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CONTAINER PORT LOCATION STRATEGY BASED ON DOMESTIC PORT CHOICE MODELING AND OPTIMAL LINER ROUTING APPROACH*

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1. Introduction

For a port to prosper and exerts its dominance among rival ports, it relies highly on its customers – carriers and shippers. Previous studies have recommended several approaches to port planning and container freight flow analysis notably based on forecasting demand model and port choice transportation route. However, containerized freight flow modeling reflecting the existing location of ports has not been stressed and in the paper, to put this point forward port choice logit model and optimal liner routing formulation were introduced and applied. These two models were considered to fit into the specific problems facing the Malaysian ports described in the succeeding section. The study also proposed a new framework concept of port planning strategy by integrating both models taking Malaysia's case into perspective. To minimize the disparity between the selection of local ports (under the control of port authorities) and the selection of port of call by mainline vessels (no control by port authorities), both the models need to be integrated. In addition, the decision for container ports to seek hub or spoke status are based on the suitability (or otherwise) of their facilities for deep sea vessels, their locations and inland links, the extent of port competition and the size of their hinterlands.

The purpose of the study is to propose container port location strategy (location) based on OD analysis (port choice model) and that of carriers and shippers behavior requirement (liner routing model) taking Malaysia's case into perspective.

2. State of the Problems and Scope of Study

Two major problems facing Malaysia's ports are:

1. The high reliance on foreign lines in the international trade (85% of trade)
2. High external trade via Singapore port (transshipment) - handling 60% in volume of Malaysia's foreign trade (US$20 billion) causing leakage of economy.

For the above issues, the two possible strategies for the Malaysian ports are:

1. to reduce the volume of cargo fed via Singapore (alternative in geographical dominance, hinterland),
2. to attract/encourage more direct calls and transshipment cargo (significant cargo based /threshold).

For the first strategy, a port choice logit model will be implemented followed by optimal liner routing model for the latter which act as a predictive model to the choice behavior. The objective of study is to propose Malaysia container port location and planning strategy through port choice logit model and optimal liner routing

The general framework of the study is given by Figure 1. The details of each model are further discussed in the succeeding section.

3. Port Choice Modeling

This section can be divided into two parts; physical cargo distribution involving the analysis of domestic freight flow OD (production center to loading port), and port choice behavior probabilities (application of logit model). Despite the abundance of studies on modal and travel choice, most are related to passenger demand analysis[1]- the source of reference for freight analysis (port choice modeling). Earlier study of port choice selection[2] was carried out but only limited to origin and destination analysis without attempting any mathematical model. The port choice model introduced here is an extension to the above work.

Figure 2 shows the steps of analysis adopted. Initially, Japan is taken as the case study due to the availability of data and facing similar problems (transshipment using foreign ports). The approach adopted for Japan is similarly applied to Malaysia. Main steps in the Figureure are further explained below.

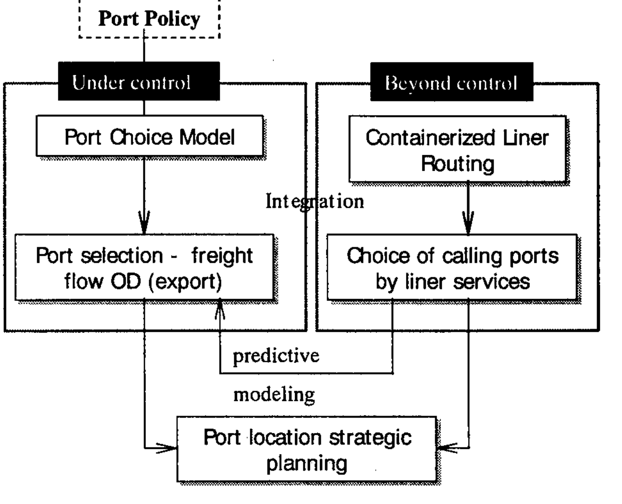

Figure 1: General Framework of Study

*Keywords: Freight Flow, Terminal Planning
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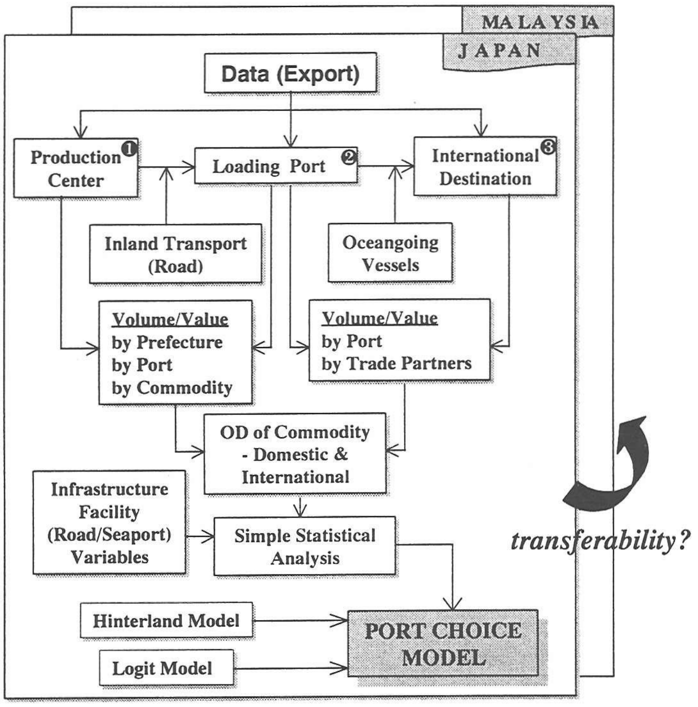


Figure 2: Study Flow of Port Choice Model

Table 1: Analysis DataBase

Country	OD Observations	Port Choice	Remark
Japan	418	24	1993 Survey
Malaysia	19	5*	Questionnaire

