Topic: Shipping
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RISK ASSESSMENT OF BLOCKADE OF THE MALACCA STRAIT USING INTERNATIONAL CARGO SIMULATION MODEL

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Abstract:

Malacca Strait is very important for international maritime shipping, not only in East Asian countries but also of all over the world. If the Strait is blocked due to some reasons, the entire Asian economy will be thoroughly affected, not only for international transport sectors. This paper aims to assess economic impact of the blockade of the Malacca Strait quantitatively, by applying the simulation model the author had developed.

Until now, the author had developed the model to simulate international cargo flow including maritime, rail and road transport in East Asia. The model outputs international cargo flow by transport route on the land and sea, when inputting the transport demand of international cargo from origins to destinations and status of transport network. The author already validated the model accuracy to reproduce the actual international cargo flow to some extent, and extended to incorporate all of the international land and hinterland transport network in East Asia including Japan, Korea, China, and ASEAN countries, not only international maritime shipping network. In this paper, using the model, several simulation results are shown and compared, based on the scenarios to assume the blockade of the Malacca Strait, especially from the viewpoints of how the transport pattern of international cargo is changed in East Asia, how the cargo is shifted to other routes, how cargo throughput in each Asian port is changed, and what international transport cost is increased.

Keywords: risk assessment, Malacca Strait, international cargo, transport cost, simulation model

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1. INTRODUCTION

Malacca Strait is very important for international maritime shipping, not only of East Asian countries but also of all over the world. If the Strait is blocked due to some reasons, the entire Asian economy will be thoroughly affected, not only for international transport sectors. The considerable risks to block to pass through the Strait are, for example, natural disaster such as tsunami, terrorism, unexpected huge accident, piracy. For example, Southeast Asia including the Strait used to be the most dangerous area to suffer from piracy until recently. Another example of risk is earthquake and tsunami. In the Indian Ocean Tsunami happened in 2004, not only many people were killed, many port facilities were damaged in many countries in Southeast Asia and South Asia, and needed long time to be restored.

This paper aims to assess economic impact of the blockade of the Malacca Strait quantitatively, by applying the simulation model the author had developed. In this paper, the authors focus on a direct impact what international shipping cost will increase due to the blockade of the Strait, although other economic impact such as the long-term impacts on international/regional markets and governance systems can be considered. The one of reasons why the authors focus only on the international shipping cost is that, according to microeconomic theory, a benefit or loss due to some transport policies and/or related events can be calculated from the increased or decreased amount of international shipping cost if equilibrium on international shipping market is realized, although it is difficult to assume the market equilibrium under such a confused situation.

Until now, the authors (for example, Shibasaki et al., 2009; Shibasaki et al., 2010) had developed the model to simulate international cargo flow including maritime, rail and road transport in East Asia, called the MICS (model for international cargo simulation). The model can output international cargo flow by transport route on the land and sea, when inputting the transport demand of international cargo from origins to destinations and status of transport network. The author already validated the model accuracy to reproduce the actual international cargo flow to some extent, and extended to incorporate all of the international land and hinterland transport network in East Asia including Japan, Korea, China, and ASEAN countries, not only international maritime shipping network.

In this paper, using the model, several simulation results are shown and compared, based on the scenarios to assume the blockade of the Malacca Strait, especially from the viewpoints of how the transport pattern of international cargo is changed in East Asia, how the cargo is shifted to other routes, how cargo throughput in each Asian port is changed, and what international transport cost is increased.

This paper is structured in the following way: Section 1 concerns introduction; Section 2 introduces the brief description of the model that the author had already developed; Section 3 describes the extension of the model to the ASEAN region; Section 4 expresses a few risk scenarios, shows their simulation results, and discusses the implications derived from the simulation results; and Section 5 address conclusions.

2. MODEL STRUCTURE

2.1. General Outline

The model outputs transportation patterns of container cargo on maritime and land network, given a regional cargo transport demand (OD cargo volume), service level of each port such as the number of berths by water depth or port charges, and information related to the transportation network (transportation costs and time etc.). The outputs are tabulated for each port to calculate the handling volume and transshipment cargo volume by port.

The model focuses on the behavior of "shippers" and "ocean-going shipping companies" who are the principal actors in the international container cargo shipping market. A "shipper" makes reference to the freight and shipping time by route indicated by each ocean-going carrier group, and selects a carrier group for maritime transport, ports used for import/export, and land transport route and mode for each cargo. Here, the selection for the shipper is determined to minimize the "recognized generalized costs" including not only the shipping cost and time, but also factors which cannot be observed by the model developer. Also, the selection is divided into two steps in the model; choice of carrier group and the others including ports, land route and mode.

On the other hand, the "ocean-going shipping company", which cargo transport demand is given as an input, assumingly behaves to maximize profit for each alliance (ocean-going carrier group). Each group determines a freight and vessel size by port pair (combination of port for export and import) and maritime transportation route such as ports of call and transshipment ports, so that the profit (= income – costs) of their own group is maximized with taking into account the behavior of other groups' freights and shipping time. Herein, carrier groups assumingly behave within a shortsighted scope, although they consider shipper's behavior as far as they can. Concretely, an ocean-going carrier behaves to maximize its own profit in short term, considering shipper's behavior to select a carrier; however, the carrier cannot predict a midterm behavior of shipper such as selection or change of port used for export and import. In other words, each carrier group is assumed to have only short-term strategy to compete with other carrier groups and deprive them of their cargo, not any midterm strategy to encourage changing port for export and import for shippers. This assumption reflects the actual situation of an international maritime container shipping market in which change of freights or an entry and exit of carrier frequently occur and which carrier often determines shipping routes through trial and error.

Summarizing the above discussion, in this research the authors develop two models as described below; namely, a short-term model in which cargo shipping demands by port pair are assumingly not changed, so that each carrier group determines freights by port pair to maximize its own profit, reflecting behavior of other carrier groups and shipper's choice of carrier group. The other is a midterm model in which shipping demands by port pair can be changed due to shipper's unrestricted choice of port used for export/import but shipping demands by regional pair (i.e. a demand from a 'true' origin to a 'true' destination) are fixed. In the midterm model, shippers and carrier groups are countervailed each other and neither of them has no power to control the international maritime container shipping market. Therefore, the authors assume a Nash equilibrium to reach in which all shippers and all ocean-going shipping companies cannot improve their own objective function when the behavior of the other party is not changed.

The following sections explain a profit maximization model (short-term model) of ocean-going carriers reflecting shippers' choice of carrier groups and an equilibrium model (midterm model) between ocean-going carriers and shippers including shippers' choice of port used for export/import separately.

2.2. Short-term Model – Profit Maximization Model of Ocean-going Carriers reflecting Shippers' Carrier Group Choice

2.2.1. Formulation

Ocean-going carriers determine freights by route in order to maximize their own profit, under the condition that cargo transport demands by route are given. Herein, the authors assume that each carrier group determines their freight with taking into account the freights and other factors on the level of service of the route for the other groups. In order to reflect the fact that various elements other than the freight can be included in supplied transportation services, it is assumed that all transport demand are not assigned to the group with the lowest freight on a given route but rather some of them are assigned to groups with relatively high freights. In other words, the model is a Bertrand equilibrium (price competition) model in an oligopolistic market with product differentiation as an extraneous element to freights.

The profit maximization behavior by each carrier group is formulated as

$$\max_{p,x} \pi_g , \quad \forall g \in G , \tag{1}$$

$$s.t. \; \pi_g = \sum_{a \in A} \left\{ \left(p_{ag} - c_{ag} \right) \cdot q_{ag} \left(p_{a1}, \cdots, p_{ag}, \cdots, p_{aG} \right) \right\}. \tag{2}$$

The constraint condition (2) means that profit π_g for each carrier group g is defined as the total revenue minus total shipping cost of the group. Herein, p_{ag}: the freights (JPY/TEU) indicated by a carrier group g on a maritime OD pair (combination of port used for import and export, hereafter calling "port pair") a, c_{ag}: the shipping cost (JPY/TEU) of carrier group g on port pair a, q_{ag}: shipping volume of carrier group g on port pair a, A: set of port pairs, and G: set of carrier groups. Each carrier group g determines freights p_{ag} on a port pair a to maximize profit making reference to the freights $p_{ag'}$ of other groups g' ($\forall g' \in G, g' \neq g$) on the same port pair and carrier group selection behavior of shippers, given total demand d_a for each port pair. The shipping volume q_{ag} of carrier group g on port pair a is assumingly formulated as the following stochastic choice behavior of shippers, taking into account the factors which cannot be observed by the model developer

$$q_{ag} = d_a \cdot prob_{ag} , \tag{3}$$

$$s.t. \; prob_{ag} = \frac{\exp\left(-\theta \cdot GM_{ag} \right)}{\sum_{g \in G} \exp\left(-\theta \cdot GM_{ag} \right)} , \tag{4}$$

wherein $prob_{ag}$: probability of carrier group g selection on a port pair a, θ: variance parameter, and GM_{ag}: generalized cost of maritime shipping when using a carrier group g on a port pair a. The shipper makes a selection based on service levels provided by each group (freights, frequency, shipping time, etc.) and is not concerned with the shipping details such as the actual path and vessel size used which are determined by the carrier groups. The generalized cost of maritime shipping GM_{ag} is formulated as

$$GM_{ag} = p_{ag} + vt_{shpr} \cdot TM_{ag} , \tag{5}$$

wherein vt_{shpr}: value of time for shipper (JPY/TEU/hour), and TM_{ag} : total time of maritime shipping (also including waiting time etc.) for carrier group g on a port pair a (hour).

2.2.2. Solution

As shown in Equation (3)-(5), the shipping volume q_{ag} does not depend on the freights $p_{a'g}$ of any other port pairs a' ($\forall a' \in A, a' \neq a$) than that in the question and the shipping cost c_{ag} is assumingly fixed in the short-term model. Therefore, Equation (1) and (2) are rewritten as the following profit maximization *by port pair*

$$\max\lfloor \hat{p}_{ag} - c_{ag}, 0 \rfloor, \quad \forall a \in A, \forall g \in G \, , \tag{6}$$

$$s.t. \;\; \hat{p}_{ag} = \arg\max_{p} \left\{ \left(p_{ag} - c_{ag} \right) \cdot q_{ag} \left(p_{a1}, \cdots, p_{ag}, \cdots, p_{aG} \right) \right\}, \tag{7}$$

wherein a function "max[x, y]" in Equation (6) means choosing larger one from x and y, and a function "$\arg\max_{p} f(p)$" means choosing p to maximize $f(p)$. These equations stand that the freight $\hat{p}_{ag}$ is determined in order to maximize the profit for each port pair but if $\hat{p}_{ag}$ is lower than the shipping cost c_{ag}, it is defined as the same amount as c_{ag} supposing non-negative profit.

