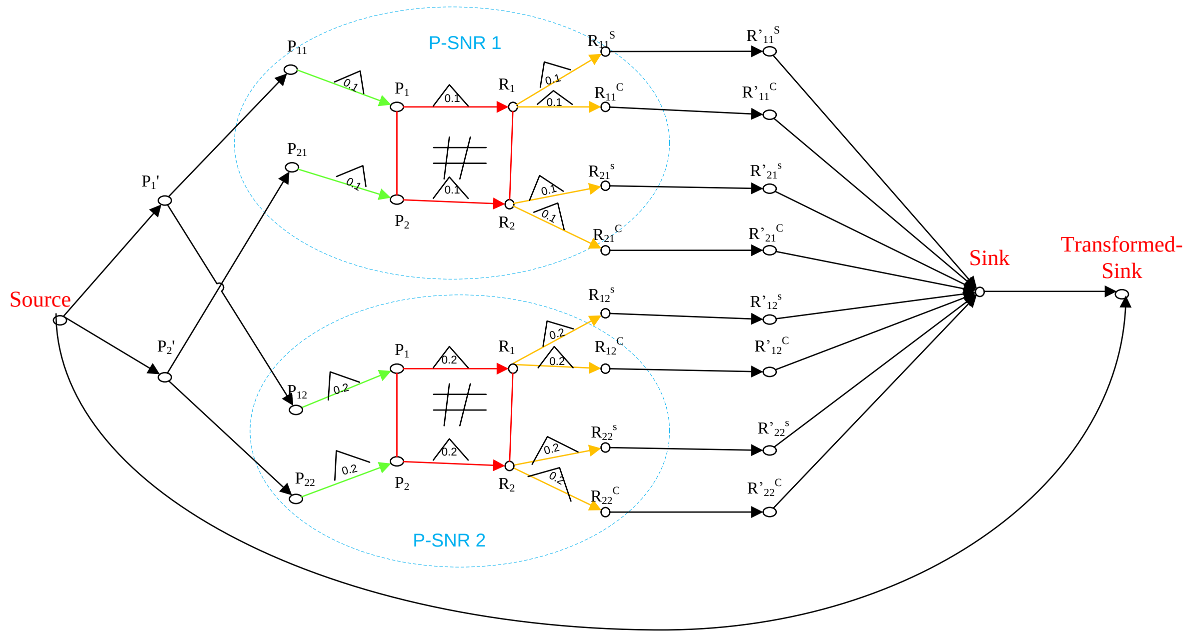


Figure 5. An Example of Network Representation for Excess Supply Case

PRIMAL-DUAL ALGORITHM

Many algorithms for solving the MCMF problem combine ingredients of both shortest path and maximum flow algorithms. Many of these algorithms solve a sequence of shortest path problems with respect to maximum flow-like residual networks and augmenting paths. One of the algorithms is the Primal-dual algorithm (Ahuja *et al*.,1993). Its algorithmic strategy is at every iteration, it solves a shortest path problem and augment flow along one or more shortest paths. It uses a maximum flow computation to augment a pseudo-flow simultaneously along several shortest paths. Such pseudo-flow is maintained to satisfy the Reduced Cost Optimality conditions.

In Reduced Cost Optimality conditions, a feasible solution x^* is an optimal solution of the minimum cost flow problem if and only if some sets of node potentials π satisfy the reduced cost of arc (i,j) (c_{ij}^{π}) is always greater or equivalent to zero, for every arc in the graph at the optimal condition.

The primal-dual algorithm generally transforms the minimum cost flow problem into a problem with a single excess node and a single deficit node, by introducing a source node and a sink node.

The primal-dual algorithm solves a maximum flow problem on a sub-graph of the residual network, called the admissible network. The admissible network is defined with respect to a pseudo-flow that satisfies the reduced cost optimality conditions for some node potentials.

The admissible network contains only those arcs in residual network with a zero reduced cost.

MODEL SOLUTION

In this section, we propose step-wise of solution of MCMF problem as formulated in equation (1)~(8) by exploiting NR as described in the previous section. Figure 6 shows the developed step-wise. It can be explained as follows:

Step 1 : It concerns to the process of defining Product Sub NR of all types of products. It includes defining the link capacity as well as link unit cost. All the link capacities are set as infinity and link unit cost as a constant. Their magnitudes refers to resource-based flow, that is they all are converted into resource/raw material magnitude.

