

International Freight Flow Modeling considering Cross-Border Transport Especially Focused in Mekong River Area

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Abstract

Until now, authors have developed an international freight flow model which is mainly focused on international maritime transport but also including domestic transport network in Japan and China. By using this model, international freight transport policy such as port investment as well as improvement of connection between port and road in each country of Asia, especially focused on Japan and China. In this paper, we extend a range of the model to international land transport in Southeast Asia region. In particular, in Mekong River Area, which includes South part of China (Yunnan Province), Vietnam, Cambodia, Thailand, as well as Laos (one of landlocked countries located in this area), there are several projects to improve social infrastructure for passing through national border in this area. Thus, authors are now extending the model to include the international land transportation network in Mekong River Area in order to evaluate the policies for improvement of cross-border facilities and smoothing international land freight flow. In this paper, authors show the idea of the model extension after rough description of the previous model already developed by authors and several simulation results. In addition, for the model calculation, we also need to prepare several kinds of input data, especially on the OD volume of cargo between countries and/or regions. Thus, we also provide in the paper a simple methodology on estimation of OD volume in regional base, based on country-base OD data that we had already estimated in other papers.

This paper will be also helpful for other inland regions and landlocked countries to provide the methodology of model development to evaluate policies with similar objectives.

Keywords International container cargo, Cross-border, International land transport network, Mekong river delta

Introduction

During the past decades, Asian economies achieved the great development. Due to this reason, Asia is becoming one of the biggest freight goods generations and consumptions areas in the world. In particular, called as ‘World’s Factory’, China imports a huge amount of raw materials from overseas, and exports the products to the world everyday.

Consequently, Asian ports are also becoming the busiest ports in the world. In terms of container handled, 20 of the world’s top 30 container ports were located in Asia in 2004. Within them, there are 9 Chinese mainland ports; in particular, Hong Kong, Shanghai, Shenzhen ports take the top 4 ports with Singapore port in the world. On the other hand, especially in Southeast Asia, there are several talks to much tighten each other economically such as Free Trade Agreement, and such movements are now towards including East Asian Countries such as China, Japan and South Korea. According to this movement, the “Cross Border Issue” that deals with international land transport network needed

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much investment and improvement for infrastructure and solving various related problems at crossing national border becomes hot issue, especially in Mekong River Area which is consisted from Yunnan Province of P. R. China, Vietnam, Cambodia, Thailand, and Laos as well as Northeast Asian Region.

The authors have been developing a model (Shibasaki et al. 2005a and Ma et al. 2006) which can produce the movement of international freight container, focused in East Asian region, in order to simulate and evaluate international freight transport policy for each country such as port investment as well as improvement of connection between port and road. This model also considers the use of different types of ships, transshipments, and the number of different berth at each port. In addition, the model also incorporates the land transport network in Japan and China as hinterland transport means.

In this paper, an extension of the model is examined to include the international land transportation network in Mekong River Area, in order to evaluate the policies for improvement of cross-border facilities and smoothing international land freight flow. First, after the basic idea and rough structure of the previous model that had been already developed by authors are introduced, an idea of the model extension is shown. Second, information on some input data newly needed, how to estimate, and their estimation results are roughly introduced. Finally, several calculation results of policy simulation should be shown.

Rough Structure of the Developed Model

We developed a model to reproduce the international maritime container cargo flow between all of the Japanese ports handling containers, the major ports of East Asia China, and other areas, as well as the land transport of container cargo within Japan and China, when the OD cargo flows between regions are given. The ports dealt with the previous model and land transport network are shown in Figure 1 and 2.

Container cargo flows were treated as traffic flows on the networks, in a manner that reflects the behavioral principles of shippers and carriers each other, the major actors in the container cargo transport market, according to such network assignment principles as user equilibrium (UE) assignment or system optimum (SO) assignment. Specifically, networks are developed for container cargo transport not only between ports, but also within each port and in domestic shipping / land transportation areas. As shown in Figure 3, this model consists of two sub-models; one is for the carriers and the other is for the shipper. They pursue their optimal behavior independently based on each principle, while exchanging information on OD cargo flows by carrier (from shipper to carrier) and freight rates between ports (from carrier to shipper), until resulted in equilibrium.