Since the shipping cost c_{ag} does not depend on neither the shipping volume q_{ag} nor freights p_{ag}, when the freights of other groups are fixed ($\bar{p}_{ag'}, \forall g' \neq g$), the first-order condition of Equation (7) for each group g is written as

$$\frac{\partial \left\{ p_{ag} \cdot q_{ag} \left(\bar{p}_{a1}, \cdots, p_{ag}, \cdots, \bar{p}_{aG} \right) \right\}}{\partial p_{ag}} = 0 \, . \tag{8}$$

Therefore, when inputting Equation (3)-(5) into this, if $prob_{ag} \neq 0$, it is acquired

$$prob_{ag} + \frac{1}{\theta \cdot p_{ag}} - 1 = 0 \, . \tag{9}$$

Equation (9) can be solved by using a quasi-Newton method.

2.3. Midterm Model – Equilibrium Model of Ocean-going Carriers and Shippers considering Shippers' Port Choice

2.3.1. Outline

In this model, given regional cargo transport demand, both ocean-going carriers and shippers behave optimally each other according to respectively different objective functions in the context of a relationship of freights and shipping time by port pair and transport demand. They are assumed to reach Nash equilibrium conditions that when the other actor's behavior is given, a party cannot optimize their own objective function anymore.

Concretely, each shipper chooses a optimal shipping route including ports used for import/export, making reference to the generalized cost GM_{ag} shown in Equation (5) indicated by each ocean-going carrier group and other factors. On the other hand, each ocean-going carrier group determines the freights for each port pair and transportation pattern, given the shipping volume q_{ag} of carrier group g on port pair a acquired from the results of shippers' behavior as shown in the following sections.

2.3.2. Carrier Model: Formulation and Solution

In this midterm model, the profit maximization behavior for each carrier group is formulated as

$$\max_{p,x} \pi_g, \quad \forall g \in G, \tag{10}$$

$$s.t.\quad \pi_g = \sum_{a\in A} p_{ag} \cdot q_{ag}(p_{a1},\cdots,p_{ag},\cdots,p_{aG}) - \sum_{v\in V} x_{vg} \cdot t_{vg}(x_{11},\cdots,x_{vg},\cdots,x_{VG}), \tag{11}$$

$$q_{ag} = \sum_{k\in K_{ag}} h_{akg}, \quad \forall a \in A, \quad \text{and} \tag{12}$$

$$x_{vg} = \sum_{a\in A}\sum_{k\in K_{ag}} \delta^{v}_{akg} h_{akg}, \tag{13}$$

wherein x_{vg}: container flow of link v (in the carriers' cost minimization model) for carrier group g, $t_{vg}(x_{,1},\cdots,x_{vg},\cdots,x_{VG})$: shipping cost of link v for carrier group g per container (TEU), V: set of links, h_{akg}: shipping volume of containers on a path k in shipping demand q_{ag} of group g on a port pair a, δ^{v}_{akg}: Kronecker delta (δ^{v}_{akg}=1; when a link v is included in the path k: δ^{v}_{akg} = 0; when not included), and K_{ag}: path choice set of shipping demand q_{ag}.

The different point from the short-term model shown in Equation (1) and (2) is that each shipping cost t_{vg} depends on container flow x_{vg} in the constraint condition (11). Note that the cost t_{vg} is defined as generalized cost including shipping time; in other words, by considering shipping time, notion of shippers is indirectly reflected in the cost minimization model of carriers. The other constraint condition (12) and (13) on cargo shipping demand q_{ag} and shipping amount x_{vg} guarantee that all of cargo are transported.

Since Equation (10) cannot be solved by $\delta\pi_g/\delta x = 0$ and $\delta\pi_g/\delta p = 0$ due to difficulty of differentiation, the above problem is solved by a following stepwise procedure; first, focusing in minimization of total shipping costs expressed by the second term; and second, profit maximization as shown in 2.2 when shipping cost in each port pair is fixed. Namely,

Step 0. $n = 0$; initial shipping demand $\{q^{(0)}_{ag}\}$ by port pair for each carrier group is given, estimated by shipping demand by region pair (which is expressed as $\{Q_{rs}\}$ in next section) and the share by ports of maritime container flow for each carrier group.

Step 1. $n = n + 1$.

Step 2. The cost minimization problem is solved under fixing shipping demand $\{q^{(n-1)}_{ag}\}$ for a previous period as below

$$\min_{x}\left\{\sum_{v\in V} x^{(n)}_{vg} \cdot t^{(n)}_{vg}\left(x^{(n)}_{11},\cdots,x^{(n)}_{vg},\cdots,x^{(n)}_{VG}\right)\right\}, \qquad \forall g \in G.$$

Step 3. The profit maximization problem is solved according to the solution described in section 2.2 (short-term model) when shipping cost $\{c^{(n)}_{ag}\}$ in each port pair is fixed, by calculating from the link costs $\{t^{(n)}_{vg}\}$ and cargo flow $\{x^{(n)}_{vg}\}$ determined in Step 2 as below

$$\max_{p} \sum_{a\in A}\left\{\left(p^{(n)}_{ag} - \bar{c}^{(n)}_{ag}\right) \cdot q^{(n)}_{ag}\left(p^{(n)}_{a1},\cdots,p^{(n)}_{ag},\cdots,p^{(n)}_{aG}\right)\right\}, \quad \forall g \in G.$$

Note that when n = 1, the freights $\{p_{ag}^{(n-1)}\}$ in the previous iteration which are used in the above calculation is substituted by the sum of monetary costs on the lowest-cost route using each link cost $\{t_{vg}^{(1)}\}$ which is obtained in Step 2.

Step 4. If the demand $\{q_{ag}^{(n-1)}\}$ for a previous period is converged comparing with the cargo demand $\{q_{ag}^{(n)}\}$ from Step 3 to confirm convergence, or the repeat count *n* reaches an upper limit, the calculation is over. If not, return to Step 1.

In the above calculation procedure, the cost minimization problem stated in Step 2 is described as a problem to determine a cargo flow of each link on international maritime container shipping network as shown in Figure 1.

$$\min_{x}\left\{\sum_{v\in V} x_{vg}\cdot t_{vg}\left(x_{11},\cdots,x_{vg},\cdots,x_{VG}\right)\right\},\quad \forall g\in G. \tag{14}$$
$$s.t.\ (12),\ (13)$$

As shown in Figure 1, in this model, as links are set by vessel size, the decision problem of each link flow includes the problem to determine, not only the handling volume for each port, but also the vessel size transported. Equation (14) corresponds to a system optimum in a traffic network equilibrium assignment methodology. Since the cost function t_{vg} for each link depend not only on flow x_{vg} for a given link but also on the flow $x_{v'g}, \forall v' \in V$ of other links in the same carrier group and the links $x_{vg'}, \forall g' \in G$ of other carrier groups, in this network equilibrium assignment problem, interference from the flow of other links needs to be incorporated. For detail, please refer to Shibasaki et al (2005).

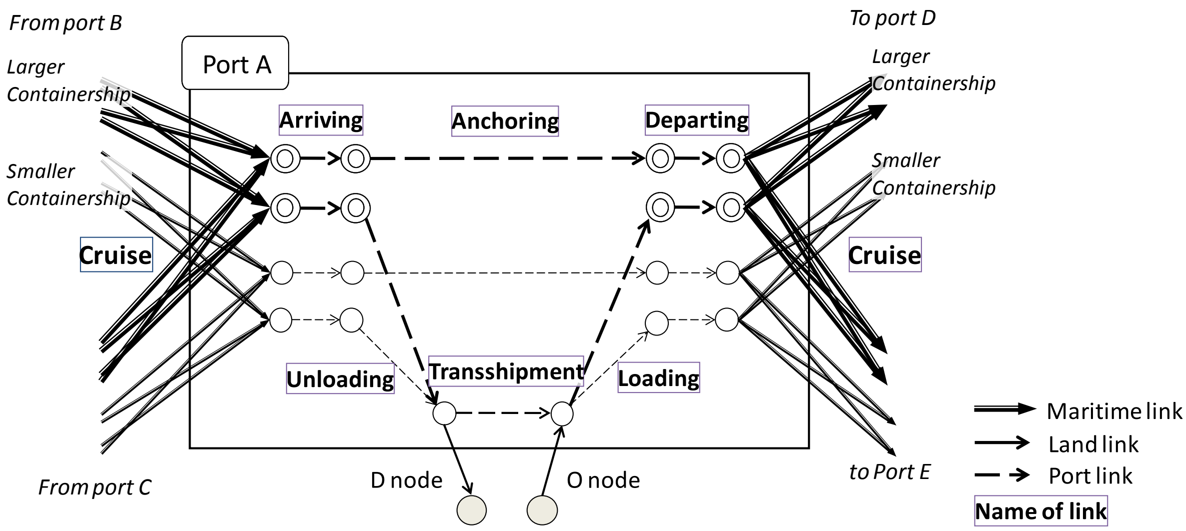

Figure 1. Network structure of carrier's cost minimization model (Source: Shibasaki et al. 2005)

2.3.3. Shipper Model: Formulation and Solution

In this model, cargoes are assigned on a network as shown in Figure 2. The maritime transportation link is herein defined as the direct linkage between an export ports and an import ports irrespective of the actual maritime transportation route and the shipping company used which are considered in the carrier model. A stochastic (but not equilibrium) network assignment model is also applied in this model taking into account factors which cannot be observed by the model developer. Widely, a logit model is applied for this type of problem;

however, the authors do not apply due to the computational difficulties associated with the large number of choices in the logit model which requires enumeration of transportation routes in advance in a large-scale network like this model or the expanded model discussed below.