Step 2 : We proceed to the development of Transformed Sub NR by adding dummy nodes and links, as well as their link capacities and unit costs into the P-SNR's. Justifications described in the previous section are applied to set the magnitude of the link capacity and unit cost. All the magnitudes refers to resource-based flow.

Step 3 : In case of total supply is not in balance with total demand, we add Excess Supply or Excess Demand Sub NR. It is included setting of its link capacities and unit costs. In this step, we come to the final NR.

Step 4 : We solve MCMF problem of final NR by using Primal-dual Algorithm.

Step 5 : Find the optimal link flow and the associated paths. All the magnitudes are still in resource-based unit.

Step 6 : Since the demand side is always in product-based magnitude, we need to convert the optimal link flow of step-5 into product-based unit by applying Resource Conversion Coefficient.

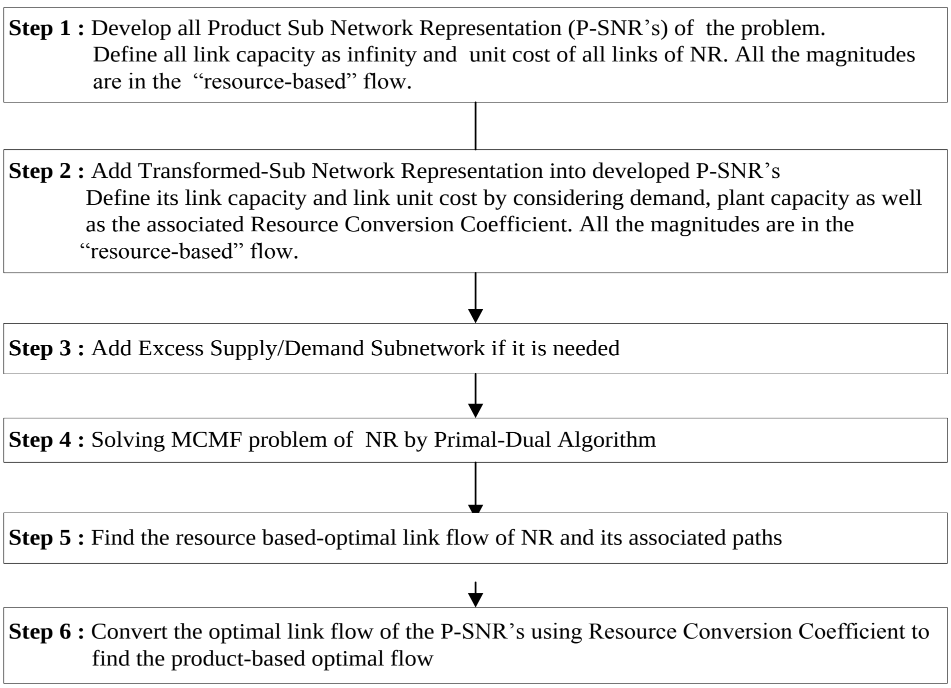


Figure 6. Step-wise of Model Solution

ILLUSTRATIVE EXAMPLE

In order to illustrate more clearly the mechanism presented in the step-wise described in previous section, an illustrative example is discussed. The physical network of the example consists of 2 plant nodes (P_1~P_2), 1 consolidation center node (CC_1) and 2 retailer nodes (R_1~R_2). Its distribution system deals with 2 types of product (product-1 and 2) and 2 types of demand, those are subsidized and commercial demand. Such physical network is similar to the one in figure 1. The following tables indicate total resource capacity of all plants , demands on retailer nodes, resource conversion coefficient (μ_m), and product selling price.