* inclusive of Singapore

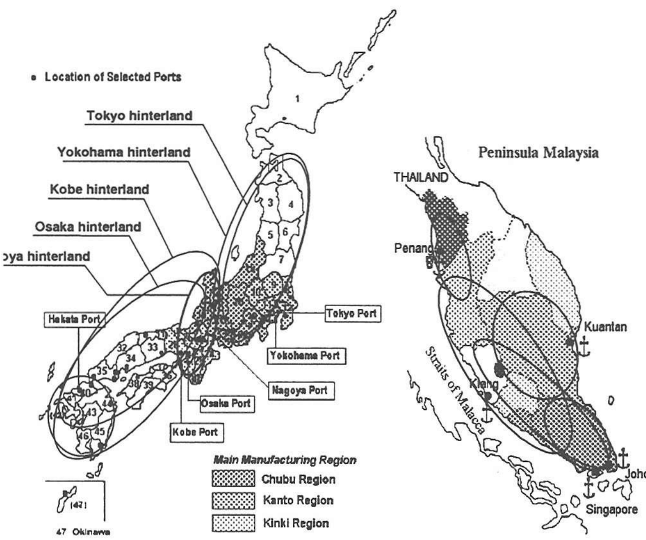
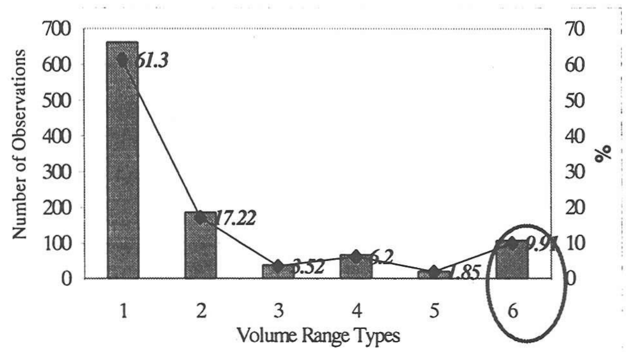


Figure3: Port Hinterland Demarcation



1: Vol = 0%share, 2: 0%<Vol<0.5%, 3: 0.5%<Vol<1%, 4: 1%<Vol<5%, 5: 5%<Vol<10%, 6: Vol >10%share

Figure 4: Data Distribution Analysis

(1) Data Base and Types of Data

Summary of database is given in Table 1. There were seven types of data selected; cargo value, freight tonnage, production areas (Japan – 47 prefectures, Malaysia – 12 states), port of loading, commodity types (13 sectors), inland mode of transport (truck), and destination country (Japan – 7 regions, 46 countries). Due to the small size sample of the Malaysian case, the results of analyses performed would not be well represented. Thus, in some cases, where applicable only the Japan case analyses were performed.

(2) Hinterland Demarcation

a) Physical Cargo Distribution

In the freight flow OD analysis, demarcation of hinterland through hinterland model can be attained. Hinterland effects depend upon the port's geographical location and each port usually accommodates some of the freight cargo from the production centers (domestic hinterland) better than others. In addition, the variations in the containerized freight passing through a port will depend upon the changing economic of the geographical area that constitutes its hinterland. There are two major elements to consider in this section:

1. to consider the boundaries of the hinterland,
2. to determine whether port can be categorized by commodities and regional destination.

b) Results of the Analysis

Port hinterland demarcation (from port viewpoint) reflecting the influence of ports' selection by shippers is illustrated in Figure 3. By taking the original data, gross overlapping of hinterland occurred in addition to small volume share observed from remote production areas. To have a more distinct demarcation, 10% volume share of OD pairs were considered with reference to Figure 4.

For the 13 commodity sectors considered, ports cannot be categorized based on commodity types but can be identified on the basis regional destination. Relating to Japan's case for the former, the main ports handle nearly the same major commodity types consisting of machinery, electrical appliances, transport vehicles, and chemicals. For minor ports, similar pattern is observed but toward a smaller share. Ports in term of regional destination (6 regions) can be classified as follows with respective volume share; Tokyo port- Europe (23%), Nagaya port – North America (26%), Osaka port – Oceania (22%), and Yokohama and Kobe – South America (41% and 35%). These are derived from the significant difference between the top and second rank in terms of regional volume share.

(3) Port Choice of Shippers

a) Logit Model – Solution Procedure

Logit model is a good way of examining the determinants with dependent variable (two or more discrete choices). If C_t is the choice set for the t^{th} observations, and observation t chooses the i^{th} alternative out of C_t, then the expression for the choice probability is given by:

$$\Pr(i \text{ } is \text{ } chosen \text{ } from \, C_t \,|\, Z) = \frac{\exp[bZ_{ti}]}{\sum_j \exp[bZ_{tj}]} \tag{1}$$

whereby;

j = the number of alternatives available
Z = represents the independent variables
C_t = choice set for the t^{th} observations
b = coefficients of the unknown parameters to be estimated

The likelihood function expression is given by equation 2 and maximized using MLEs principle to yield MLE estimators (Eq.2):

$$\ln L = -\sum_t \ln[\sum_j \exp((Z_{tj} - Z_{ti})b)] \tag{2}$$

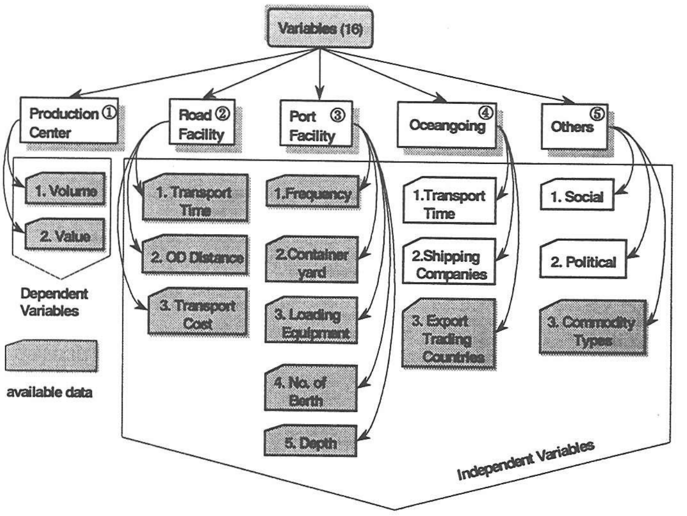


Figure 5: Variables for the Selection of Ports

The values of b can be obtained through iterative algorithm. In this study however, logit model can be further characterized involving 3 types:

i. Conditional logit - choice-specific data (conditional variables) and coefficients are equal over all choices. To cater each prefecture/state choosing among the port choices.
ii. Multinomial logit – chooser-specific data (multinomial variables) and coefficients vary over the choices. A constant term – measures fixed port characteristic not measured by other variables. The model is also identified by normalizing the multinomial coefficients of the first choice to zero.
iii. Mixed logit - involves both types of data and coefficients of i) and ii). i

