A Linear Programming Model For Short Sea Shipping And Multimodal Inland Transportation In Myanmar

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ABSTRACT: This paper considers the problem of determining transportation quantity and mode in transporting international cargoes between Myanmar and her trading countries, especially focusing on the countries in South East Asia to check the extent of using short sea shipping, and inland transportation. The objective of the paper is to minimize transportation costs by mode between cargo origin and destination, subject to the maximum cargo volumes being handled at each seaport. In order to optimize the short sea shipping and inland transportation in Myanmar, this paper suggests a linear programming model, which is an operations research technique.

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I. INTRODUCTION

Short sea shipping (SSS) may be defined as a “maritime highway transportation system” according to the definition by EU committee and it includes canal, river, other inland waterway as well as coastal shipping system. SSS services are more fuel efficient than trucks so that they can contribute to improving air quality and reducing noise. SSS also plays a key role in reducing the road and terminal congestion as well as the number of trucks and trains traveling on crowded port access routes. As a result, SSS development may provide a more cost-effective alternative to building new roadways and rail lines. In particular, a new concept of “Motorway of the Sea” in Europe has contributed to reducing the amount of money spent on infrastructure projects, and maintenance costs. Such inefficiency is reported to stem, among others, from imbalanced cargo flows inbound and outbound at its loading and discharging ports and insufficient modal shift among different modes.

Under this context, this paper deals with an intermodal routing problem of international container cargoes (IRP) in Myanmar SSS region. The problem is to determine both the cargo flow quantity, i.e., volume of container cargoes, and the transportation mode in each trade route, while satisfying the demand of cargoes in foreign seaports and Myanmar cities with the supply in Myanmar cities and foreign seaports, respectively, at a planning stage. The objective of the problem is to minimize the total logistic costs, i.e.shipping and land transportation costs. In this study, we develop a linear programming model to solve the IRP, which is an operations research technique.

Problems closely related to the IRP are concerned with network design and multimodal network flow problems. The network design problem has been widely considered in the literature, in which there are a variety of its applications including transportation, telecommunication, and power systems (Costa 2005). Magnanti and Wong (1984), Minoux (1989), and Balakrishman (1997) have dealt with applications, models, and methods of the network design. On the other hand, the multimodal network flow problem determines the transportation flow and mode. A thorough review of the methods of the multimodal network flow problem have been made by Crainic and Rousseau (1986), Guelat *et al.* (1990), Crainic *et al.* (1990), Drissi-Kaitouni (1991), Haghani and Oh (1996) and Nijkamp *et al.* (2004). The next section describes the IRP in more detail and develops a linear programming model. The container cargo data for test are summarized in Section 3 and the test results and their policy implications are described in Section 4. Finally, this research is concluded to suggest future research directions.

II. MODEL DEVELOPMENT

A. Cargo Flow Network

In this section, we develop a linear programming model. We first explain a cargo flow network. Figure 1 shows an example of the network. In the figure, the dotted area represents sea, while the shaded area represents the inland of Myanmar. In the network, each node corresponds to foreign seaports, Myanmar seaports, inland container depots (ICD), and Myanmar cities. For example, nodes F1 and F2 indicate foreign seaports, D1 and D2 Myanmar seaports, I1 and I2 ICDs, and C1 and C2 Myanmar cities, respectively. Note that foreign seaports are those not in Myanmar. In Figure 1, each arrow represents transportation flow of cargoes: solid arrows mean import flows, dotted arrows represent export flows, and bolded arrows indicate coastal shipping flow. Note that the arrows in the shaded area represent short sea shipping if the arrows are connected between Myanmar, seaports, and between foreign seaports in South East Asia and Myanmar seaports. In the figure, the numbers located at the left end imply the supply and the demand amounts at foreign seaports, while those located at the right end imply those at Myanmar cities. For example, 500 twenty foot equivalent units (TEU) and 10,000 TEU are the number of cargoes supplied and the number of the cargoes demanded at foreign seaport F1, respectively. The transportation in the country is done by trucks and trains in a direct way to a destination (cities or Myanmar seaports), by coastal shipping and by way of an ICD. It is assumed in the process of such transportation that trains and trucks are operated between seaports and the ICDs while trucks are only operated between ICDs and cities, according to the real situation in Myanmar. Here, the flow between ICDs is assumed not to occur based on the real situation in Myanmar.