Table 1. Resource Capacity

Plant	Resource Capacity
1	6
2	14

Table 2. Demand on certain product

Retailer	Demand on product			
	1^S	1^C	2^S	2^C
1	50	20	10	30
2	30	10	20	40

s : subsidized product ; c : commercial product

Table 3. Resource conversion coefficient

Product	Resource conversion coefficient (μ_m)
1	0.1
2	0.2

Table 4. Product Selling Price

Retailer	Product Selling Price			
	1^S	1^C	2^S	2^C
1	10	20	15	30
2	10	30	15	40

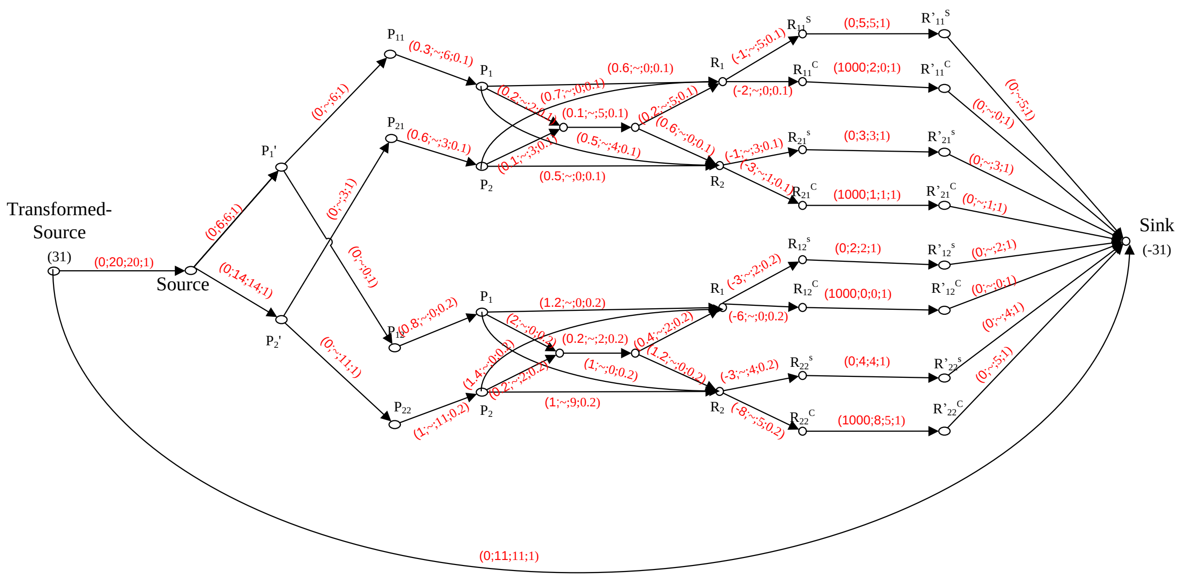
s : subsidized product ; c : commercial product

The NR of such example is shown in figure 7. It is included the result of the optimization, which takes form of “resource-based optimal flow”. The result can also be drawn in the form of superimposed P-SNR as figured in figure 8.
Since the total resource consumed (31 units) is larger than total resource capacity (20 units), hence the example is categorized as Excess Demand Case. Obviously, there will be some demands that could not be satisfied. In most cases, selling prices of commercial products are

higher than the ones of subsidized products, hence priority to satisfy subsidized product is becoming important, particularly in excess demand case. For this example, eventhough selling price of subsidized products are lower than the one of commercial products (table 4), it can be drawn from figure 8 that all subsidized products are fully satisfied, while the commercial ones on Retailer-1 (R_{11}^{C} and R_{12}^{C}) could not be satisfied at all and commercial demands of product-2 on Retailer-2 (R_{22}^{C}) is fulfilled only 62.5% of its demand (25 of 40 units). The flows of optimality give the objective value as -1230.

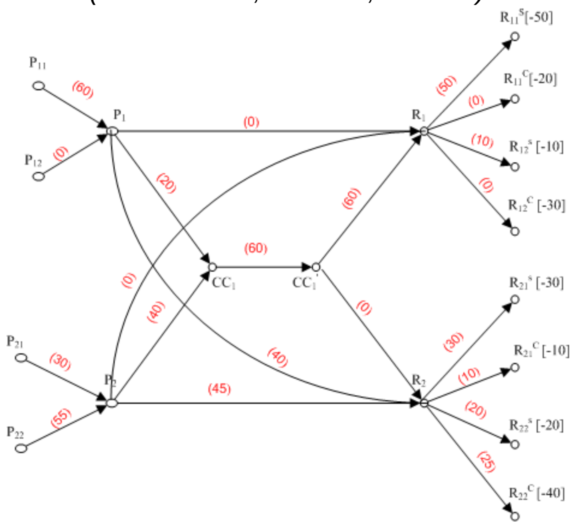
In contrast, if the optimization does not consider such priority rule, the system could attain higher objective value, that is -2390. In such case, all commercial products are entirely satisfied, while the subsidized ones could not be. Eventhough the optimization gives higher objective value, it fails to accomodate the obligation of the system to satisfy entirely subsidized demands.

In order to show the advantage of the proposed model, we carried out some exercises to compare the results of proposed model to the one of existing model which is used by the company under consideration and base its optimization on "product-based assignment". Basically, as described in the previous sections, the existing model makes use of merely transportation cost and the optimization is carried out by each plant independently, there is no integration among the plants. Each plant deals with its own retailers which are determined by the principle of least cost of distribution and limited by its production capacity (in term of product). Table 5 shows the result of the exercises.