Example of a model with n choices:

$$V_i = a_i + Xb_i + Z_i g + e_i \quad i = 1,\cdots,n$$

where;

X -multinomial variables with coefficients b_i

Z -conditional variables with coefficients g

Vi - latent values which are not observed but the chosen alternative is one with the highest value

If the disturbances e_i have the Generalized Extreme Value distribution, then the observed choice probabilities have the similar form as:

$$\Pr(i) = \frac{\exp(a_i + Xb_i + Z_{ig})}{\sum_j (\exp(a_j + Xb_j + Z_{jg}))} \tag{3}$$

The related variables (port terminal and road facilities) having impact of varying degrees to the selection of ports is given in Figure 5.

For the selected variables, the following analyses were carried out:

1. Correlation analysis
2. Multiple regression analysis taking volume (share) as the dependent variables and the remaining variables as independent variables.

For the port choice modeling, in calculating the parameter estimation, two model groups with different combinations of independent variables were tested as described below:

1. Model 1 – without port specific dummy variables (conditional logit)
   i. Model 1a – cost and frequency
   ii. Model 1b – effective variables (excluding multicollinearity)
   iii. Model 1c – all independent variables
2. Model 2 – with port specific dummy variables (each dummy variable represents each port)
   i. Model 2a – only port specific dummy variables
   ii. Model 2b – dummy variables + effective variables
   iii. Model 2c – dummy variables + all variables
   iv. Model 2d – dummy variables + cost

Table 2: Port Choice Modeling – Regression Analysis

	Independent Variables											R^2	
Volume	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	Japan	Malaysia
●	●											0.3641	0.4825
●		●										0.3642	0.1118
●			●									0.4001	0.3969
●				●								0.3922	0.2649
●					●							0.3327	0.2716
●						●						0.1345	0.3902
●							●					0.1670	0.3208
●								●				0.0917	0.2706
●									●			0.2145	0.3847
●										●		0.1596	0.2378
●											●	0.0399	-
●		●	●	●		●						-	0.6844
●			●	●	●	●				●	●	0.3608	-
●			●	●								0.2875	0.5254

Table 3: Parameter Estimation – Model 1b

Variable	Japan		Malaysia	
	Parameter Estimation	t-stats	Parameter Estimation	t-stats
X1				
X2			-0.00225	-2.7257
X3	-0.0000229	-54.572	-0.0000289	-8.1329
X4	0.004564	6.3622	0.000768	1.6087
X5	0.27521	6.7193		
X6	0.004026	3.1696	-0.089407	-5.8079
X7				
X8				
X9				
X10	0.462405	21.111		
X11	0.59439	3.4567		

X1:distance, X2:time, X3:inland transport cost, X4:frequency, X5:trading partners; X6:berth no, X7:berth length, X8:crane no, X9:storage, X10:porth depth, X11:commodity

Table 4: Parameter Estimation-Model 2d (Malaysia)

Port	Parameter Est.	t-stats
A1- Penang	1.34673	3.7826
A2 – Klang	-0.510600	-3.2046
A3 – Ktn	(normalized to zero)	
A4 – Johor	0.142005	0.5315
A5 – Spore	-0.947208	-4.7154
X2 – Time	-0.002515	-2.7435
X3 – Cost	-0.000026	-5.6794

Table 5: Parameter Estimation - Japan

A1	4.96710	10.5794	1.26226	4.27591
A2	1.05958	2.12218	-1.033373	-2.37341
A3	5.35992	11.4170	1.68620	5.71272
A4	3.81724	7.96870	1.77018	5.40826
A5	4.88563	10.3803	1.79896	6.33406
A6	2.09353	3.70815	(not selected)	
A7	4.77936	10.1761	1.29203	4.74007
A8	5.96453	12.7466	2.21717	8.19246
A9	2.05673	4.28365	(not selected)	
A10	3.62670	7.83306	0.80271	3.04863
A11	3.05401	6.57444	0.22543	0.83777
A12	(port not selected)			
A13	0.82228	1.50032	(not selected)	
A14	2.13427	4.16147	-0.44633	-1.11170
A15	1.12089	1.91679	(not selected)	
A16	1.73612	2.67438	(not selected)	
A17	2.78828	4.83803	(not selected)	
A18	4.15898	7.72216	0.42020	1.10568
A19	2.83067	5.60910	(normalized to zero)	
A20	1.70859	2.97871	(not selected)	
A21	0.47284	0.42764	(not selected)	
A22	0.80719	1.17579	(not selected)	
A23	1.43348	2.49772	(not selected)	
A24	(normalized to zero)		(not selected)	
Cost	-0.000248	-49.6447	-0.0000147	-11.1299

A1: Tokyo, A2:Niigata, A3:Yokohama, A4:Shimizu, A5:Nagoya, A6:Yokkaichi, A7:Osaka, A8:Kobe, A9:Shimonoseki, A10:K/Kyushu, A11:Hakata, A12:Tomakomai, A13:Hitachi, A14:F/Toyama, A15:Kanazawa, A16:Tsuruga, A17:Maizuru, A18:Sakai, A19:Hiroshima, A20:T/Kudamatsu, A21:Iwakuni, A22:Mitajiri, A23:Imabari, A24: Shibushi,
Cost: inland transportation cost

b) Results of the Analysis

By performing the correlation analysis, multicollinearity among the variables can be determined. Taking collinearity value of less than 0.9, the effective variables (six variables) are transportation cost, frequency, trading partners, berth number, port depth, and commodity types. For Malaysian case, the occurrence of multicollinearity is more rampant due to the size of sample.