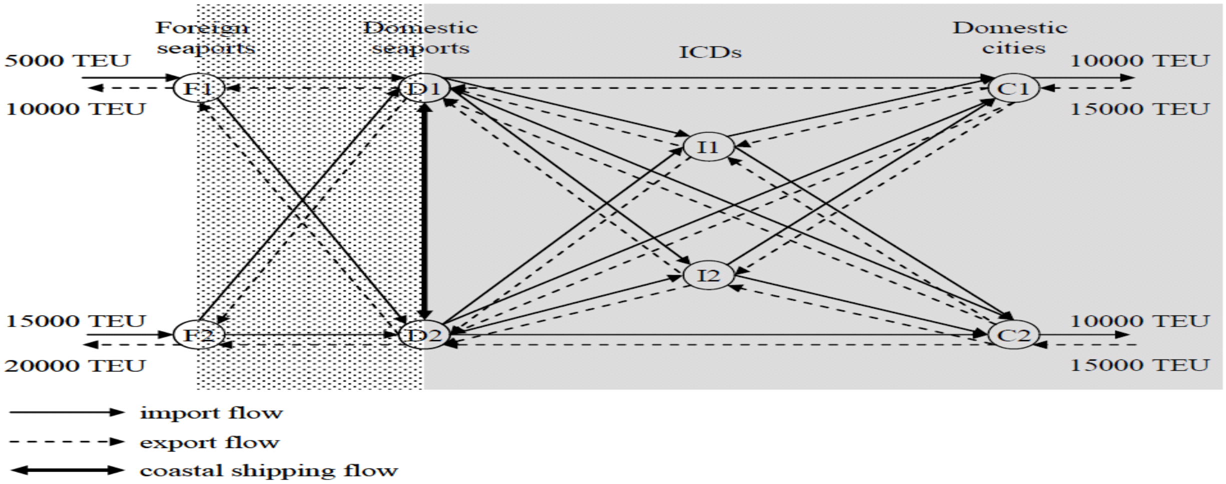

Figure 1. An example of the cargo flow network

B. Description of Intermodal Routing Problem of International Container Cargoes (IRP)

A problem for a given cargo flow network is to determine the cargo flow quantity and the amount transported by each transportation mode over one planning period while matching the demand of cargoes in Myanmar cities and foreign seaports with the supply of cargoes in foreign seaports and Myanmar cities, respectively, for the objective of minimizing the sum of shipping and inland transportation costs. The shipping costs imply the total costs charged in the process of cargoes transported between foreign and Myanmar seaports. They include the holding and carrying costs, and terminal handling charge. The holding cost implies the cost incurred by holding cargoes during the transportation, while the carrying cost is the one charged for transporting cargoes. Finally, the terminal handling charge is the cost incurred by the stevedoring service of cargoes at a Myanmar seaport. Here, we do not take into account the terminal handling charge at foreign seaports because we assume that it has already been reflected in the price figures at foreign seaports. It is necessary to note that the model in this paper considers cargoes transported after shipping from foreign seaports. In addition, the inland transportation cost implies the total cost charged to cargoes transported in Myanmar, including the holding and carrying costs of the cargoes. The IRP considers two restrictions: capacity restriction and vehicle restriction. The former implies that there is a limitation on the total cargo volume being handled at each seaport. The latter has two constraints during one research planning period, depending on transportation mode types: for truck, the constraint in the form of the total available time of trucks and for train, the constraint in the form of the maximum number of trains. It is the model in this study that considers two transportation modes, truck and train, because they are main transportation means in Myanmar. In other words, the total time of trucks available at each Myanmar seaport or city can be restricted during the planning period. Likewise, the restriction for train is given in the form of the maximum number of trains, which implies the total number of trains operated on each train line during the planning period.

C. Model Development with Some Assumptions

Finally, some assumptions have been made for the model as follows:

(a) every parameter used in the model is given and deterministic;

(b) single product type is considered;

(c) one type of ship is used while shipping cargoes from foreign to Myanmar seaports; while transporting cargoes, congestion never occurs; and

(d) all transportation modes are perfect in state. That is to say, they are not out of order throughout the planning period.