A shipper chooses a route (including mode of hinterland transport and port used for export/import) to minimize expected generalized shipping costs, given freights for maritime and land transport, the shipping time, etc. Herein, when K_{rs} is path choice set of regional cargo transport demand on a regional OD pair (hereafter calling "regional pair") rs ($rs \in \Omega$; Ω is set of regional pair), a cargo m chooses a path k to maximize utility U_{rskm} including error term ε_{rskm}, that is,

$$U_{rskm} > U_{rsk'm}, \quad \forall k \in K_{rs}, \forall k' \in K_{rs}, k \neq k', \forall rs \in \Omega, \tag{15}$$

$$s.t. \, U_{rskm} = -G_{rsk} + \varepsilon_{rskm}, \tag{16}$$

wherein G_{rsk}: shipping cost (JPY/TEU) of path k on a regional pair rs. If error term ε_{rskm} follows Gumbel distribution, a choice of shipper is formulated as

$$f_{rsk} = Q_{rs} \cdot \frac{\exp(-\theta \cdot G_{rsk})}{\sum_{k \in K_{rs}} \exp(-\theta \cdot G_{rsk})}, \tag{17}$$

wherein f_{rsk}: cargo volume on a path k between regional pair rs, and Q_{rs}: shipping demand (TEU) between regional pair rs. The shipping cost G_{rsk} for each path is expressed by the equation below.

$$G_{rsk} = \sum_{a \in k} \Lambda_a + \sum_{b \in k} GL_b + \sum_{i \in k} (GPX_i + GPM_i + GPT_i), \tag{18}$$

wherein Λ_a: the minimum expected cost (composite cost) for maritime links a including a path k, which is a log-sum variable reflecting the selection result of carrier group as shown in Equation (3)-(5) in section 2.2. More precisely,

$$\Lambda_a = -\frac{1}{\theta} \cdot \ln \sum_{g \in G} \exp(-\theta \cdot GM_{ag}) + \zeta, \tag{19}$$

wherein ζ: adjustment parameter to avoid the log-sum variable to be negative. GL_b in Equation (18) is the generalized shipping cost on land links b including the path k, expressed as

$$GL_b = CL_b + vt_{shpr} \cdot TL_b, \tag{20}$$

wherein CL_b : freight on land link b (JPY/TEU), and TL_b : shipping time (hours) on land link b. Additionally, GPX_i, GPM_i, GPT_i in Equation (18) are the cost of a port link i including the path k. Figure 3 shows the network structure in each port which is omitted from Figure 2. As shown in Figure 3, a receipt (of export cargo) and a dispatch (of import cargo) link are respectively set to take account of the lead time in each port. In addition, an inter-carrier transshipment link is also considered for each port taking into account the transshipment determined by the shipper. These link costs are defined as

$$GPX_i = vt_{shpr} \cdot TPX_i \ , \quad (21)$$

$$GPM_i = vt_{shpr} \cdot TPM_i \text{, and} \quad (22)$$

$$GPT_i = CPT_i + vt_{shpr} \cdot TPT_i \text{,} \quad (23)$$

wherein, TPX_i: lead time when export in port i (hours), TPM_i: lead time when import in port i (hours), CPT_i: freight when transshipped between carrier groups (JPY/TEU), and TPT_i: shipping time when transshipped between carrier groups (hours).

Also, a relationship between the path flow f_{rsk} and the shipping demand d_a for each port pair is expressed as

$$d_a = \sum_{rs \in \Omega} \sum_{k \in K_{rs}} \delta'^{a}_{rsk} \cdot f_{rsk} \text{ , } \forall a \in A \text{ ,} \quad (24)$$

wherein δ'^{a}_{rsk}: Kronecker delta (δ'^{a}_{rsk}=1; when a link a is included in the path k on the regional pair rs: δ'^{a}_{rsk} = 0; when not included).

As shown above, a stochastic network assignment model without any flow-independent link is applied in this model. The cargo flow for each link is calculated using the Dial algorithm.

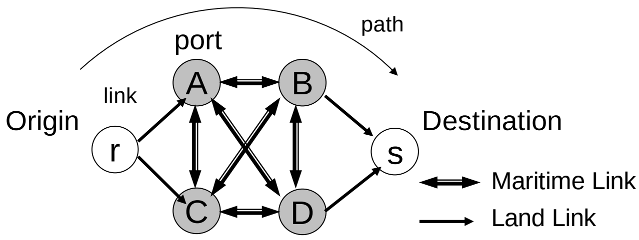

Figure 2. Schematic view of network structure of shipper model (Source: Authors)

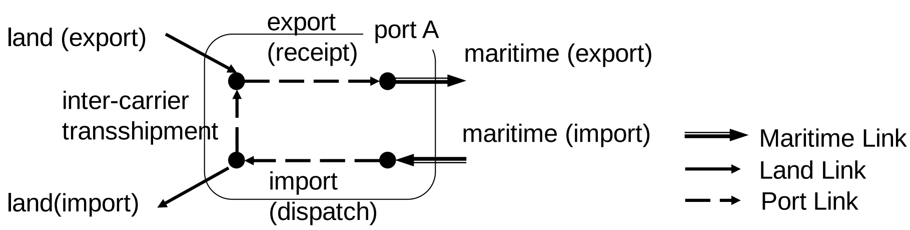

Figure 3. Network structure in port of shipper model (Source: Authors)

2.3.4. Procedure of Calculation to Acquire Nash Equilibrium Solution

Using initial conditions as a starting point and alternately repeating both shipper and carrier model calculations, a local optimum solution is obtained according to following steps.

Step 0. [Setting initial condition] N = 0 and an initial calculation of profit maximization problem of carrier groups is performed inputting initial values $\{q^{(0)}_{ag}\}$ for shipping demand and initial link cost $\{t^{(0)}_{vg}\}$ with respect to initial flow $\{x^{(0)}_{vg}\}$ by carrier group and using the solution method described in section 2.3.2. In this manner, the shipping time $\{TM^{(0)}_{ag}\}$ and freights $\{p^{(0)}_{ag}\}$ by port pair for each carrier group are calculated.

Step 1. $N = N + 1$.

Step 2. [Shipper model calculation] Based on the shipping time $\{TM_{ag}^{(N-1)}\}$ and freights $\{p_{ag}^{(N-1)}\}$ by port pair for carrier group calculated in the last step, calculation of the route choice model for shipper as shown in 2.3.3 is performed. In this manner, shipping demand $\{d_a^{(N)}\}$ by port pair for the overall carrier group is calculated.

Step 3. [Calculation of cargo shipping demand by carrier group] Cargo shipping demand $\{q_{ag}^{(N)}\}$ for each carrier group is calculated according to the short-term model shown in section 2.2, using freights $\{p_{ag}^{(N-1)}\}$ calculated in the previous iteration and total shipping demand $\{d_a^{(N)}\}$ by port pair acquired in the previous step as initial values.

Step 4. [Carrier model calculation] Carrier model is calculated according to the solution method described in section 2.3.2, using freights $\{p_{ag}^{(N-1)}\}$ calculated in the previous iteration and shipping demand $\{q_{ag}^{(N)}\}$ by port pair for each carrier group calculated in Step 3 as initial values. In this manner, the shipping time $\{TM_{ag}^{(N)}\}$ and the freights $\{p_{ag}^{(N)}\}$ by port pair for each carrier group, and the link flow $\{x_{vg}^{(N)}\}$ in the network of the cost minimization model for carrier group can be obtained.

Step 5. [Convergence test] The sum $\{XC_{ijsg}^{(N)}\}$ of the four types of cruising link flow in the network of the cost minimization model for carrier group calculated in Step 4 is compared with the sum $\{XC_{ijsg}^{(N-1)}\}$ of the previously existing link flow and checked for convergence. If it is converged or the repeat count N approaches an upper limit, the process is terminated, if not, return to Step 1.

3. MODEL EXTENSION AND INPUT DATA

3.1. Model Extension to ASEAN Countries

In order to do simulations for ASEAN Countries, a hinterland transport network in East Asia except Japan needs to be incorporated in the above model. The network to be incorporated includes roads, railways, and ferries as shown in Figure 4. The total length of such network is more than 333,000 km, and it has 4,885 links in South East Asia alone. Some container ports and ferry ports were also added, bringing the total to 33 container ports and 11 additional ferry ports throughout the entire ASEAN region.

3.2. Data Preparation

Many types of input data need to be prepared for the model. They can be divided into four types: 1) the transport demand of container cargo (OD cargo volume) by region; 2) transport network data, such as the physical distance and operational costs of both international maritime shipping and hinterland transport; 3) the service level at each port, such as the number of berths by depth, various fares and costs associated with berthing and sizes; and 4) initial input, such as link flow between ports by ship size and by carrier and total volume of containers handled by the ports. This model was basically developed based on year-2003 data, for which the latest data are available, such as that of the Survey Report of International Container Cargo Flow, conducted by the Japanese government every five years.

These four types of data are all difficult to obtain, especially the estimation of regional cargo transport demand. To make an OD cargo matrix on a regional basis, the cargo transport demand on a country basis estimated with the trade model explained in Chapters 2 and 3 is proportionally divided in principle according to the share of magnitude of regional economy, such as GRP (gross regional products), based on statistics issued by each government (e.g. Department of Statistics Malaysia, 2001, Statistical Yearbook Thailand 2004, Socio-Economic Statistical Data of 64 Provinces and Cities by Statistical Publishing House Ha Noi, 2005, and Statistical Yearbook of Indonesia, 2004).

The original model was developed under a network including 17 Japanese container ports, 8 Chinese ports, and 25 other Asian ports. There were four categories of containership size (under 1000 TEU, 1000-2500 TEU, 2500-4000 TEU, and over 4000 TEU). The extended model also targets the same Japanese ports and another 63 container ports in Asia including ASEAN and China. Some input data related to the ports are shown in Table 1.

3.3. Confirmation of Model Accuracy

The reproducibility of the model in terms of the container cargo throughput in all Asian ports is shown in the left side of Figure 5. As shown in the figure, predicted container cargo throughput was reproduced well by the developed model for most of the Asian ports. When focusing on ASEAN ports, the reproducibility is fine, as shown in the right side of Figure 5. Estimated international cargo flow on the land transport network is also shown in Figure 6.

