Supply Chain Network Design with Preferential Tariff under Economic Partnership Agreement

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Abstract

In this paper, we present a supply chain network design model to best utilize available preferential tariff under economic partnership scheme. Process to check applicability of preferential tariff, i.e., duty-free, for each transit from a site to the other in the supply chain network is embedded in the model, which can treat both cases with and without preferential tariff uniformly upon given regional economic partnership scheme. Effective utilization of preferential tariff yields significant reduction of supply chain cost. The effectiveness of the model was evaluated with small sample case and is currently under evaluation through numerical experiments with data in actual case.

Keywords
Supply chain network design, Preferential tariff, Optimization

1. Introduction
Excellence of supply chain management is vital not only to obtain high operational efficiency but also to survive in global competition. Especially, it is often said that supply chain network design as well as product design and set-up for execution processes determines 80% of total supply chain costs, while operational efforts at execution stage such as order processing, procurement, production, shipping and distribution cover only 20%. Therefore, optimal design of supply chain network is one of the fundamental key factors in strategic decision making.

Primary purpose of supply chain network design is to establish the best supply chain network with the lowest total cost to achieve required performance in line with the company's supply chain strategy. In the past, supply chain network design problem was simply to determine location of sites for factories, warehouses and distribution centers where costs associated with supply chain could be evaluated with straightforward linear calculation. Due to recent rapid changing business environment, managerial issues and interests in supply chain strategy have changed and thus requirements for supply chain network design have changed and got complicated. Among such issues, effective utilization of preferential tariff under economic partnership scheme is significant since it makes direct impact on supply chain cost.

Recently many countries try to establish economic partnership with countries which have close trade relation. Especially, together with regional economic security considerations, economic partnership agreement is established among multiple countries in a region. In the south-east Asia, ATIGA (ASEAN Trade in Goods Agreement) and AJCEP (ASEAN-Japan Comprehensive Economic Partnership Agreement) are typical exercises. When a preferential region spreads across multiple countries, how to "overlay" supply chain network on the region is one of key issues in supply chain strategy.

However, to the best of our knowledge, there has been no research on supply chain network design model with utilization of preferential tariff under economic partnership scheme. In this paper, we present a model that enables us to best utilize available preferential tariff in supply chain network design.

2. Basic Setup for Supply Chain Network Design Problem

Here we start with the fundamental model for supply chain network optimization as follows;

Notation

$G:(N,A)$	Network of supply chain consisting of nodes N and arcs A
N	Set of nodes that describe functions in supply chain
A	Set of links that describe product flow relations among nodes
$\tilde{N}_n$	Set of nodes on the path from node n to the end node of the supply chain including node n
H	Planning horizon
β_n	Quantity of product at node n needed per a final product
$d(t_p,t)$	Demand quantity of final product during $(t-1,\ t]$ by the production plan made at t_p
$\bar{d}(t)$	Average demand quantity during $(t-1,\ t]$
$d_n(t_p,t)$	Quantity of demand for node n from its succeeding node during $(t-1,\ t]$ by the production plan made at t_p
$x_n(t_p,t)$	Quantity of product to be processed at node n during $(t-1,\ t]$ by the production plan made at t_p
$\bar{x}_n$	Average total quantity of product to be processed at node n over the planning horizon
z_{nk}	Binary variable for site location selection, which is 1 if the k th location option for node n is selected and 0 otherwise
O_{nk}	The k th location option for node n
K_n	Number of location options for node n
P_n	Processing time at node n
P_{nk}	Processing time at node n with option k
$T_{m,n}$	Transit time from node m to node n
$T_{mh,nk}$	Transit time from node m with option h to node n with option k
L_n	Lead-time from shipping at node n to completion of process at the end node
$C1_n$	Unit processing cost at node n
$C1_{nk}$	Unit processing cost at node n with option k
$C2_{m,n}$	Unit transit cost from node m to node n
$C2_{mh,nk}$	Unit transit cost from node m with option h to node n with option k
$C3_n$	Fixed cost at node n for planning horizon
$C3_{nk}$	Fixed cost of node n with option k for planning horizon