Now, we present a linear programming model to solve optimally. First, the notations used in the single product type model are summarized below. (Note that parameters and variables given below are for one planning period.)

Sets

I	set of foreign seaports
J	set of Myanmar seaports
K	set of Myanmar cities
C	set of ICDs
M	set of modes {1, 2, 3} where 1 represents truck, 2 train, and 3 vessel

Parameter

n_m	TEU that can be carried by mode *m*
nf_i	TEU that can be carried by vessel departed from (arriving at) foreign seaport
t_{ij}	transit time via mode m from depot i to destination j
cd_{ijm}	cost of transporting an unit of cargo (TEU) via mode m from depot i to destination j which is calculated as $cd_{ijm} = h \cdot t_{ijm} + cm_{ij}$ where *h* is the inventory holding cost per TEU and unit time and cm_{ij} is the price per TE from depot *i* to destination *j*
cf_{ij}	cost of shipping an unit of cargo from depot i to destination j, calculated as $cf_{ij} = cd_{ij4} + thc_j$ where thc_j is the terminal handling charge per unit TEU
u_{jm}	available time of mode m at Korean seaport j
v_{ijm}	available number vehicles of mode m between depot i to destination j
sf_i	supply amount from foreign seaport i
sd_k	supply amount from city k
df_i	demand amount in foreign seaport i
dd_k	demand amount in city k
a_j	capacity of Korean seaport j
b_c	capacity of ICD

Decision Variables

SI_{ij}	import amount from foreign seaport i to Myanmar seaport j
SE_{ji}	export amount from Myanmar seaport j to foreign seaport i
DI_{jk}	import amount from Myanmar seaport j to city k
DE_{kj}	export amount from city k to Myanmar seaport j

AI_{jkm}	import amount via mode m from Myanmar seaport j to city k
AE_{kjm}	export amount via mode m from city k to Myanmar seaport j
CI_{jck}	import amount from Myanmar seaport j to city k via ICD c
CE_{kcj}	export amount from city k to Myanmar seaport j via ICD c
TI_{jcm}	import amount from Myanmar seaport j to ICD c via mode m
TE_{cjm}	export amount from ICD c to Myanmar seaport j via mode m
TI_{ckm}	import amount from ICD c to Myanmar seaport j via mode m
TE_{kcm}	export amount from city k to ICD c via mode m

Now, the linear programming model is given below.

$$\text{Minimize} \sum_{i\in I}\sum_{j\in J} cf_{ij}\cdot\left(SE_{ji}+SI_{ij}\right)+\sum_{j\in J}\sum_{k\in K}\sum_{m\in\{1,2\}} cd_{jkm}\cdot\left(AI_{jkm}+AE_{kjm}\right)$$

$$+\sum_{j\in J}\sum_{c\in C}\sum_{m\in M} cd_{jcm}\cdot\left(TI_{jcm}+TE_{cjm}\right)+\sum_{c\in C}\sum_{k\in K} cd_{ck1}\cdot\left(TI_{ck1}+TE_{kc1}\right)$$

subject to

$$(1)\ \sum_{j\in J} SI_{ij} = sf_{i} \qquad \text{for all } i \in I$$

$$(2)\ \sum_{j\in J} DE_{kj} = sd_{k} \qquad \text{for all } k \in K$$

$$(3)\ \sum_{j\in J} DI_{jk} = dd_{k} \qquad \text{for all } k \in K$$

$$(4)\ \sum_{j\in J} SE_{ji} = df_{i} \qquad \text{for all } i \in I$$

$$(5)\ \sum_{i\in I} SI_{ij} = \sum_{k\in K} DI_{jk} \qquad \text{for all } j \in J$$

$$(6)\ \sum_{k\in K} DE_{kj} = \sum_{i\in I} SE_{ji} \qquad \text{for all } j \in J$$

$$(7)\ \sum_{i\in I}\left(SI_{ij}+SE_{ji}\right) \le a_{j} \qquad \text{for all } j \in J$$

$$(8)\ \sum_{j\in J}\sum_{k\in K}\left(CI_{jck}+CE_{kcj}\right) \le b_{c} \qquad \text{for all } c \in C$$