The carrier sub-model

For the carrier sub-model, each container carrier determines the patterns of maritime transport, namely ports where cargo is transshipped and the sizes of vessels that call in each port, based on information on port charges, terminal handling charges, congestion situation in each port, and transport cost by type of ship, etc., when the amounts of cargo between ports are given. Note that the rates per TEU fall as the ship size increases due to economies of scale. Also, as cargo is centered into a certain inter-port link (called “cruise link”), traffic frequency for this link increases and the time cost falls. On the other hand, if a lot of ships call in the port, shipping congestion of vessels waiting to berth may rise. The conceptual network of each port is shown in Figure 4.

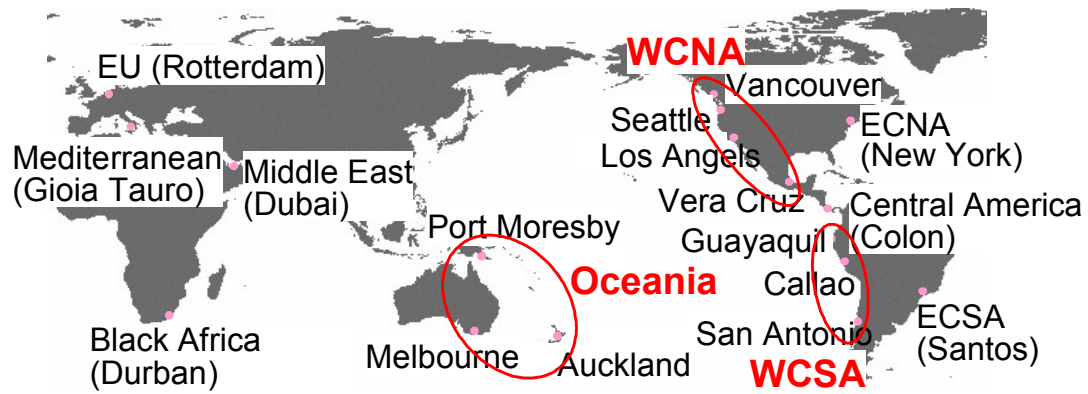
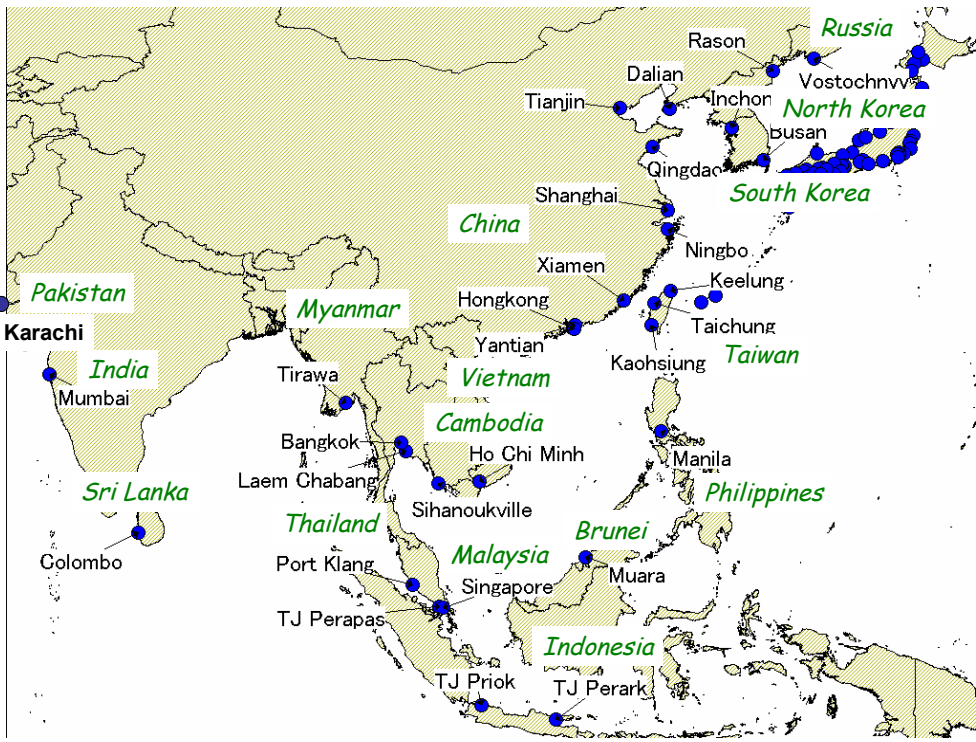
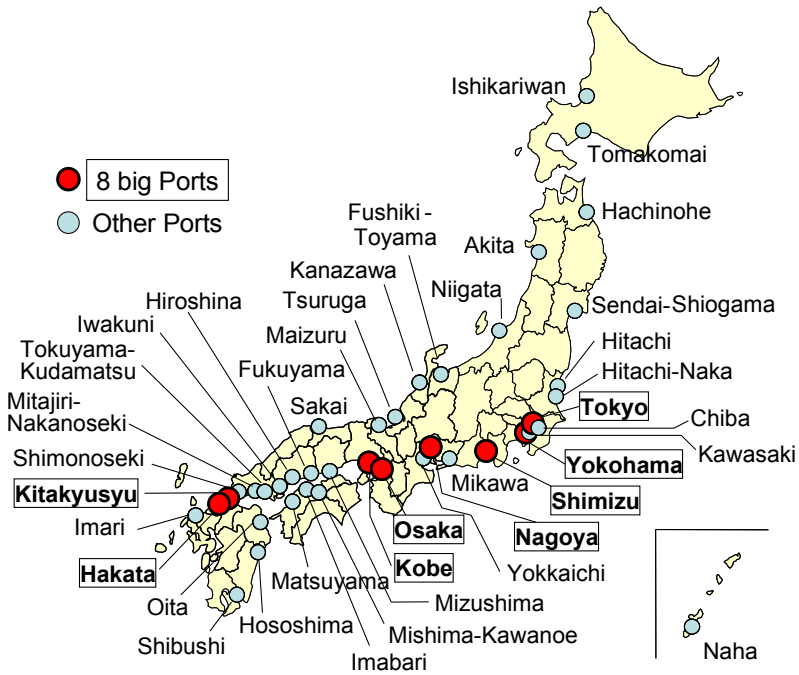