Table 2 shows the results of coefficient of determination regression analysis. The combination of variables (elimination of multicollinerity) determined from correlation analysis provided values of 0.3608 (Japan) and 0.6844 (Malaysia).

In the parameter estimation, model 1b (without port specific intercepts and with effective variables) is selected due to the suitable results obtained. For model 2 (with port specific intercepts), only model 2d provides reasonable results but includes only one variable (transportation cost). The remaining models show singularity problem due to fixed characteristic of ports variables. It is unknown whether with or without port intercept provides a better estimation method. Data with volume share > 10% were also tested whereby 24 port choice is reduced to 12 ports. Result wise, no marked improvement was observed. Results of parameter estimation for model 1b and 2d are given in Tables 3, 4, and 5.

The choice probabilities (observed and predicted) for each $(i - j)$ were then calculated using equation 1. In the case of Japan with 24 selected ports, the model is validated with R^2 of 0.7194 as illustrated by the scatter diagram in Figure 6.

From the choice probability results, the predicted hinterland obtained from the model is also validated when compared with the observed hinterland resulting from mapping as demarcated in Figure 3 earlier. This can be shown in Table 6, taking

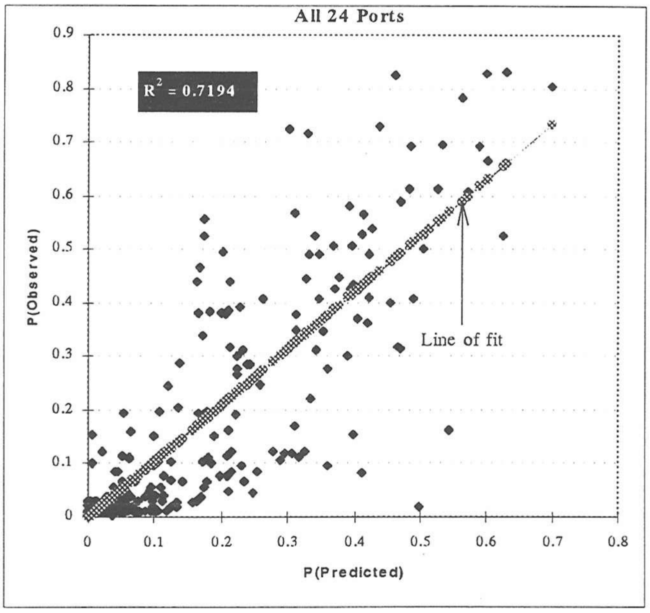


Figure 6: Scatter Diagram for All 24 Ports – Japan

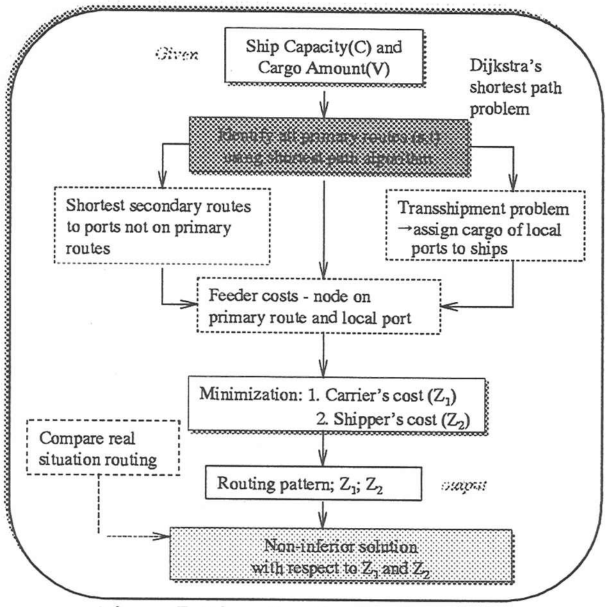


Figure 7: Liner Routing Methodology

Table 6: Validation of Port Hinterland (Observed and Predicted) for the ports of Tokyo, Yokohama, and Kobe

PORT - TOKYO																																														
R^2 = 0.8210	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
1. Port Hinterland - V>10%(mapping)	■	■	■	■	■	■	■	■	■	■	■	■	■	■				■	■		■																									
2. Logit Model (Obs) - P > 10%	■	■	■	■	■	■	■	■	■	■	■	■	■	■				■	■		■																									
3. Logit Model (Pre) - P > 10%	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■		■																									

PORT - YOKOHAMA																																														
R^2 = 0.8244	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
1. Port Hinterland - V>10%(mapping)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■		■																									
2. Logit Model (Obs) - P > 10%	■	■	■	■	■	■	■	■	■	■		■	■	■	■			■	■		■																									
3. Logit Model (Pre) - P > 10%	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■		■																									

PORT - KOBE																																														
R^2 = 0.8263	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
1. Port Hinterland - V>10%(mapping)	■														■	■	■							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
2. Logit Model (Obs) - P > 10%	■														■	■	■			■				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
3. Logit Model (Pre) - P > 10%		■													■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	

the major ports of Tokyo, Yokohama and Kobe as an illustration. It shows the matching of prefectures between observed and predicted hinterland.

Apart from establishing the probabilities of selecting existing ports, the model can also handle forecasting of ports (being selected) based on the new location using the calculated parameters and increase its attractiveness by manipulating the variables.

4. Optimal Containerized Liner Routing

Some attempts to analyze the ship routing and scheduling were done in the past but only a few are related to the container ships especially as a routing problem. Ronen[3,4] provides an extensive review from 1983 to 1993. Al-Kazily[5] models containerized shipping through economic perspective. Kuroda et al[6,7] introduced Stackerberg Game approach seeking the equilibrium between carriers and shippers but not a routing problem. Imai et al [8] proposes a model explaining the strategies of containerized liner services under given inter-port cargo volume which is more relevant to this section in terms of establishing port location strategy but didn't account for the optimal solution results. Based on the previous model structure, the study proposed a different scope of application with the variations in cargo demand and inclusion of port charges with various updating to the data input.