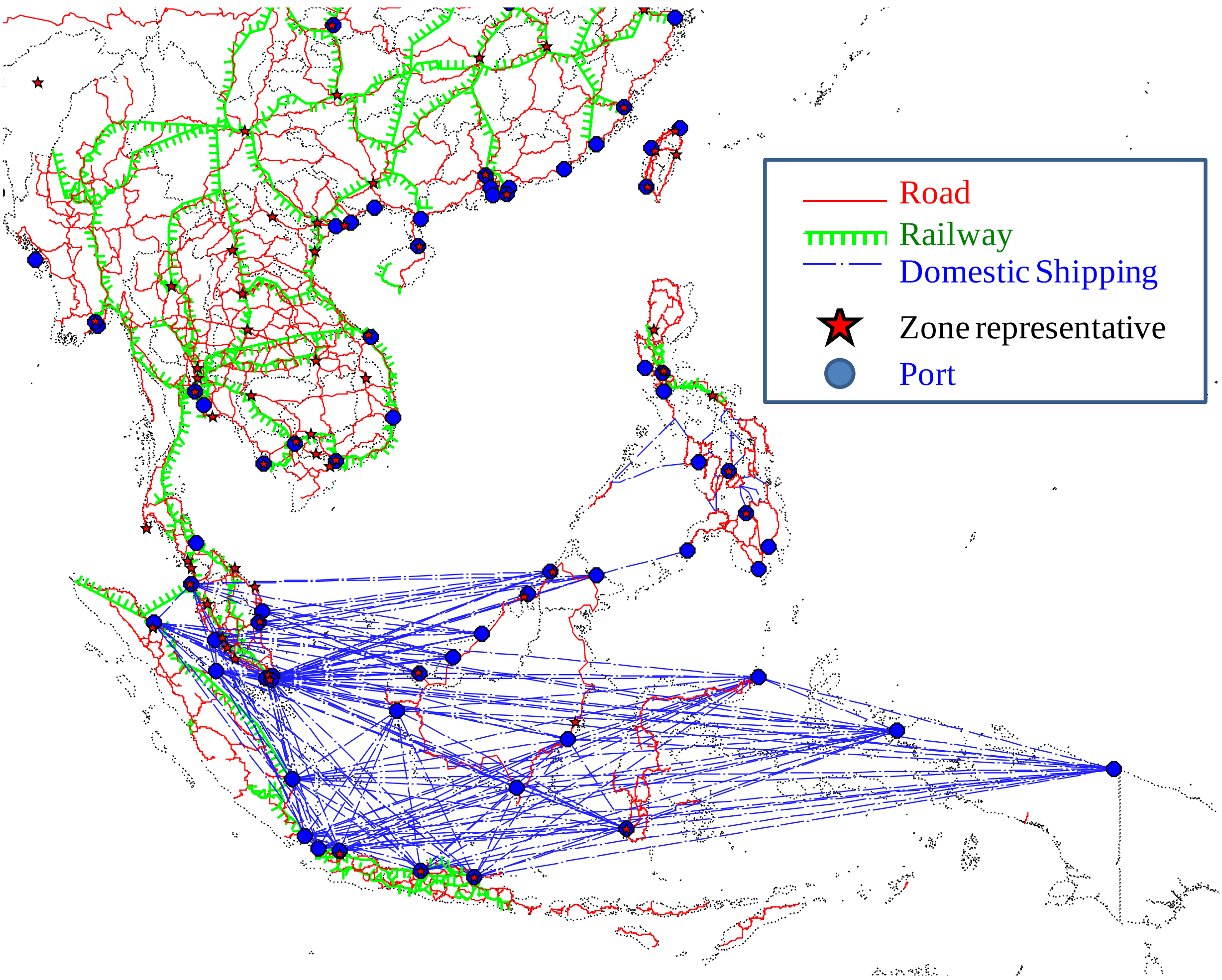

Figure 4. The hinterland transport network in ASEAN countries, incorporated into the model (Source: Authors)

Table 1. Model input data by port targeted (as of 2003)

No.	Port Name		Handl-ing Charge (US$/TEU)*	Port Charge* (thousand US$/vessel)				Terminal Charge (million US$/year/berth)*	Handling Time** (hours)			Number of berth***				Container Cargo Throughput*** (thousand TEU, excluding empty containers)				Trans-ship-ment Ratio*
				–1000 TEU	1000–2500 TEU	2500–4000 TEU	4000 TEU–		Export Cargo	Import Cargo	Trans-ship-ped Cargo	> –11m	–11– –13m	–13– –14m	< –14m	Total	Export	Import	Trans-ship	
1	Japan	Tomakomai	150	17.6	20.5	24.9	33.7	10.8	72	72	48	0	0	0	1	102	36	65	0	0%
2	Japan	Sendai-Shiogama	150	17.6	20.5	24.9	33.7	10.8	72	72	48	0	1	0	1	71	40	31	0	0%
3	Japan	Tokyo	150	17.6	20.5	24.9	33.7	10.8	72	72	48	3	2	0	10	2,527	914	1,304	308	12%
4	Japan	Yokohama	150	17.6	20.5	24.9	33.7	10.8	72	72	48	0	7	10	6	1,862	789	855	218	12%
5	Japan	Niigata	150	17.6	20.5	24.9	33.7	10.8	72	72	48	4	1	0	0	82	20	62	0	0%
6	Japan	Shimizu	150	17.6	20.5	24.9	33.7	10.8	72	72	48	0	5	0	1	424	262	161	0	0%
7	Japan	Nagoya	150	17.6	20.5	24.9	33.7	10.8	72	72	48	3	6	0	2	2,065	1,093	973	0	0%
8	Japan	Yokkaichi	150	17.6	20.5	24.9	33.7	10.8	72	72	48	0	2	0	0	154	88	65	0	0%
9	Japan	Osaka	150	17.6	20.5	24.9	33.7	10.8	72	72	48	3	4	5	3	1,203	326	833	44	4%
10	Japan	Kobe	150	17.6	20.5	24.9	33.7	10.8	72	72	48	5	8	5	10	1,564	801	723	40	3%
11	Japan	Mizushima	150	17.6	20.5	24.9	33.7	10.8	72	72	48	5	0	0	0	70	38	32	0	0%
12	Japan	Hiroshima	150	17.6	20.5	24.9	33.7	10.8	72	72	48	7	0	0	1	111	71	40	0	0%
13	Japan	Tokuyama-Kudamatsu	150	17.6	20.5	24.9	33.7	10.8	72	72	48	0	1	0	0	70	50	20	0	0%
14	Japan	Hakata	150	17.6	20.5	24.9	33.7	10.8	72	72	48	0	1	2	1	310	125	185	0	0%
15	Japan	Kita-Kyushu	150	17.6	20.5	24.9	33.7	10.8	72	72	48	3	4	0	0	317	172	145	0	0%
16	Japan	Shibushi	150	17.6	20.5	24.9	33.7	10.8	72	72	48	4	0	0	0	19	3	16	0	0%
17	Japan	Naha	150	17.6	20.5	24.9	33.7	10.8	72	72	48	0	0	1	0	29	4	25	0	0%
18	South Korea	Busan	80	6.5	9.4	13.8	22.6	6.9	48	24	24	0	7	2	11	9,819	3,455	2,239	4,125	42%
19	South Korea	Kwangyang	80	6.5	9.4	13.8	22.6	6.9	48	24	24	0	0	0	6	768	466	302	0	0%
20	South Korea	Incheon	80	6.5	9.4	13.8	22.6	6.9	72	48	60	0	3	0	2	758	460	298	0	0%
21	North Korea	Najin	20	6.5	9.4	13.8	22.5	5.0	312	432	276	1	0	0	0	197	47	150	0	0%
22	Far East Russia	Vostochniy	20	7.5	10.4	14.8	23.5	5.0	72	48	60	0	2	2	0	618	532	86	0	0%
23	Far East Russia	Vladivostok	20	7.5	10.4	14.8	23.5	5.0	72	48	60	0	2	0	0	215	185	30	0	0%
24	China	Dalian	50	6.8	9.7	14.1	22.8	5.0	72	72	168	0	3	4	0	1,101	674	427	0	0%
25	China	Tianjin	50	6.8	9.7	14.1	22.8	5.0	72	72	168	0	1	4	3	1,930	1,173	757	0	0%
26	China	Qingdao	50	6.8	9.7	14.1	22.8	5.0	72	72	168	0	2	0	6	2,767	1,693	1,074	0	0%
27	China	Lianyungang	50	6.8	9.7	14.1	22.8	5.0	72	72	168	0	2	0	0	213	130	83	0	0%
28	China	Shanghai	50	6.8	9.7	14.1	22.8	5.0	72	72	168	7	6	5	4	7,397	4,526	2,871	0	0%
29	China	Ningbo	50	6.8	9.7	14.1	22.8	5.0	72	72	168	0	0	3	3	1,717	1,051	667	0	0%
30	China	Fuzhou	50	6.8	9.7	14.1	22.8	5.0	72	72	168	2	3	0	1	525	321	204	0	0%
31	China	Xiamen	50	6.8	9.7	14.1	22.8	5.0	72	72	168	0	2	3	0	1,645	1,006	639	0	0%
32	China	Shenzhen	50	6.8	9.7	14.1	22.8	5.0	72	72	168	0	2	0	10	5,494	3,361	2,133	0	0%
33	China	Guangzhou	50	6.8	9.7	14.1	22.8	5.0	72	72	168	0	6	0	0	2,781	1,701	1,079	0	0%
34	China	Zhongshan	50	6.8	9.7	14.1	22.8	5.0	72	72	168	4	0	0	0	524	321	204	0	0%
35	China	Fangcheng	50	6.8	9.7	14.1	22.8	5.0	72	72	168	0	2	0	0	33	20	13	0	0%
36	China	Haikou	50	6.8	9.7	14.1	22.8	5.0	72	72	168	2	0	0	0	151	92	59	0	0%
37	China	Nanjing	50	6.8	9.7	14.1	22.8	5.0	72	72	168	0	2	0	0	341	209	133	0	0%
38	China	Wuhan	50	6.8	9.7	14.1	22.8	5.0	72	72	168	6	0	0	0	99	61	39	0	0%
39	China	Chongqing	50	6.8	9.7	14.1	22.8	5.0	72	72	168	1	0	0	0	88	54	34	0	0%
40	Hong Kong	Hong Kong	100	15.8	18.7	23.1	31.8	22.6	24	24	12	0	0	0	23	14,649	378	1,452	12,819	88%
41	Chinese Taipei	Keelung	60	12.4	15.3	19.7	28.4	8.7	48	48	48	0	14	0	0	1,800	817	928	55	3%
42	Chinese Taipei	Taichung	80	12.4	15.3	19.7	28.4	8.7	48	48	48	0	0	0	6	901	422	479	0	0%
43	Chinese Taipei	Kaohsiung	50	12.4	15.3	19.7	28.4	8.7	48	48	48	4	5	0	10	7,222	2,360	2,681	2,180	30%
44	Philippines	Subic Bay	30	6.5	9.5	13.9	22.6	5.0	72	96	84	0	3	0	0	51	18	33	0	0%
45	Philippines	Manila	30	6.5	9.5	13.9	22.6	5.0	72	96	84	19	7	2	1	1,650	404	726	519	31%
46	Philippines	Batangas	30	6.5	9.5	13.9	22.6	5.0	72	96	84	2	0	0	0	2	1	2	0	0%
47	Philippines	Cebu	30	6.5	9.5	13.9	22.6	5.0	72	96	84	4	0	0	0	391	140	251	0	0%
48	Philippines	Davao	30	6.5	9.5	13.9	22.6	5.0	72	96	84	4	0	0	0	40	14	26	0	0%
49	Vietnam	Haiphong	72	6.5	9.4	13.8	22.5	1.5	72	96	84	3	0	0	0	338	187	151	0	0%
50	Vietnam	Da Nang	72	6.5	9.4	13.8	22.5	1.5	72	96	84	5	4	0	0	30	16	13	0	0%
51	Vietnam	Ho Chi Minh City	72	6.5	9.4	13.8	22.5	1.5	72	96	84	10	6	2	0	1,321	729	592	0	0%
52	Cambodia	Phnom Penh	100	8.7	13.0	13.8	22.5	2.5	72	120	96	3	0	0	0	12	4	8	0	0%
53	Cambodia	Sihanoukville	100	5.8	9.4	13.8	22.5	2.5	72	120	96	1	0	0	0	230	76	154	0	0%
54	Thailand	Laem Chabang	84	7.3	10.2	14.6	23.4	1.6	72	48	60	0	0	0	7	2,703	1,708	881	114	4%
55	Thailand	Bangkok	84	7.3	10.2	14.6	23.4	1.6	72	48	60	21	0	0	0	1,261	789	427	45	4%
56	Thailand	Songkhla	84	7.3	10.2	14.6	23.4	1.6	72	48	60	3	0	0	0	78	51	27	0	0%
57	Malaysia	Kuantan	60	9.7	12.6	17.0	25.7	5.0	72	48	60	0	3	0	0	88	54	34	0	0%
58	Malaysia	Pasir Gudang	60	9.7	12.6	17.0	25.7	5.0	72	48	60	0	0	0	3	439	271	168	0	0%
59	Malaysia	Tanjung Pelepas	40	9.7	12.6	17.0	25.7	5.0	72	48	48	0	0	0	6	4,369	122	75	4,171	95%
60	Malaysia	Port Klang	60	9.7	12.6	17.0	25.7	5.0	72	48	60	0	0	0	19	7,713	2,223	1,377	4,113	53%
61	Malaysia	Penang	60	9.7	12.6	17.0	25.7	5.0	72	48	60	2	3	0	0	402	249	154	0	0%
62	Malaysia	Kuching	60	9.7	12.6	17.0	25.7	5.0	72	48	60	6	6	0	0	120	74	46	0	0%
63	Malaysia	Kota Kinabalu	60	9.7	12.6	17.0	25.7	5.0	72	48	60	3	0	0	0	156	96	60	0	0%
64	Singapore	Singapore	70	10.1	13.0	17.4	26.2	6.2	24	24	12	6	15	4	18	13,607	1,566	1,020	11,021	81%
65	Myanmar	Thilawa	100	6.5	9.4	13.8	22.5	5.0	72	120	96	2	3	0	0	255	112	143	0	0%
66	Indonesia	Surabaya (Tanjung Perak)	50	7.7	10.7	15.0	23.8	5.0	48	144	96	11	0	0	0	1,314	845	470	0	0%
67	Indonesia	Semarang	50	7.7	10.7	15.0	23.8	5.0	48	144	96	2	0	0	0	373	240	133	0	0%
68	Indonesia	Jakarta (Tanjung Priok)	50	7.7	10.7	15.0	23.8	5.0	48	144	96	2	4	0	6	2,229	1,433	797	0	0%
69	Indonesia	Belawan	50	7.7	10.7	15.0	23.8	5.0	48	144	96	5	0	0	0	245	158	88	0	0%
70	Indonesia	Pontianak	50	7.7	10.7	15.0	23.8	5.0	48	144	96	4	0	0	0	147	94	52	0	0%
71	Indonesia	Balikpapan	50	7.7	10.7	15.0	23.8	5.0	48	144	96	0	2	0	0	58	38	21	0	0%
72	Indonesia	Ujyung Pandang	50	7.7	10.7	15.0	23.8	5.0	48	144	96	0	2	0	0	197	127	70	0	0%
73	Brunei Darussalam	Muara	20	6.5	9.4	13.8	22.5	5.0	48	24	36	0	2	0	0	193	104	89	0	0%
74	Bangladesh	Chittagong	20	6.5	9.4	13.8	22.5	5.0	120	96	108	2	0	0	0	1,249	256	993	0	0%
75	India	Jawaharlal Nehr	50	7.5	10.4	14.8	23.5	3.5	72	144	108	0	5	0	0	4,602	1,650	2,952	0	0%
76	Sri Lanka	Colombo	80	7.5	10.4	14.8	23.5	5.0	72	72	24	4	1	2	4	1,569	256	227	1,086	69%
77	Pakistan	Karachi	50	7.5	10.4	14.8	23.5	5.0	96	72	84	5	3	0	0	1,963	374	1,589	0	0%
78	Russia (European Area)		130	13.1	16.0	20.4	29.2	5.0	72	48	60	0	0	0	100#	2,867	1,488	1,379	0	0%
79	PNW		270	16.5	19.4	23.8	32.6	5.0	48	24	36	0	0	0	100#	12,327	6,213	6,114	0	0%
80	PSW		270	16.5	19.4	23.8	32.6	5.0	48	24	36	0	0	0	100#	26,292	9,851	16,441	0	0%
81	East Coast of North America		270	16.5	19.4	23.8	32.6	5.0	48	24	36	0	0	0	100#	16,062	6,877	9,185	0	0%
82	West Coast of South America		50	7.5	10.4	14.8	23.5	5.0	96	96	96	0	0	0	100#	2,200	1,399	801	0	0%
83	East Coast of South America		50	7.5	10.4	14.8	23.5	5.0	72	96	84	0	0	0	100#	5,813	4,004	1,809	0	0%
84	Middle East		50	7.5	10.4	14.8	23.5	5.0	48	24	36	0	0	0	100#	9,521	5,844	3,678	0	0%
85	Mediterranean		50	7.5	10.4	14.8	23.5	5.0	72	72	72	0	0	0	100#	15,027	6,344	8,683	0	0%
86	Europe		130	13.1	16.0	20.4	29.2	5.0	24	24	24	0	0	0	100#	28,460	12,071	16,390	0	0%
87	Africa		130	13.1	16.0	20.4	29.2	5.0	216	336	276	0	0	0	100#	5,813	4,144	1,669	0	0%
88	Oceania		50	6.5	9.4	13.8	22.5	5.0	24	72	48	0	0	0	100#	4,523	3,026	1,498	0	0%