Figure 1. Ports treated in the model –

Japanese ports (above), Asian ports (middle), other areas (below)

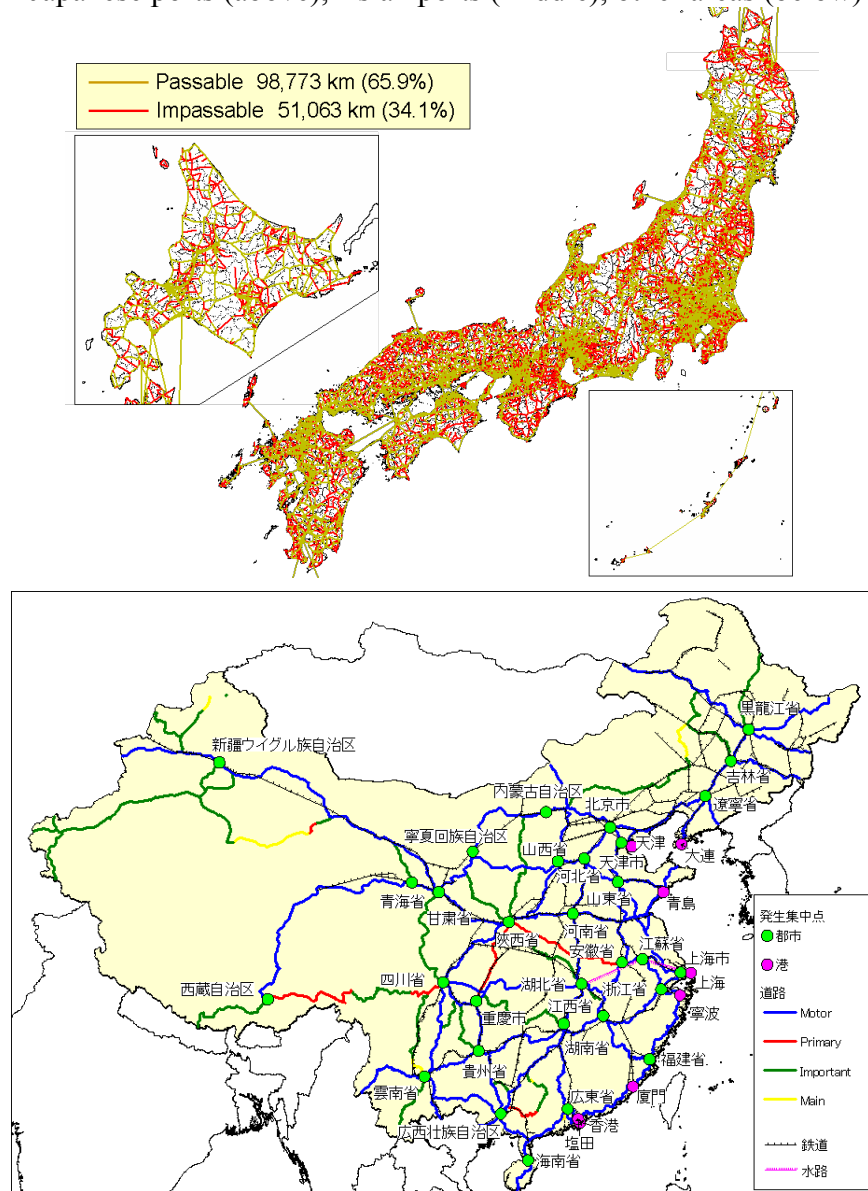


Figure 2. Land transport network: Japan (above) and China (below)