(1) Analytical Framework and Methodology

The framework and methodology in the liner routing problem is given by Figure 7. From the Figure, ship capacity and volume were given. Using shortest path algorithm method, all sets of primary route alternatives were determined by considering shortest secondary routes and transshipment problem (feeder costs). Using multi-objectives function (double integer formulation) carrier's cost and shipper's cost were calculated. The optimal non-inferior solution corresponding to specific routing is then selected.

(2) Problem Formulation and Procedure

Based on the fact that the selection of trade route by each ship is governed by carriers and shippers, two objectives function are considered with the following formulation costs (Z_1, Z_2).

Minimize:
$$Z_1 = \sum_{v=F} \left\{ f^M \left(C, U^v\right) + \sum_{p \in S^v} 2\left(G^p + \sum_{i=L} G^i\right)\left(H_p + T_p\right) \right\} \tag{4}$$

$$Z_2 = 2\left\{ \sum_{k=K} \sum_{v=F} g^{kv} f^F \left(\sum_{i \in P} \sum_{j=P} y_{ij}^{kv} \right) + \sum_{p=S^v} \sum_{i=L_p} G^i T_p \right\} \tag{5}$$

Subject to:

$$\sum_{j \in Q} u_{ij}^v - \sum_{j \in N_i} u_{ji}^v = \begin{cases} 1 & (i = s, v \in F) \\ 0 & (i \neq s, i \neq t, v \in F) \\ -1 & (i = t, v \in F) \end{cases} \tag{6}$$

$$\sum_{i \in Q} \sum_{j \in Q} u_{ij}^v \leq |Q| - 1 \qquad (s, t \notin Q, Q \subset P, |Q| \geq 2, v \in F) \tag{7}$$

$$\sum_{j \in M_i} y_{ij}^{kv} - \sum_{j \in N_i} y_{ji}^{kv} = \begin{cases} \leq 1 & (i = k, k \in K, v \in F) \\ = 0 & (i \neq k, i \notin S^v, k \in K, v \in F) \\ \geq -1 & (i = S^v, k \in K, v \in F) \end{cases} \tag{8}$$

$$\sum_{j \in M_k} y_{kj}^{kv} = \sum_{j = N_p} y_{jp}^{kv} \qquad (k \in K, p \in S^v, v \in F) \tag{9}$$

$$\sum_{v \in F} \sum_{j \in M_k} y_{kj}^{kv} \geq 1 \qquad (k \in K) \tag{10}$$

$$U^v = \sum_{i \in P} \sum_{j \in P} h_{ij} u_{ij}^v \qquad (v \in F) \tag{11}$$

$$\sum_{v \in F} g^{kv} = G^k \qquad (k \in K) \tag{12}$$

$$\sum_{k \in K} g^{kv} \leq C - \sum_{i \in S^v} G^i \qquad (v \in F) \tag{13}$$

$$K = \left\{ i \in P \,\middle|\, \sum_{v \in F} \sum_{j \in N_i} u_{ij}^v = 0 \right\} \tag{14}$$

$$L_p = \left\{ k \in K \,\middle|\, y_{ip}^{kv} = 1, p \in S^v \right\} \quad (v \in F) \tag{15}$$

$$S^v = \left\{ k \in K \,\middle|\, \sum_{k \in K} \sum_{v \in F} \sum_{j \in N_i} y_{ji}^{kv} \geq 1, \sum_{v \in F} \sum_{j \in M_i} u_{ij}^v \geq 1 \right\} (v \in F) \tag{16}$$

$$S^v \subseteq HB \quad (v \in F); \quad g^{kv} \geq 0 \quad (k \in K, v \in F) \tag{17)(18}$$

$$u_{ij}^v \in (0,1) \qquad (all\ arcs(i,j), v \in F) \tag{19}$$

$$y_{ij}^{kv} \in (0,1) \qquad (all\ arcs(i,j), k \in P, v \in F) \tag{20}$$

Feeder route assignment can be solved by the following equations (transshipment problems[9]):

Minimize:
$$\sum_{k \in K} \sum_{v \in F} c^{kv} g^{kv} \tag{21}$$

Subject to:

$$\sum_{v \in F} g^{kv} = G^k \qquad (k \in K) \tag{22}$$

$$\sum_{k \in K} g^{kv} \leq C - \sum_{i \in S^v} G^i \quad (v \in F) \tag{23}$$

$$c^{kv} = Min_{i \in S^v} \left\{ B_i^* + T_i \right\} \tag{24}$$

$$B_i = f^F\left(\sum_{i\in P}\sum_{j\in P} x_{ij}\right) \tag{25}$$

$$\sum_{j\in M_i} x_{ij} - \sum_{j\in N_i} x_{ij} = \begin{cases} 1 & (i = p, p\in S^v) \\ 0 & (i \neq s, i \neq k) \\ -1 & (i = k) \end{cases} \tag{26}$$

$$x_{ij} \in (0,1) \quad (all \quad arcs(i,j)) \tag{27}$$

where,

C: ship capacity; Q: subset of P that is not empty, K: the set of local ports, P: the set of nodes
HB: the set of hub candidates, F: the set of ships,
L_p: the subset of K such that ports are covered by feeders from hub p
M_i: the set of nodes being connected to node i by an actual arc (i,j)
Ni.the set of nodes being connected to node i by an actual arc (j, i)
S^v: the sets of hubs on the primary route of ship v U^v: cruising time of the primary route of ship v
h_{ij}; transport time from nodes i to j, $f^M(\,)$: cost function of a ship, $f^F(\,)$: tariff function of a vessel
H_p: handling cost per container at hub p T_p: port cost per container at hub p
G^i: the amount of containers of port i s: the origin of primary routes t: the destination of primary routes
u_{ij}^v : =1if a primary route connects by ship v nodes i to j, = 0 otherwise
y_{ij}^{kv} : =1 if a secondary route to local port k by ship v connects nodes i to j, = 0 otherwise
g^{kv} : amount of containers of local port k sent from/to a hub on a primary route of ship v
x_{ij} =1 if arc $(i-j)$ is selected for secondary route
B_i^* : optimal function value of equations (25)-(27)

(3) Scope of Analysis

A container liner trade in general connects geographically two separate regions, each has certain ports of call. In the study, a liner trade with one origin and multiple destinations is considered. The regions and the ports selected are as follows:

1. Liner routing connecting North America (USA), Asia (Japan), and ASEAN (Singapore) are considered since they command 55% (value) of Malaysia's overall trade.
2. Eight ports were considered with the distribution as follows:
   i. USA– Long Beach(8) – departure/return point
   ii. ASIA – Hong Kong (1), Kaohsiung(3), Busan (5), Yokohama(6)
   iii. ASEAN – Main ports – Singapore(2), Malaysian ports – Klang(25) and Johor(81).