We model a supply chain as a network $G:(N,A)$ in which nodes in N are functions in the supply chain and arcs in A are links that describe product flow relations among nodes. Following the network model scheme of Graves and Willems (2005), we introduce binary variable z_{nk} for selection of site location for each node, which works as defined in the Notation above. We select one option for each node, i.e., $\sum_{k=1}^{K_n} z_{nk} = 1$, and the values of cost and time at nodes and links between nodes depend on selection of location options. Now we formulate the supply chain network design problem as follows;

Optimization model

$$\min C = \sum_{n \in N} C1_n \, \overline{x}_n + \sum_{(m,n)\in A} C2_{m,n} \frac{\beta_m}{\beta_n} \overline{x}_n + \sum_{n \in N} C3_n \ , \tag{1}$$

subject to

$$\begin{aligned} \overline{x}_n &= \sum_{t=1-L_n}^{H-L_n} E\left\{x_n(t_p, t)\right\} \\ &= \beta_n \sum_{t=1}^{H} \overline{d}(t) \end{aligned} \tag{2}$$

$$L_n = \sum_{(i,j)\in A, i,j \in \tilde{N}_n} \left(T_{i,j} + P_j\right) \tag{3}$$

$$C1_n = \sum_{k=1}^{K_n} C1_{nk} z_{nk} \tag{4}$$

$$C2_{m,n} = \sum_{h=1}^{K_m} \sum_{k=1}^{K_n} C2_{mh,nk} z_{mh} z_{nk} \ , \quad (m,n) \in A \tag{5}$$

$$C3_n = \sum_{k=1}^{K_n} C3_{nk} z_{nk} \tag{6}$$

$$P_n = \sum_{k=1}^{K_n} P_{nk} z_{nk} \tag{7}$$

$$T_{m,n} = \sum_{h=1}^{K_m} \sum_{k=1}^{K_n} T_{mh,nk} z_{mh} z_{nk} \ , \quad (m,n) \in A \tag{8}$$

$$\sum_{k=1}^{K_n} z_{nk} = 1 \tag{9}$$

$$z_{nk} \in \{0,1\}, \forall n, k \tag{10}$$

The objective function is sum of total processing cost, total transit cost and fixed cost incurred depending on location selection. When a link connects sites in different countries, i.e., describes export from one country to the other, cost due to tariff is included in the corresponding transit cost value. The problem is typically an MIP (Mixed Integer Programming) problem and can be solved by ordinary MIP solvers.

3. Optimization Model with Preferential Tariff

Effective utilization of preferential tariff yields significant reduction of supply chain cost. Preferential tariff is applied to a product that satisfies the corresponding criteria. One of typical criteria is ratio of value added in the region. For example, if a product made in an AFTA country contains value added in AFTA region of more than or equal to 40% of FOB value of the product, it is qualified for export to the other AFTA country with the preferential tariff, i.e., without duty. In order to clear the criterion, the company needs to present certificate of origin of the product by calculating sum of value added in the region including value of materials supplied from the partner countries.

In order to take the effect of preferential tariff into supply chain network design problem, judgment process for applicability of preferential tariff must be embedded in the optimization process. We propose to formulate the supply chain network design problem as the following optimization model which includes applicability check of preferential tariff of no duty for each link in the network. The model can treat both cases with and without preferential tariff uniformly upon given regional economic partnership scheme.