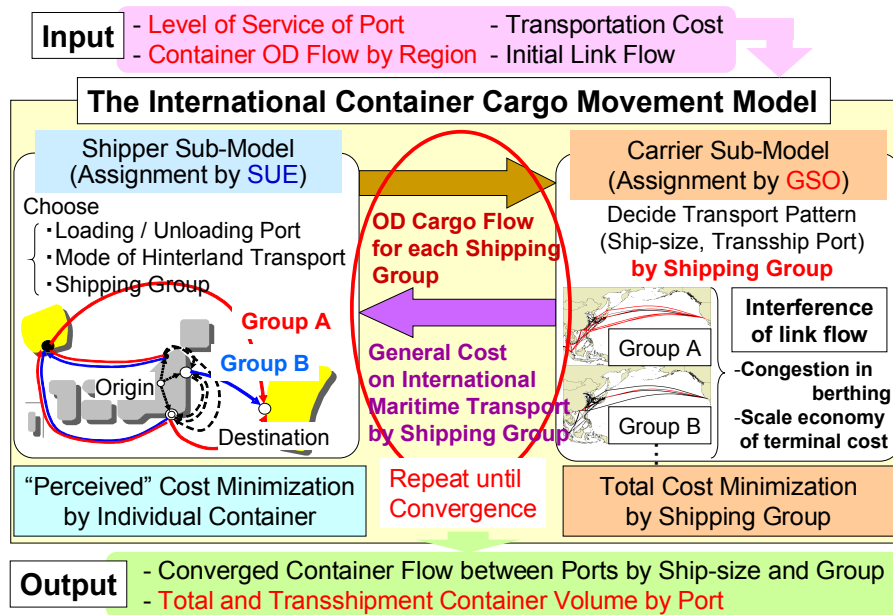


Figure 3. Framework of the Model and Relationship between Two Sub-models

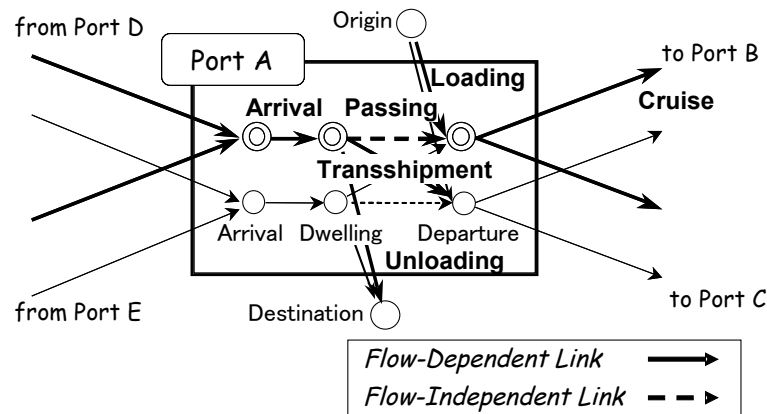


Figure 4. Container Transport Network in Carrier Sub-Model

There are six types of links: i) *loading & cruise* (connecting between each port by vessel size category), ii) *passing & cruise* (same as i), iii) *ship-berthing* (set by port by vessel size category), iv) *loading* (same as iii), v) *unloading* (same as iii), and vi) *transshipment* (connecting between each vessel category by port). The reason why cruise links, which connect each port on the sea, are divided into two types of links is that there are expected to be differences in departure waiting-time from the port, between when passing through and keeping aboard on the containership and when loading to the ship from the container-yard. Each link has a corresponding flow-dependent or flow-independent link cost. Containers will be carried from an origin port to a destination port, through paths on the network according to path costs, which are defined as the sum of link costs on those paths. For the formulations of link functions of both sub-models and parameter estimation, since the space is limited, please refer the paper of Shibasaki et al (2005a) for the details. In addition, seven ship-size categories are prepared for the model. As the ship size increases, it needs the deeper berth when calls at a port. Berths in ports are also classified into seven categories. By this way, it can also examine the impact of the berths construction and ship fleet arrangements on the whole transport network.