Source: * authors' estimation. ** World Bank: Doing Business. *** Containerisation International Yearbook etc.
Notice: # hypothetical assumption that there are no port congestions at all in non-Asian ports.

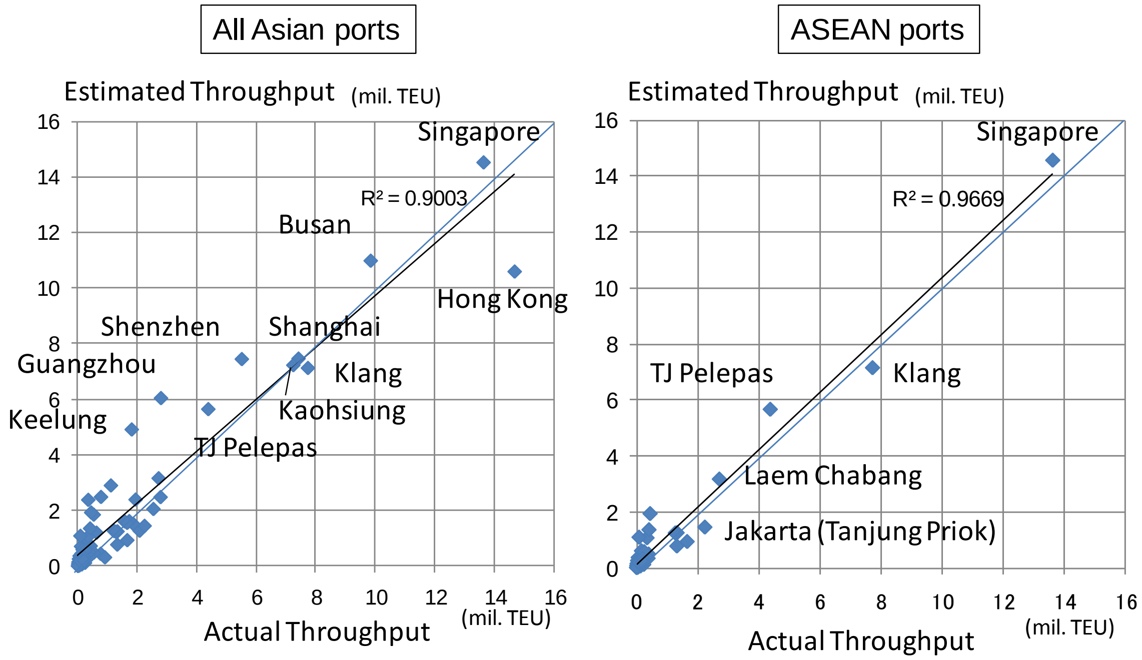

Figure 5. Reproducibility of the model in terms of container cargo throughput (Sum of import, export and transshipped containers; in 2003) (Source: Authors)