$$(9)\ DI_{jk} = \sum_{m\in\{1,2\}} AI_{jkm}+\sum_{c\in C} CI_{jck} \qquad \text{for all } j \in J \text{ and } k \in K$$

$$(10)\ DE_{kj} = \sum_{m\in\{1,2\}} AE_{kjm}+\sum_{c\in C} CE_{kcj} \qquad \text{for all } j \in J \text{ and } k \in K$$

$$(11)\ \sum_{k\in K} CI_{jck} \le \sum_{m\in\{1,2\}} TI_{jcm} \qquad \text{for all } i \in I \text{ and } c \in C$$

$$(12)\sum_{j\in J} CI_{jck} \leq TI_{ck1} \qquad \text{for all } c \in C \text{ and } k \in K$$

$$(13)\sum_{j\in J} CE_{kcj} \leq TE_{kc1} \qquad \text{for all } c \in C \text{ and } k \in K$$

$$(14)\sum_{k\in K} CE_{kcj} \leq \sum_{m\in(1,2)} TE_{cjm} \qquad \text{for all } j \in J \text{ and } c \in C$$

$$(15) SI_{ij} \leq nf_i \cdot v_{ij4} \qquad \text{for all } i \in I \text{ and } j \in J$$

$$(16)\sum_{k\in K} t_{jk1} \cdot AI_{jk1} + \sum_{c\in C} t_{jc1} \cdot TI_{jc1} \leq n_1 \cdot u_{j1} \qquad \text{for all } j \in J$$

$$(17) AI_{jk2} \leq n_2 \cdot v_{jk2} \qquad \text{for all } j \in J \text{ and } k \in K$$

$$(18) TI_{jc2} \leq n_2 \cdot v_{jc2} \qquad \text{for all } j \in J \text{ and } c \in C$$

$$(19)\sum_{k\in K} t_{ck1} \cdot TI_{ck1} + \sum_{j\in J} t_{cj1} \cdot TE_{cj1} \leq n_1 \cdot u_{c1} \qquad \text{for all } c \in C$$

$$(20) SE_{ji} \leq nf_i \cdot v_{ji4} \qquad \text{for all } i \in I \text{ and } j \in J$$

$$(21)\sum_{j\in J} t_{kj1} \cdot AE_{kj1} + \sum_{c\in C} t_{kc1} \cdot TE_{kc1} \leq n_1 \cdot u_{k1} \qquad \text{for all } k \in K$$

$$(22) AE_{kj2} \leq n_2 \cdot v_{kj2} \qquad \text{for all } k \in K \text{ and } j \in J$$

$$(23) TE_{cj2} \leq n_2 \cdot v_{cj2} \qquad \text{for all } j \in J \text{ and } c \in C$$

$$(24) SI_{ij}, SE_{ji} \geq 0$$

$$(25) DI_{jk}, DE_{kj} \geq 0$$

$$(26) AI_{jkm}, AE_{kjm} \geq 0$$

$$(27) CI_{jck}, CE_{kcj} \geq 0$$

$$(28) TI_{jcm}, TE_{cjm} \geq 0$$

$$(29) TI_{ckm}, TE_{cjm} \geq 0$$

The objective function of the model denotes the sum of shipping and inland transportation costs. Constraints (1) - (4) represent the supply and demand restrictions. In more detail, constraints (1) and (2) indicate the supply restrictions, which imply that the cargoes going out from a foreign seaport and a Myanmar city should be equal to the supply amount coming in the seaport and the city, respectively. On the other hand, constraints (3) and (4) reflect that demands in a foreign seaport and a Myanmar city should be satisfied, respectively. Constraints (5) and (6) represent the flow conservation, which implies that the amount of cargoes coming to a Myanmar seaport is equal to the amount of cargoes going out from the seaport. Constraints (7) and (8) state that the total amount of cargoes handled at a Myanmar seaport and an ICD cannot exceed the capacity of the seaport and the ICD, respectively. Constraints (9) and (10) generate the amount of cargoes transported directly (by truck and train),and by way of an ICD. Constraints (11) - (14) calculate the amount of cargoes transported by truck and train. Constraints (15) - (23) represent that the total transported amount of cargoes cannot exceed the total volume that can be transported by available vehicles. In particular constraints (16), (19), and (22) depict that the total time required for using trucks is either less than or equal to their available time at each depot. Finally, the rest of constraints (22) - (29) are concerned with the conditions on the decision variables.