The number in brackets is the ranking of port traffic league as per 1996. Among the 8 ports considered, all has the hub port status except for the Malaysian ports. Ships of various sizes, 3000 4800, 6000, and 7200TEU were considered to see their influence.

(4) Data Requirement

The types of data required for the liner routing formulation are listed below.

i. Cruising time between ports (distance and speed)
ii. Ship capacity and cost relationship
iii. Ship capacity and displacement relationship
iv. Handling costs and port charges
v. Total demand of cargo at selected ports (weekly)
vi. Secondary and primary route tariff
vii. Cost functions of ships
viii. Maximum cruising time for primary route

(5) Results of Analysis

The non-inferior solutions sets for the respective ship sizes are represented by Figures. 8, 9, 10 and 11. Variables in the model, primarily the threshold volume of the selected of ports can be arbitrarily increased/decreased to see the shifting of routing pattern. In the routing case, two cases of traffic loading with respect to Singapore port were considered. First, by considering only the volume handled without transshipment activity, and secondly by including transshipment volume but excluding the Malaysian transshipment volume to Singapore (from 755teu/week to 1255teu/week). These cases are shown by Figures. 10 and 11 under 3000TEU vessel. For 7200TEU ship, since the total cargo is 5187TEU, the better solution is to use 6000TEU ship.

From the above, the optimal solutions for the various ships sizes (Z_1, and Z_2 are in US$) traffic volume handled are:

1. 6000TEU- Solution 8:Z_1=13637x10^3, Z_2=1097x10^3
2. 4800TEU- Solution 5:Z_1=18823x10^3, Z_2=1097x10^3
3. 3000TEU(Case1) – Solution 10: Z_1=1504x10^3, Z_2=1097x10^3
4. 3000TEU(Case2) – Solution 11: Z_1=1521x10^3, Z_2=965x10^3