This sub-model is expected to provide a solution for minimizing the total cost by each carrier group (GSO: Group-based System Optimum assignment). GSO is a unique assignment methodology, derived from the normal System Optimum (SO) assignment, which minimizes the total transport cost. This methodology is based on the fact that because the alliances of the container cargo carriers, especially in long-distance shipping, are very solid, they may minimize the total cost in each alliance.

However, there is interference between carrier groups in berthing because all berths are assumed for public use without any distinction for group.

The solution uses Frank-Wolfe's algorithm (cf. Sheffi 1985) on the flow-dependent network. Because some of the link costs include decreasing flow functions, there is a non-convex problem with a number of local minimums. This fact may be interpreted practically in that the real state of observed transport depends heavily upon past history. Accordingly, this model regards the present conditions as the starting-point, and inputs the present flow pattern as the initial values, from which the model intends to simulate the future transport pattern.

The shipper sub-model

It is assumed that each shipper determines the routes involved in hinterland transport, loading and unloading at ports, and carriers, after considering international maritime transport costs between ports given by each carrier and the conditions on hinterland transport. This study limits consideration of hinterland transport to Japan and China due to the data availability. Transport to and from countries other than Japan and China assumes that all cargo originates from and is destined for particular ports, and that the shipper selects the carrier only. It is also assumed that the amount of OD cargo between regions or ports is given. Road and water transport are only considered for hinterland transport in Japan and China, based on past and present performances. Although the behavior of carriers should be considered also in terms of hinterland transport, judging from the severe competition among them in the reality, the shipper may be regarded as having initiative in the transport market, therefore, the behavior of entities other than shippers is ignored. The network used in the sub-model is shown in Figure 5. Note that it is definitely different from those in the carrier sub-model. That is because, regarding the international maritime transport network, the shipper would select a carrier only based on such service levels as freight rates and frequency of service, without selecting a maritime transport route, such as ports of transshipment or the size of the ship. Therefore, hypothetical links are established that directly connect the individual ports.

There are thirteen types of links: i) *international maritime transport* (connecting between each port's berth by individual carrier groups), ii) *international loading* (connecting between international container yards and each carrier group berth), iii) *international unloading* (same as ii), iv) *inter-container yard between international container yards*, v) *domestic loading & cruise* (connecting between each of the Japanese ports), vi) *domestic passing & cruise* (same as v), vii) *domestic ship-berthing* (set by Japanese port), viii) *domestic loading* (same as vii), ix) *domestic unloading* (same as vii), x) *domestic land transport* (connecting between origin or destination and port), xi) *carry-in* (same as vii), xii) *carry-out* (same as vii), and xiii) *inter-container yard link between international and domestic container yard*.

In this sub-model, all link cost functions on international maritime transport and land transport are assumed to be flow-independent. Furthermore, mainly because of the lack of data, we assume there are no influences of the volume of container vehicles on land transportation time.

Another requirement of the sub-model is that, regarding selection of carriers, hinterland transport modes, and loading/unloading ports for shippers, they should be affected by factors other than those explicitly included in the model. Accordingly, the stochastic user equilibrium assignment (SUE), which is able to calculate with flow-dependent link cost functions and simultaneously consider the variance of shippers' behavior, is used in the sub-model. This is also new point of the model. Specifically, a logit-based stochastic assignment based on the random utility theory is performed according to the Dial algorithm (1971). The parameter, θ , of the logit model included in the likelihood equation is estimated by calibration in order to reproduce the real conditions most accurately, together with other unknown parameters included in cost functions. The successive average method proposed by Fisk (1980) is used as a means to solve. Furthermore, as is the case with the carrier sub-model, calculations are carried out with the present flow patterns given as initial conditions, and including

interference between the links.