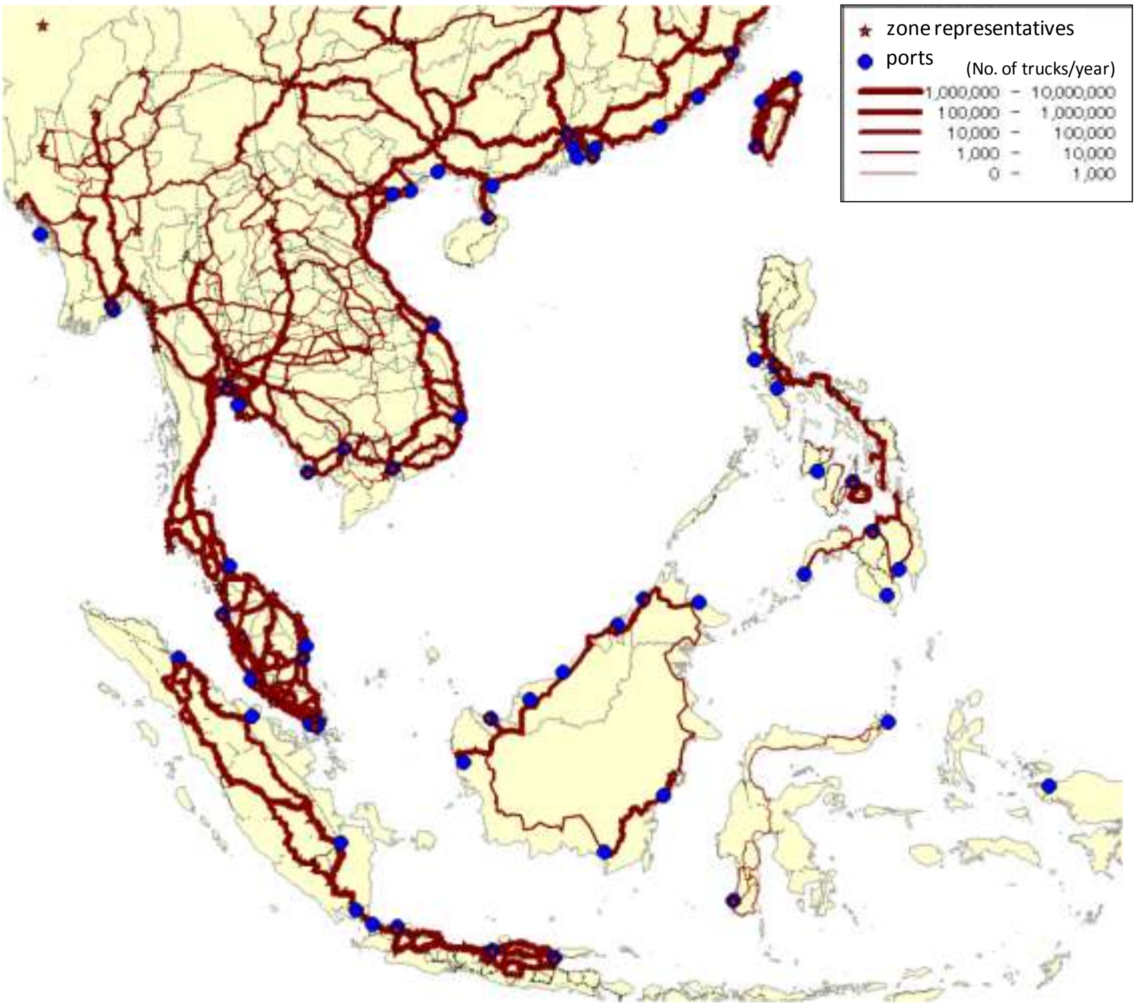

Figure 6. Estimated international cargo flow in the land transport network (in 2003) (Source: Authors)

4. RISK SIMULATION USING THE MODEL

4.1. Scenario Setting

Due to some reason, the Malacca Strait assumes to be blocked. Here, the blockade assumingly continues enough long to change the transport pattern for the carrier groups and the transport route and carriers for the shippers if needed. The carrier groups should change the shipping route of containerships which passed through the Malacca Strait until the blockade. According to our interview surveys, the alternative route is to pass through the Lombok Strait, which is located between Bali and Lombok Island, Indonesia (see Figure 7). Another alternative route, the Sunda Strait between Sumatra and Java Island, is not appropriate because it is too narrow and shallow to pass through for large ships.

The shutdown of the Malacca Strait is assumingly happened on a straight line between port of TJ Pelepas (Malaysia) and Dumai (Indonesia). Any containerships and ferries passing through the line have to detour. For the model calculation, we have to set up new network data of maritime shipping on the physical distance between related port pairs. Concretely, the physical distance of the maritime link connecting the west side (e.g. South Asia, Middle East, Europe and Africa) and the east side (e.g. East part of Southeast Asia, East Asia, North & South America) of the blockade line are replaced in the blockade scenario.

Against the blockade, we prepare four countermeasure scenarios. For these additional scenarios, the countermeasures implemented are focused on port of TJ Perak (Surabaya, Indonesia). Although the scale of port of TJ Perak is now quite smaller, compared with regional hub ports such as port of Singapore, it is located near the Lombok Strait and considered to have a potential to partly alternate the function of these hub ports. In this paper, four policies to encourage the usage of port of TJ Perak in the emergency of the blockade of the Malacca Strait are examined in order to alleviate the increase of international shipping cost due to the blockade.

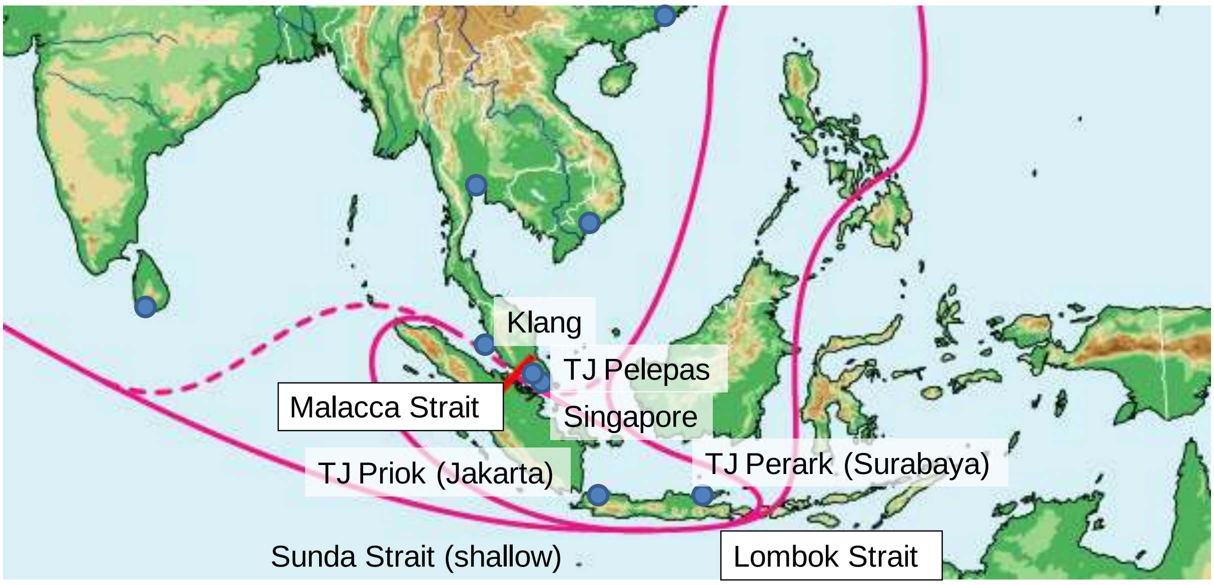

Figure 7. Detouring route after the blockade of the Malacca Strait (Source: Authors)

Another assumption is on the transport demand of international cargo of the world. If the blockade of the Strait actually happen and continue in a long time, the economy of the world, not only Southeast Asia, will be thrown into utter chaos and demand of international shipping will drastically decrease, at least in the meantime. That means the negative impact of the blockade is not limited to the increase of the shipping cost, but spread to the entire social economy of the world. In the simulation of this paper, it is assumed that the transport demand of international cargo in any areas of the world will be not affected from the blockade and that only the increase of shipping cost is negative impact to the world economy. This assumption is mainly due to simplification of the calculation; therefore, the estimated cost increase should be regarded as a minimum economic impact of the blockade.

4.2. Simulation Result of the Blockade

Figure 8 shows a comparison of the estimated volume of imported and exported container cargo in Malaysian, Singapore and Indonesian ports between two scenarios. In Scenario 0, no events are assumed to happen in 2003, which is the same result as shown in Figure 4 and 5. In Scenario 1, the blockade is assumed to happen but any countermeasures are not implemented. The estimated result shown in the figure is described as annual cargo volume. If the blockade continues for half a year, the estimated cargo volume during this period will become half in each scenario. In other words, for a discussion based on the result of the figure, the rate of difference for both scenarios is important; for example, in which ports, the increased or decreased rate is relatively high due to the blockade, etc.

According to the result shown in Figure 8, in major ports in this area, port of Klang, Singapore, and TJ Priok (Jakarta), the cargo volume handled for export/import is estimated to decrease due to the blockade. In particular, the decreased rate in port of Klang is the most significant. On the other hand, especially in some Malaysian ports including Kuantan, Pasir Gudang, and TJ Pelepas, the local cargo volume handled increase. These increased cargoes are estimated to be sifted mainly from those handled in the port of Klang and Singapore.

Figure 9 shows a difference in land cargo flow in Southeast Asia. According to the figure, it is found that the land link flows of both sides surrounding the blockade point are estimated to increase. In Malay Peninsula, as discussed above, it is found that the container cargo handled in port of Klang shift to port of Kuantan, Pasir Gudamg, and TJ Pelepas. In addition, another shift from sea to land is observed in the Sumatra Island, from a usage of port of Belawan to land transport to the Java Island across the Sumatra Island.

The result shown in Figure 10 bears out the above inference. Figure 10 shows the estimated volume of ferry/RORO cargo in Malaysian, Singapore and Indonesian ports. According to the figure, in the ports which are located in the west of the blockade point such as port of Penang, Dumai, and Belawan, the cargo volume drastically decrease after the blockade. Instead of them, in the ports which are located just in the east of the blockade point such as port of TJ Pelepas and Panjang, the increased rates in the volume are significantly larger.

Also, Figure 11 shows a comparison of the estimated volume of transhipped container cargo in Asian major ports. Similar to the result shown in Figure 8, the volume in port of Klang is estimated to drastically decrease due to the blockade, while in most of other hub ports including Singapore they are increase.

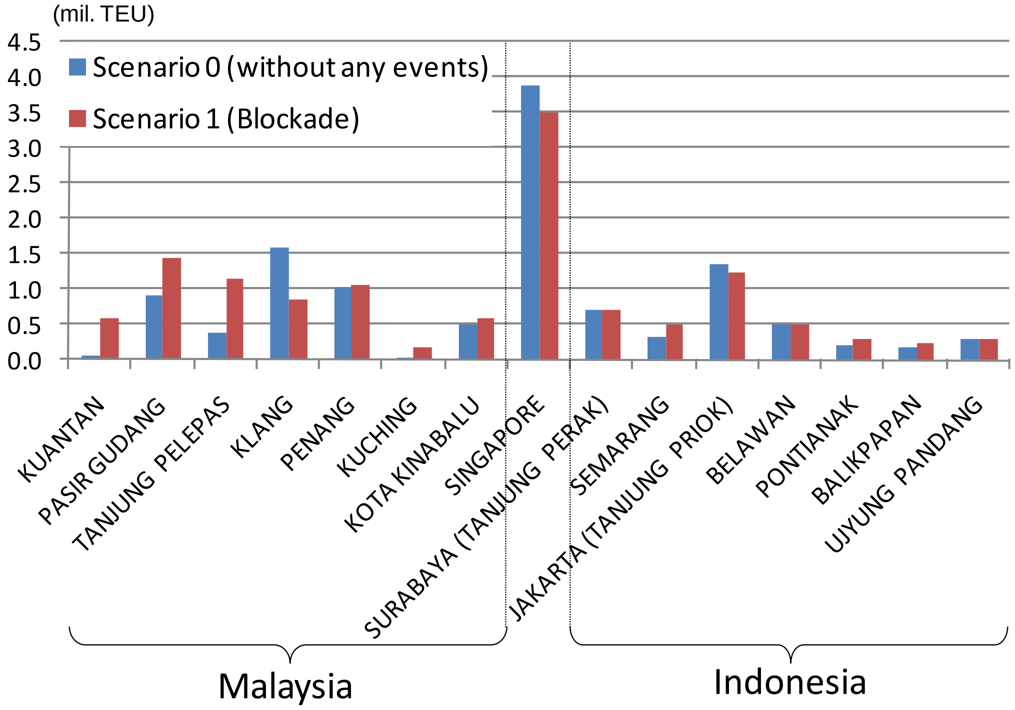

Figure 8. Comparison in estimated volume of local (imported and exported) container cargo in Malaysian, Singapore and Indonesian ports (Source: Authors)