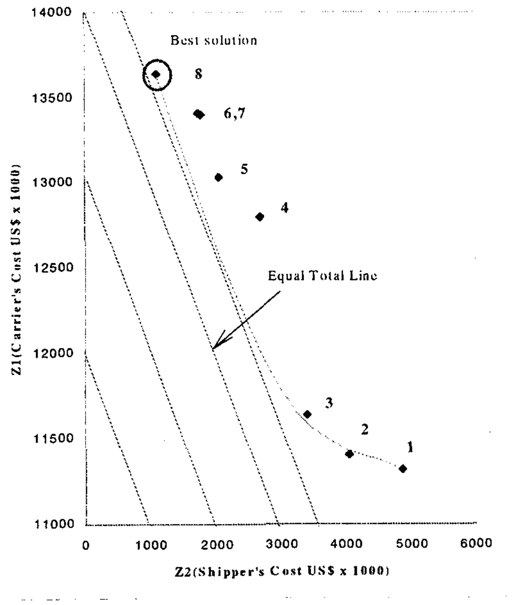


Figure 8: Non-inferior Solutions Sets – 6000TEU

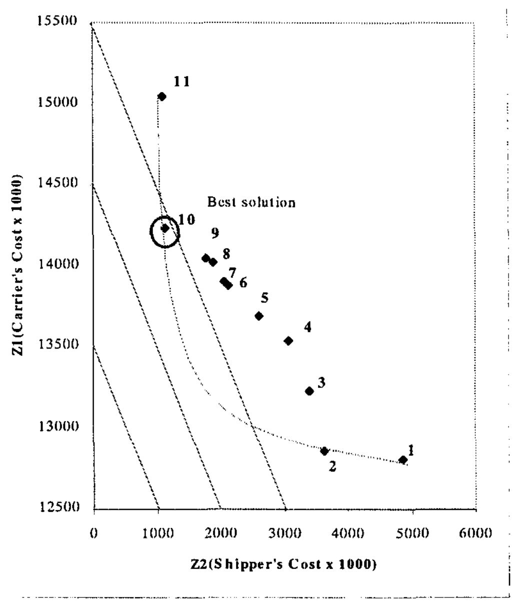


Figure 10: Non-inferior Solution Sets – 3000TEU Case 1

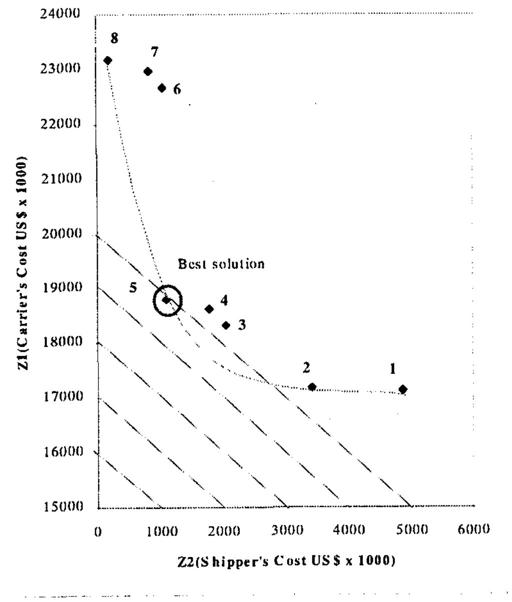


Figure 9: Non-inferior Solution Sets – 4800TEU

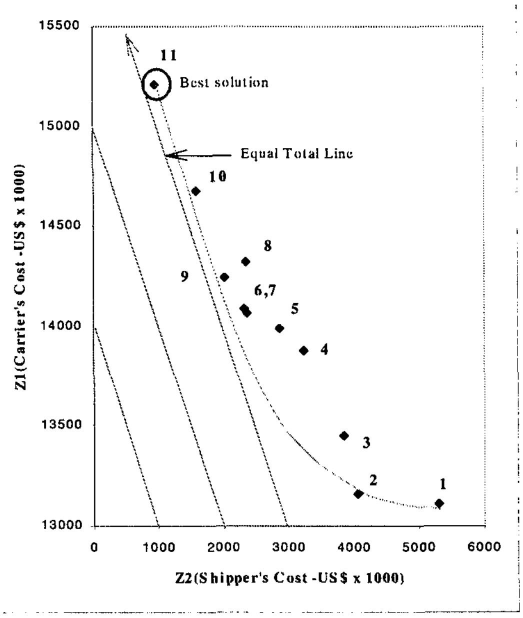


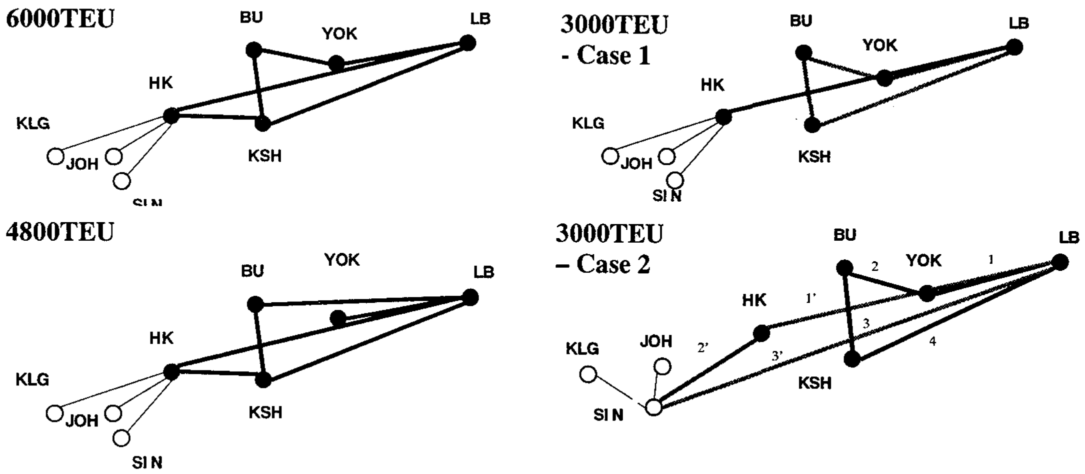
Figure 11- Non-inferior Solution Sets –3000TEU Case 2

The respective routing patterns for the above solutions are illustrated in Figure 12. Without transshipment traffic (6000, 4800, 3000TEU-Case 1 vessels), no port of call is made at Singapore.

Generally by using larger ships, the carrier's cost was reduced showing the economic of scale. It is also observed the different ship sizes produced different routing pattern. It was also demonstrated that the shifting of routing pattern is sensitive to cargo base (volume). Singapore port without transshipment traffic has to transship its cargo to nearest hub. For the Malaysian ports to be attractive, the cargo threshold needs to be increased similar to that of Singapore port. Otherwise for the transpacific trade, the ports have to satisfy by transshipping the cargo via Singapore.

5. Container Port Location Planning Strategy Proposal – Malaysia's Perspective

This section proposed a new framework concept (Figure 13) of port planning strategy by integrating both the models described in sections 4 and 5. From the Figure, both the models have their respective database and frequency is the common independent variable apart from volume – common input. The control variable in inland mode is transportation cost and for sea borne is frequency. These two variables should be the main concerned to port operators. An increase in port of call (frequency) by mainline vessels, will improved the selection of domestic ports. On the other hand, for the ports to be attractive to mother vessels, it has to accumulate sufficient threshold. By reducing the transportation cost to all Malaysian ports by 5% and diverting 10% of transshipment cargo from Singapore, Port Klang (identified as the national load center) improves 8% whilst Singapore decreases 28% in terms of selection probabilities.



BU-Busan, YOK-Yokohama, LB-Long Beach, HK-Honk Kong, KSH-Kaohsiung, SIN- Singapore, KLG-Klang, JOH-Johor