III. DATA COLLECTION

Data were collected from various sources to test and run the model as formulated in the previous section. The data are concerned with three modes for inland transportation (truck, train), two ICDs (ICD1 and ICD2), two Myanmar seaports (AWPT, and MITT), and two Myanmar cities(Yangon and Bago).

In case of foreign seaports, we selected them considering shipping routes of short sea shipping (SSS), because the main purpose of this research is to focus on SSS. Moreover, Myanmar can transport export and import cargos only on SSS. Because Myanmar's cargos are transported via Singapore and Thailand ports to other countries. Therefore, we attempted to include detailed and numerous level of seaports as possible as we can for the SSS transportation.

The seaports selected for SSS route are major ones handling Myanmar's international container cargoes in the region. Two SSS seaports were selected for the model.

Table 1. Supply and demand data (TEU) in foreign seaports

Foreign Seaport	Singapore	Thailand
Supply	94116	25008
Demand	72168	68662

Table 2. Supply and demand data (TEU) in Myanmar cities

City Name	Yangon	Bago
Supply	5365	7600
Demand	10897	6629

Table 3.Capacity of each Myanmar seaport

Port	Capacity(TEU)
AWPT	7847811
MITT	1195395

Table 4. Capacity of each ICD

ICD	Capacity(TEU)
ICD1	1,400,000
ICD2	2,000,000

IV. TEST OF THE MODEL AND DISCUSSION WITH POLICY IMPLICATION

In this section, the linear programming model is validated using the data given in Section 3 to check whether or not the model represents the real situations in Myanmar. Then, by relaxing several constraints in the model, we attempt to draw several possible policy implications for the development of SSS. For the test, the holding cost was set to US$0.42. In the test, the model was generated by Excel 2007 solver. The test results of the model are summarized in the following Table 5 and Table 6.

Table 5 shows the container cargo volume at each port. Table 6 shows the solution of the Excel 2007 solver and the real data on the ratio (share) of the throughput at each Myanmar seaport versus the total container cargo volumes both imported into and exported from Myanmar.

Table 5. Container cargo volume at each port

Port Name	Container cargo volume
AWPT	30491
MITT	0

The sum of shipping and inland transportation costs is 613497214.6.

Table 6. the ratio of the throughput at each Myanmar seaport versus the total container cargo volumes both imported into and exported from Myanmar.

Port Name	Model	Real
AWPT	100	64
MITT	0	36

As can be seen from the Table 6, the model represents the real situation quite well. Therefore, it can be concluded that the model can be used to analyze the possible effect on the cargo flow in Myanmar when future situation on the international cargo trade in Myanmar changes.

V. CONCLUSION

In this research, we considered the problem of determining the cargo flow quantity and the transportation mode in each trade route, for the objective of minimizing the sum of shipping and inland transportation costs, with restriction to both maximum cargo volumes capacitated at each seaport and maximum number of vehicles available at each transportation mode. To solve optimally the problem, we employed a linear programming model. First of all, without incremental public spending in expanding coastal port capacity, a top down approach to modal shift from land transport to SSS may contribute to developing a cost-efficient SSS network. As a result, the development of SSS plays a crucial role in reducing external costs of accident risks, environmental nuisances and congestion caused by land transport. There are some further research directions. First, the demand in foreign cities that has not been considered used in this paper is worth to be included for developing more elaborate model. In this case, the capacity of foreign seaports and all parameters corresponding to inland transportation may have to be used. Second, traffic and environmental factors, such as congestion, noise, air pollutants, and greenhouse gases, should be integrated into the model to reflect external costs. If these externalities are to be included into our research scope in the future, it is more likely to develop an integrated short sea shipping model to calculate more exact sum of shipping and inland transportation costs and explain a real situation in the South East Asia. Finally, the demand and the supply are commonly random in real situation and hence, in order to consider the randomness, stochastic demand and supply are worthwhile to be considered in future research.

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