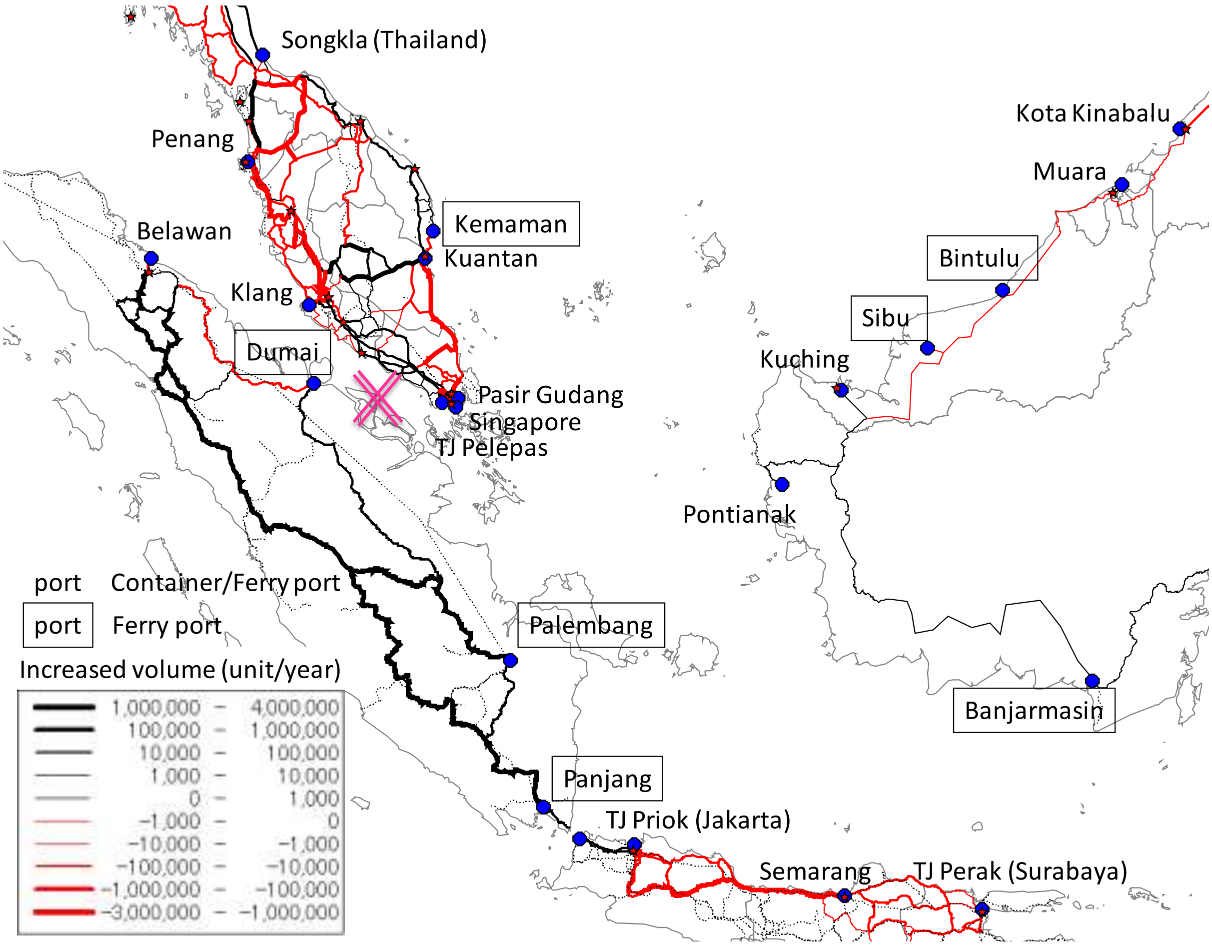

Figure 9. Difference in land cargo flow in Southeast Asia between two scenarios (Source: Authors)

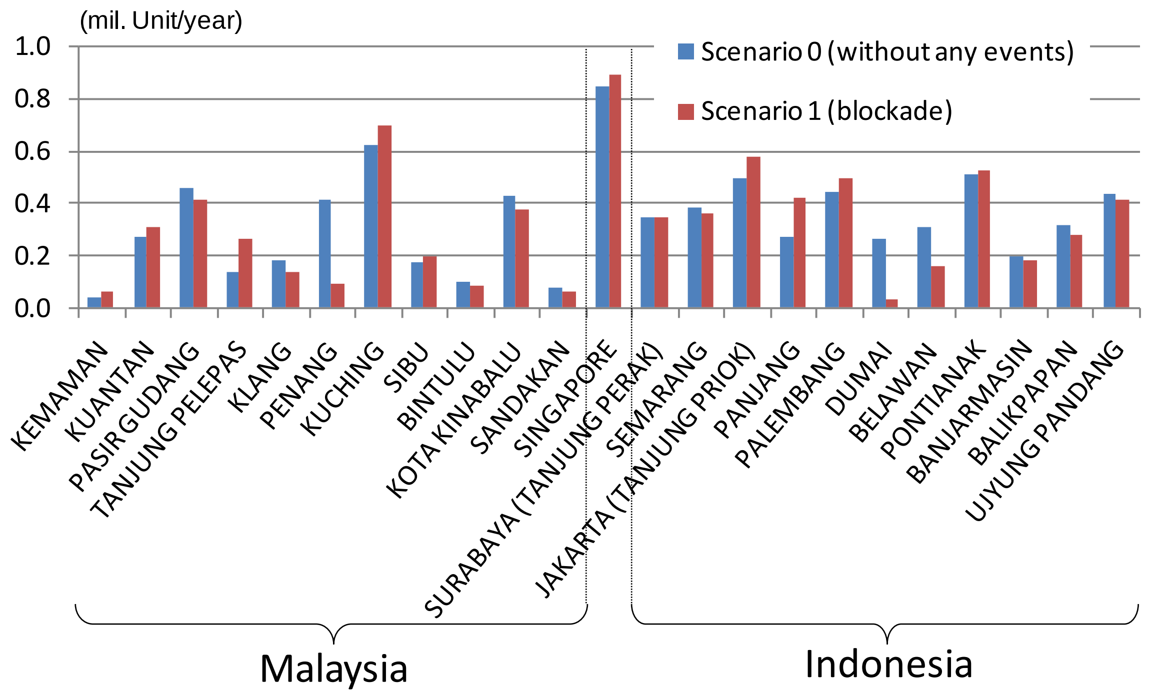

Figure 10. Comparison in estimated volume of ferry/RORO cargo in Malaysian, Singapore and Indonesian ports (Source: Authors)

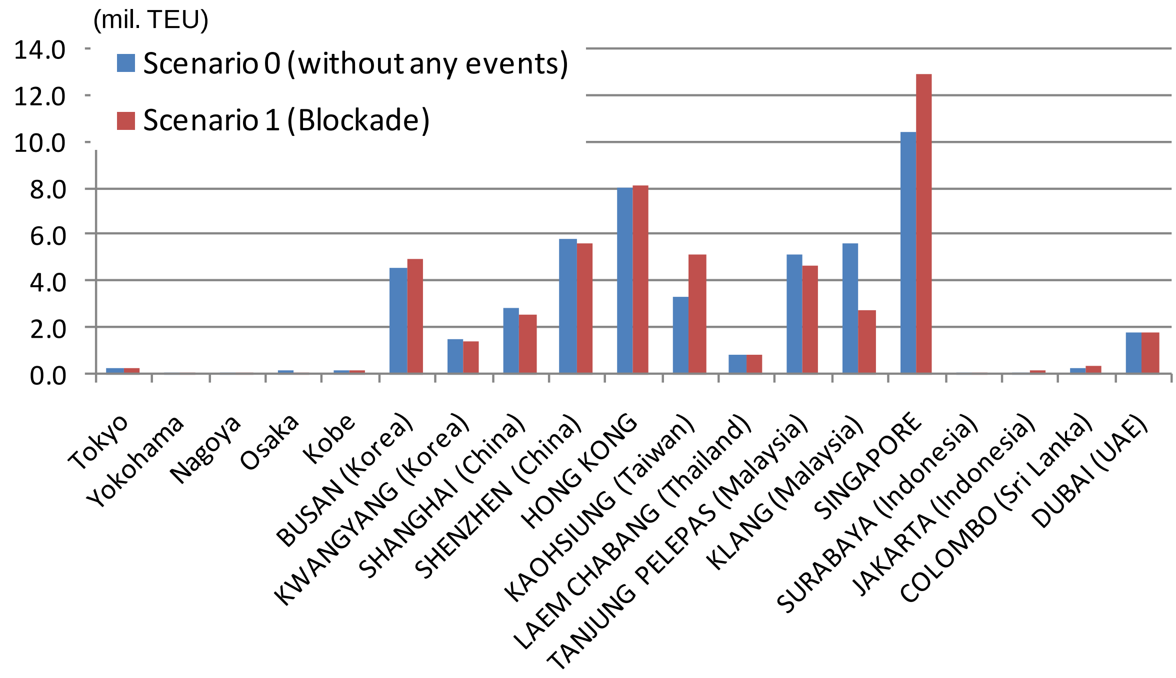

Figure 11. Comparison in estimated volume of transhipped container cargo in Asian major ports (Source: Authors)

Summarizing the above results, port of Klang is predicted to be most heavily damaged from the blockade of the Malacca Strait. The reason can be explained as follows; if the Malacca Strait is utterly shut down, Klang will become an innermost port of a fictitious huge bay of which the mouth faces to the west; therefore, it is difficult to keep the function as a hub port. On the other hand, port of Singapore can sustain the function as a hub port to the east part of Southeast Asia, because the east side of the port is open to ocean such as South China Sea and Java Sea.