Figure 12: Routing Patterns -Various Ship Sizes/Traffic

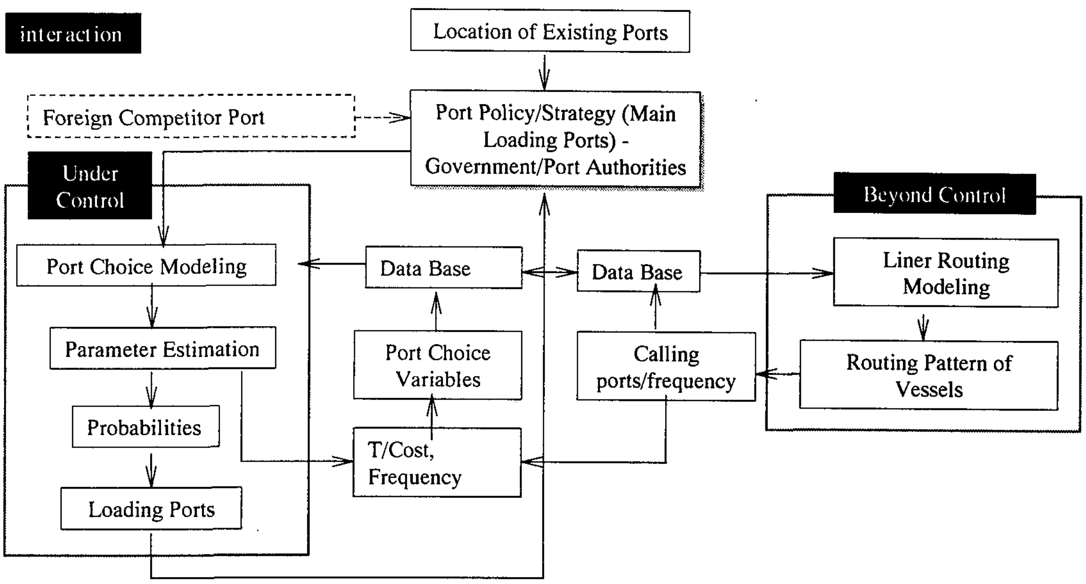


Figure 13: Port Planning Framework Based on Location Strategy

From the liner routing for transpacific trade, Malaysian ports are not in the primary route due to low cargo base. Focus should be on attracting more intra-Asian trade and feeder cargo from Bay of Bengal region and consolidating the European trade. The liner routing problem can also provide useful information for port operators in striking a trade-off between carrier's cost and shipper's cost. Since Malaysia dependence on foreign vessels is critical, to attract more foreign vessels lower shipper's cost should not be the main criteria. The relationship between carrier and shipper cost (Figures. 8-11) is deemed useful.

6. Summary and Conclusion

1. From the export physical cargo distribution OD analysis, the demarcation of hinterland (observed) by mapping can be determined exclusively.
2. Six independent variables were identified as the effective variables (excluding multicollinearity problem); transportation cost, frequency, trading partners, berth number, port depth, and commodity types.
3. Model 'without port specific intercepts' and including the variables identified in 2) were the suitable model. The weakness in the model involving 'with port specific intercepts' is the existence of singularity problem.
4. From the port choice probability results, the observed and predicted probabilities were validated with R2 = 0.7194.
5. The prediction of port hinterland derived from the port choice model is also validated by 1) based on the close match between observed and predicted prefectures.
6. The port choice model can also handle forecast (potential selection) of new ports and reevaluate the status of existing ports by manipulating the dependent and independent variables.
7. From the liner routing problem, optimal solution between carrier's cost and shipper's cost is determined through plotted graph between the two.

8. The economy of scale is observed by using larger ships. Different ship sizes reflect a different routing pattern and for the case study, 6000TEU is the best option.
9. For main vessels to make port of call, the cargo threshold is one of the fundamental criteria.
10. From the port planning strategy framework, the status and reality of Malaysian ports can be made known. Inland transportation cost, frequency and volume need to be improved.

Major conclusions arrived from the above insights can be summarized as follows:
1. The port choice model provides the selection of domestic ports based on the selected variables reflecting shipper's choice while liner routing model using double integer problem formulation provides the resultant choice of port calls. Both the models can be considered independently depending on the level of planning.
2. The liner routing problem also proves beneficial from the standpoint of attracting foreign vessels by providing non-inferior solution sets.
3. By combining port choice model and liner routing model, a more meaningful port-planning tool with respect to port location is proposed. Taking the case of Malaysia port problems, transshipment problem can be minimized if the variables identified in the models are addressed.

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References

1) Kanafani, A.: Transportation Demand Analysis, 119-148, *McGraw-Hill Series in Transportation*, 1993.
2) Osman, M. A. and Inamura, H.: Port Choice Selection Based on Cargo Physical Distribution (Containerization) for Export Promotion, *Journal of the EASTS,* Vol.2, No.1, 127-139, 1997.
3) Ronen, R.: Cargo Ships Routing and Scheduling: Survey of Models and Problems, *European Journal of Operational Research* 12, 119-126, 1983.
4) Ronen, R.: Ship Scheduling: the Last Decade, *European Journal of Operational Research* 71, 325-333, 1993.
5) Al-Kazily, J.: Modeling Containerized Shipping for Developing Countries, *Transportation Research* 16A, 271-283, 1982.
6) Kuroda, K. and Yang, Z.: Stackerberg Equilibria Analysis of Container Cargo Behavior, *Journal of the EASTS*, Vol.1, 249-295, 1995.
7) Kuroda, K. and Yang, Z.: Port Management Policy and the Influence on Behavior of Liner Shipping Companies and Shippers, *Journal to the EASTS*, Vol.2, No.1, 73-86, 1997.
8) Imai,A. et al: A Containerized Liner Routing in Eastern Asia, *J. of Infrastructure Planning and Management Japan, 1996.*
9) Winston, W. L.: Operations Research Applications and Algorithms, *PWS-Kent Publishing*, 323-366, 1991.

CONTAINER PORT LOCATION STRATEGY BASED ON DOMESTIC PORT CHOICE MODELING AND OPTIMAL LINER ROUTING APPROACH

by Meor Aziz Osman, Kazuhiko ISHIGURO and Hajime INAMURA

The focal point of the paper is the introduction and application of logit model in port choice modeling and double integer formulation in optimal liner routing approach. In port choice modeling, the model specification without port specific intercepts and six effective variables provides the suitable results (parameter estimation). The choice probability results (observed and predicted) to determined ports selection potential and demarcation of hinterland were both validated. In liner routing modeling, the resultant route choice and the optimum cost for all different vessel sizes were determined. The model also proves beneficial from the standpoint of attracting foreign vessels by providing non-inferior solution sets (relationship between carrier's cost and shipper's cost – trade off). The paper also proposed a new port planning framework concept base on location strategy by integrating both models. Transportation cost, frequency and volume, are the port operators control variables.

最適輸送経路選択に基づく国際コンテナ港湾の配置計画

メオル·アジズ·オスマン，石黒　一彦，稲村　肇

本研究は輸送費用を節減し輸出促進をするためのマレーシアの港湾開発計画を目指すものである．本研究は荷主の港湾選択をきめるロジットモデルと整数多目的計画法による大型コンテナ船の航路決定モデルが中心をなす．港湾選択モデルにおいては輸送費用，サービス頻度，品目といった従来の変数に加え貿易相手国，岸壁水深等新しい独立変数が抽出された．わが国の港湾に適用した結果，港湾選択確率も背後圏も妥当なことが検証された．航路決定モデルにおいては船型別のコスト最小化の航路が抽出された．また，非劣解集合により船社費用と荷主費用のトレードオフ関係が示され，大型船を招致するための戦略が示唆された．以上から開発途上国における港湾開発の基本戦略が示唆された．