Notes :
(Unit cost;Capacity;Flow;Resource Conversion Coefficient)
All the magnitudes refer to resource unit

Figure 7. Network Representation of the illustrative example



Notes :

(Flow)
[Demand]
All the magnitudes refer to product unit

Figure 8. Superimposed P-SNR and product-based optimal flow of the illustrative example

Table 5. The Objective Value of Existing Model and Proposed Model

CASE	Objective value	
	Existing Model	Proposed Model
Excess Demand Case (I)	-1180	-1240
Excess Demand Case (II)	-670	-866
Excess Supply	-2410	-2670
Balance	-2510	-2565

From table 5, it is shown that proposed model gives better objective value in all cases of the exercises. Since the existing model employs only the transportation cost, for the need of comparation, the objective values of the existing model as stated in table 5 are actually the "modified" values, which already include "dummy" production cost , warehouse cost, as well as revenue in association to its optimal flows.

In the result of Excess Demand Case (I), the existing model actually could not entirely satisfy certain subsidized product due to the limitation of production capacity on such product, while the proposed model could handle such problem by allocating resources to all plants more efficiently. This is essentially one of the advantage of the proposed model, besides its ability on gaining profit from selective selling price, as well as efficiency through consideration of production cost in optimization process.

In the cases of total resource is larger than total subsidized demand (in term of resource) , proposed model guarantees that all subsidized products shall be satisfied since the optimization endogenously determines production capacity of each plant (in term of product) as decision variables.

We carried out some other exercises which give the same results. Accordingly, with respect to the objective value of minimization problem, it can be concluded that the proposed model gives the better result than the existing one.

CONCLUSION

This research work is regarding MCMF problem of distribution system of PSO-SOC. In order to solve the particular issue of "multi-commodity" problem of the PSO-SOC, as well as integration of multi-plant distribution systems, we propose "resource-based optimization" concept. In such concept, resource capacities are chosen as the upper limit of the system capacity rather than product-based capacity, that is capacity with respect to the type of products. We make use of Network Representation approach to solve the MCMF problem. Consequently, the original physical network is changed to Network Representation to represent all components of the model. We solve "multicommodity" problem by developing a number of Product-Sub NR's and integrate all of them into one NR. In addition, our NR is designed to deal with the situation where the total supply is not in balance with total demand. All those approaches are intended to solve PSO-SOC problem in its distribution system and at the same time it is aimed to give contribution to research field of freight distribution. Furthermore, robustness of the proposed model still has to be tested for various properties of distribution network problems and a number of practical cases to come up with better results.

REFERENCES

Ahuja, R.K., Magnanti, T.L. and Orlin, J.B. (1993). Network Flows . Prentice Hall . New Jersey.

Bhutta, K.S., Huq, F., Frazier, G. and Mohamed, Z.(2003). An Integrated Location, Production, Distribution and Investment Model for a Multinational Corporation, International Journal Production Economics 86 , 201-216.

Dupont L. (2008) Branch and bound algorithm for a facility location problem with concave site dependent costs, International Journal Production Economics 112, 245-254.

Glover,F., Klingman, D., and Phillips, N.V. (1992). Network Models in Optimization and Their Applications in Practice. John Wiley & Sons, Inc.

Harkness, J. and ReVelle, C. (2003). Facility Location with Increasing Production Costs. European Journal of Operational Research 145, 1-13.

Iakovou , E.T. (2001). An interactive multiobjective model for the strategic maritime transportation of petroleum products: risk analysis and routing. Safety Science 39,19–29.

Ross, G.T. and Soland, R.M. (1980) A multicriteria approach to the location of public facilities, European Journal of Operational Research 4 , 307-321.

Savas, E.S. (1978). On equity in providing public services. Management Science, Vol.24 No.8, 800.

Sun, M, (2006) Solving the uncapacitated facility location problem using tabu search, Computers and Operations Research 33 , 2563-2589.

Sutanto and Nahry. (2009). Strategic design of distribution system of state-owned companies: Preliminary stage of logistics research series and evaluation on model parameters, International Journal on Logistics and Transportation (IJLT) Vol 3, No 1.

Yan, S., Juang, D.S., Chen, C.R. and Lai, W.S. (2005) Global and local search algorithms for concave cost transshipment problems, Journal of Global Optimization 33, 123-156.