Utilizing the model developed, the shipping cost of international container cargo can be also calculated. Table 2 shows the increased cost estimated by cargo country/region of international container cargo shipping due to the blockade of the Strait of Malacca. These results can be calculated from the difference of the cost in each scenario. From the table, it is found that the effects of the blockade are mostly significant in Malaysia and Singapore but widely spread over the world. In particular, not only in ASEAN countries, but also in west neighbour countries to the ASEAN such as India, Sri Lanka and Middle East, the increased rates of the shipping cost are more than 2%. This implies that these countries are strongly connected to Southeast Asia and heavily affected from the blockade because it is located exactly in between the two areas. On the other hand, even ASEAN countries, for example, in Vietnam, Cambodia and Brunei, the shipping costs are estimated to decrease. These countries are quite remote from the Strait among ASEAN countries and located along the detour route shown in Figure 6. Actually, in these counties' ports the volume handled of local and transhipped cargo increase but they are not quite large. However, it is notable that the countries (or ports) under these conditions are not always to increase their handling volume and decrease shipping cost, like Philippines and Indonesia.

Table 2. Estimated increased cost (per year) and rate of international container cargo shipping due to the blockade of the Strait of Malacca (Source: Authors)

- ASEAN countries

	Philippines	Vietnam	Laos	Cambodia	Thailand	Malaysia	Singapore	Myanmar	Indonesia	Brunei	ASEAN Total
Increased Cost (mil. US$/year	64	−172	47	−1	1,220	8,453	5,943	72	2,014	−90	11,214
Rate	0.2%	−0.3%	2.1%	0.0%	1.3%	7.1%	8.5%	0.9%	2.0%	−1.9%	2.6%

- other countries/regions

	Japan	Korea	China	Chinese Taipei	India	Sri Lanka	Russia/ Central Asia	North America	South America	Middle East	Europe	Oceania	Others	World Total
Increased Cost (mil. US$/year	−440	700	1,640	2,434	2,395	334	1,098	−530	−447	5,640	8,757	1,957	1,159	29,595
Rate	−0.2%	0.6%	0.3%	1.9%	2.0%	2.9%	0.7%	−0.1%	−0.2%	2.8%	1.0%	2.0%	0.5%	0.6%

4.3. Simulation Result on Countermeasures to the Blockade

Against the blockade, the following four countermeasure scenarios are prepared on improving the level of service in port of TJ Perak (Surabaya);

1) Scenario 1A (hereafter, S1A): all of containerships which are used to call at port of Singapore before the blockade are assumingly compelled to shift to port of TJ Priok temporally[2].

[2] Concretely, the initial maritime link flow, which is one of the input data of the model, is differently set.

2) Scenario 1B (S1B): In order to enhance its function as a transshipment port, in addition to S1A, it is assumed that two new deeper berths (over -14m depth) are newly constructed and that handling time for transshipped cargo is decreased as short as that in port of Singapore (i.e. decrease from 96 hours to 12 hours).
3) Scenario 1C (S1C): In order to enhance its function as a regional port, in addition to S1B, handling time for import and export are also decreased as short as that in port of Singapore (from 48 and 144 hours respectively to 24 hours for both).
4) Scenario 1D (S1D): In order to deal with emergency, in addition to S1C, the terminal charge is almost exempted (from 5 million US$/year/berth to 0.01 million US$).

Figure 12 and 13 show the estimated local and transshipped container cargo for each above scenario respectively. According to these figures, there are observed some effects to cargo shift, especially in S1C and S1D. The result shown in Figure 12 implies that some local cargo will shift to port of TJ Perak from other Indonesian ports as well as port of Singapore partly, by implementing the decrease of handling time for local cargo (which is firstly added in s1C). Also, the result shown in Figure 13 implies that some transshipped cargo will shift from port of Singapore, partly by forcing the mandatory temporal shift of containership (s1A) and more additionally by constructing new berths and shortening handling time for transshipment cargo (s1B). Another observation is a recovery of transshipped cargo in port of Klang. It should be interpreted due to the weakening of the function as hub port in Singapore, rather than its enforcement in port of TJ Perak.

Table 3 shows the increased or decreased cost estimated by cargo country/region of international container cargo shipping by the countermeasure, compared with the result in Scenario 1. From the table, it is found that for the cargo in the most affected countries from the blockade (i.e. Malaysia and Singapore) and Indonesia itself, the effect of the countermeasure is expected to be positive; however, in most of other countries/regions, shipping cost is estimated to increase. That implies the impact of the blockade can equalize throughout the world, although the total shipping cost of the world is estimated to slightly increase.

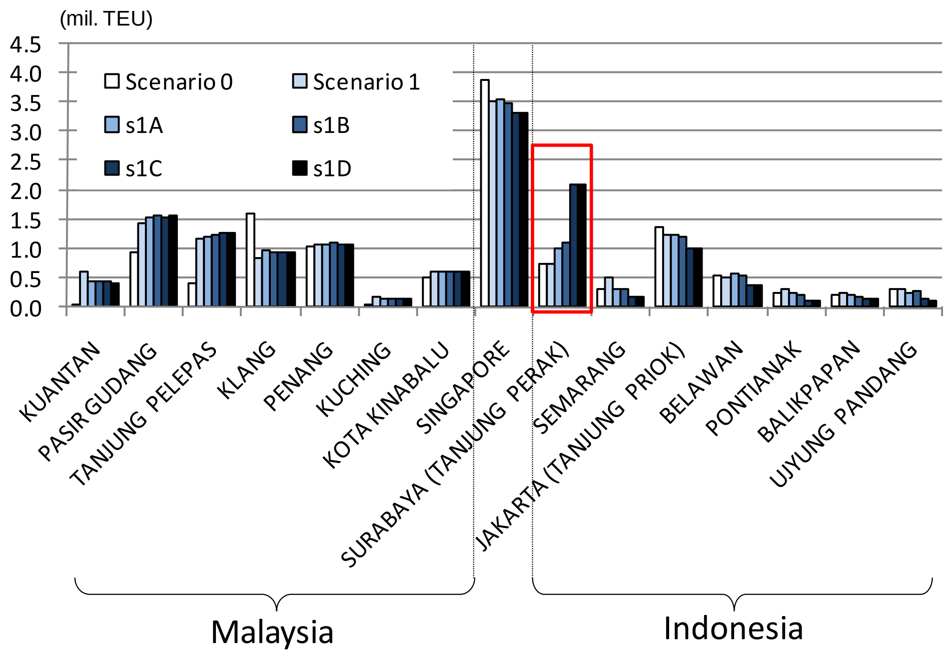

Figure 12. Comparison in estimated volume of local container cargo for each countermeasure scenario on port of TJ Perak (Surabaya) (Source: Authors)

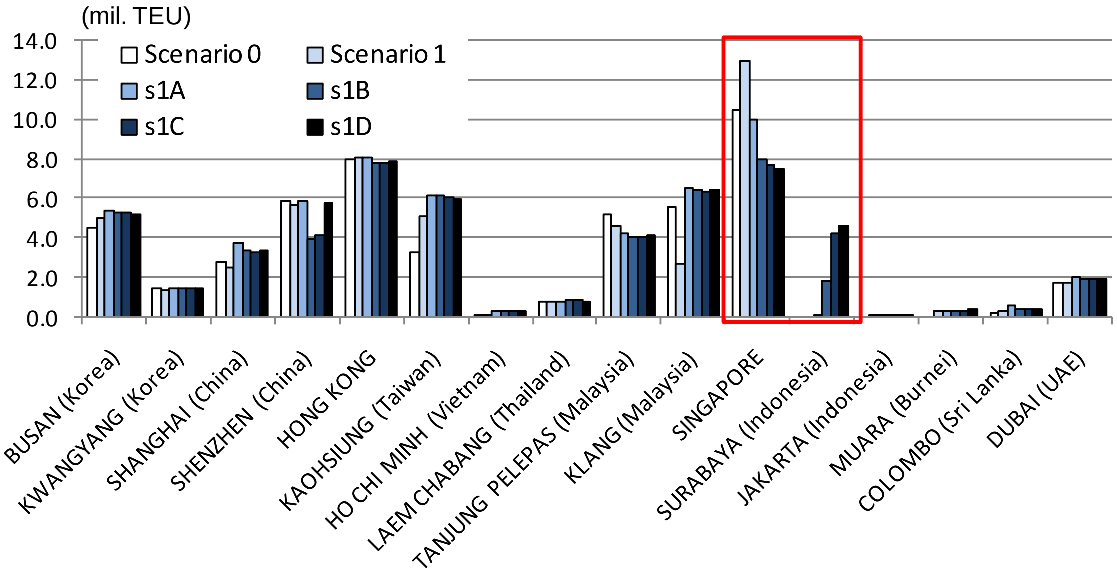

Figure 13. Comparison in estimated volume of transshipment cargo for each countermeasure scenario on port of TJ Perak (Surabaya) (Source: Authors)

Table 3. Estimated increased (or decreased) cost and rate of international container cargo shipping due to the countermeasure (s1C) comparing with the result in Scenario 1 (Source: Authors)

- ASEAN countries

	Philippines	Vietnam	Laos	Cambodia	Thailand	Malaysia	Singapore	Myanmar	Indonesia	Brunei	ASEAN Total
Increased Cost (mil. US$/year	97	34	-11	14	190	-1,275	-188	-19	-1,830	31	-2,005
Rate	0.3%	0.1%	-0.5%	0.2%	0.2%	-1.0%	-0.2%	-0.2%	-1.8%	0.7%	-0.5%

- other countries/regions

	Japan	Korea	China	Chinese Taipei	India	Sri Lanka	Russia/ Central Asia	North America	South America	Middle East	Europe	Oceania	Others	World Total
Increased Cost (mil. US$/year	538	517	2,563	481	274	-22	478	52	600	864	1,549	387	1,089	6,413
Rate	0.3%	0.4%	0.4%	0.4%	0.2%	-0.2%	0.3%	0.0%	0.3%	0.4%	0.2%	0.4%	0.5%	0.1%

5. CONCLUSIONS

This paper aimed to assess the economic impact from the viewpoint of international transport cost due to the blockade of the Malacca Strait quantitatively, by applying the simulation model the author had developed. By using the model, based on the scenarios to assume the blockade of the Malacca Strait and the countermeasures especially focused in port of TJ Perak, the results were compared and discussed in terms of the cargo volume handled (local container, ferry/RORO ship cargo, and transhipped container) in each neighbour port, land cargo flow shifted from the maritime shipping, and total and by-country shipping cost.

Since the results introduced in the previous chapter are based on some trial simulations, further simulations are needed to validate the model accuracy for detail; however, it can predict reasonable answers on which port is the most affected and in which countries the shipping cost increase. From now on, the authors consider conducting more simulations on other types of countermeasures and find more effective one.

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