Optimization model with preferential tariff

$$\min C = \sum_{n \in N} C1_n \bar{x}_n + \sum_{(m,n) \in A} \left(C2_{m,n} + C4_{m,n} \right) \frac{\beta_m}{\beta_n} \bar{x}_n + \sum_{n \in N} C3_n , \tag{11}$$

subject to the equations (2) through (10) and

$$C4_{m,n} = \sum_{h=1}^{K_m} \sum_{k=1}^{K_n} C4_{mh,nk} \left(1 - w_m e_{mh} e_{nk}\right) z_{mh} z_{nk} , \quad (m,n) \in A \tag{12}$$

$$C4_{mh,nk} = r_{mh,nk} V_m , \quad (m,n) \in A \tag{13}$$

$$e_{nk} \in \{0,1\}, \forall n, k \tag{14}$$

$$w_n \in \{0,1\}, \forall n , \tag{15}$$

where $C4_{m,n}$ ($C4_{mh,nk}$) is unit cost due to tariff on export from node m (with option h) to node n (with option k), $r_{mh,nk}$ is normal tariff rate without preference on export from node m with option h to node n with option k, and V_n is value of product at node n. Since the value of product at a node depends on selection of location, we introduce a valuation function $V_n(\cdot)$ as in equation (16), where $\hat{N}_n$ is set of all the upstream nodes of node n including n. The valuation function $V_n(\cdot)$ returns value of product at node n upon given set of option selection variables z_{mh} for node m in $\hat{N}_n$.

$$V_n = V_n\left(\{z_{mh}\}\right), \quad m \in \hat{N}_n \tag{16}$$

The binary parameter e_{nk} in the equation (12) is to identify location included in the economic partnership region, which is 1 if the k th location option for node n is in the region and 0 otherwise. In order to judge if the product at node n is qualified for preferential tariff, we introduce binary dependent variable w_n, which is 1 if the product at node n satisfies the corresponding criterion. Criterion to be used depends on the rule adopted in the agreement. For example, Qualifying Value Content (QVC) rule, which is used in many economic partnership agreements including ATIGA, is described as equation (17) with a given threshold value of θ.

$$\theta \le \frac{V_n - NV_n}{V_n} , \tag{17}$$

where NV_n is sum of value of products supplied from the immediate upstream nodes of node n, which are NOT in the economic partnership region. Using e_{nk}, NV_n is calculated by the equation as follows;

$$NV_n = \sum_{m \in \breve{N}_n} \left\{ V_m \sum_{h=1}^{K_m} (1 - e_{mh}) z_{mh} \frac{\beta_m}{\beta_n} \bar{x}_n \right\}, \tag{18}$$

where $\breve{N}_n$ is set of all the immediate upstream nodes of node n.

Note that some countries participate in multiple economic partnership schemes (For example, ASEAN countries are under ATIGA and also participate in AJCEP with Japan). In such a case, the above model is assessed for each scheme and the best solution over all the schemes will be the optimal solution.

4. Conclusion

In this paper, we present a supply chain network design model to best utilize available preferential tariff under economic partnership scheme. The model can treat both cases with and without preferential tariff uniformly upon given regional economic partnership scheme. Since effective utilization of preferential tariff yields significant reduction of supply chain cost, we believe it contributes to establishment of competitive supply chain in many fields. By our preliminary experiment with sample data, we observed the model could yield reduction of cost due to tariff by 27% in a case of auto-parts supply chain. It will be evaluated through numerical experiments with data in actual case.

Remained issues include extension of varieties of preferential tariff criterion other than QVC rule and integrated model to solve the problem with multiple possible economic partnership schemes.

References

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Biography

Kenichi Funaki is General Manager of Service Innovation Research Department at Yokohama Research Laboratory, Hitachi Ltd. He received B.E. (1991), M.S. (1993) and Dr. Eng. (2001) in Industrial Engineering from Waseda University, Tokyo. His papers have appeared in International Journal of Production Economics, Journal of the Operations Research Society of Japan, IEEE Transactions on Reliability, Transactions of the Japan Society of Mechanical Engineers, Journal of Japan Industrial Management Association and others. He teaches management systems at Hokkaido University as a visiting associate professor and production and logistics systems at Tokyo Metropolitan University as a visiting lecturer. He was a visiting research executive at Supply Chain and Logistics Institute, Georgia Institute of Technology in 2008 and 2009. His research interests include supply chain management, service engineering and analytics for business innovation.

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