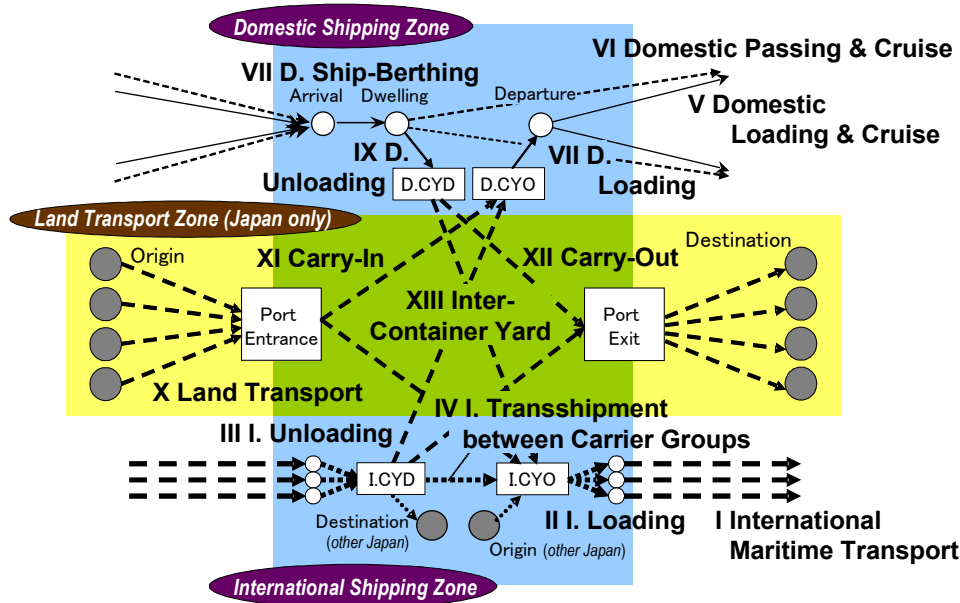


Figure 5. Container Transport Network in Shipper Sub-Model

Data preparation

The model includes 87 ports, of which are top 40 Japanese container ports, 7 Chinese container ports (Dalian, Tianjin, Qingdao, Ningbo, Shanghai, Xiamen, Yantian), 23 major East and South Asian ports, and 17 representative ports in countries or continents other than Asia, as shown in Figure 1. For East and South Asian ports, we set at least one port at one country. For other continents than East and South Asia, in consideration of further application purpose, each APEC member country is exceptionally dealt as single while other countries are aggregated into 8 continents.

The input data required for this model could be divided into five types; 1) amount of OD container cargo by region or port, 2) initial flows of cruise links by carrier, 3) service level on each port, such as number of berths by depth, various costs associated with berthing and sizes, initial total volume of containers handled by port, 4) operational costs for international maritime transport and hinterland transport (including domestic shipping and land transport), and 5) transport network data such as physical distance for each link. This model was basically developed by year-2003 data, where the latest data are available such as Survey Report of International Container Cargo Flow, conducted by Japanese government every five year. These five types of data are all difficult to be obtained, especially the amount of container OD data, which estimation methodology is elaborately described in Shibasaki et al. (2005b). In this study, China OD data was estimated on the province level.

Estimation result of unknown parameters and reproducibility of the model

The estimation result of unknown parameters is shown in Table 1. For the estimation, the combination of linear searches by the golden section and approximate derivation of steepest descent directions were used. Through trial and error process with simultaneous pursuit of accuracy and efficiency of estimation, we set five as the number of times of the golden section per linear search, and three as the number of repeating times of derivation of steepest descent directions. Every unknown parameter needs to be initially set, thus initial values are also shown in the Table 1. Compared with error rates (i.e. square root of error sum of square / sum of initial flow) among four cases including above two cases and other two cases that values are set at upper limit and lower limit, the difference of error rate between initial values and estimated parameters are found to be not negligible.

Table 1. Estimated results of unknown parameters in the model

parameter	θ	vt shpr	vt carr	$\gamma 1$	$\gamma 2$	error rate
unit	-	(1,000 JPY/h)		-	-	
initial value	0.01 ^{*1}	1.348 ^{*2}	1.348 ^{*2}	120 ^{*1}	5 ^{*1}	0.0792
lower limit	0.001	0.01	0.01	10	1	0.1018
upper limit	0.1	10.0	10.0	1000	10	0.0858
estimated	0.0131	1.350	1.346	119.9	5.03	0.0789

source: *1 empirically set based on past results etc.

*2 the Guideline of Port Investment Evaluation

The reproducibility of the amounts of handled containers in Japanese ports and transshipped containers across all Asian ports seems to be better, which are shown in Figure 6. In particular, as shown in the left side of the figure, the total volume of containers for each Japanese port is well reproduced, although a little underestimation for the largest ports. In terms of transshipment of containers in all of Asian hub ports, as shown in the right side of Figure 6, overestimation in some ports and underestimation in others are observed. In particular, some ports in China, which are said to have no actual transshipment, due to a lack of statistics data, transshipment rate are estimated for the model. However, it is reasonable to consider that some transshipment might exist, judging from other sources and interview results.

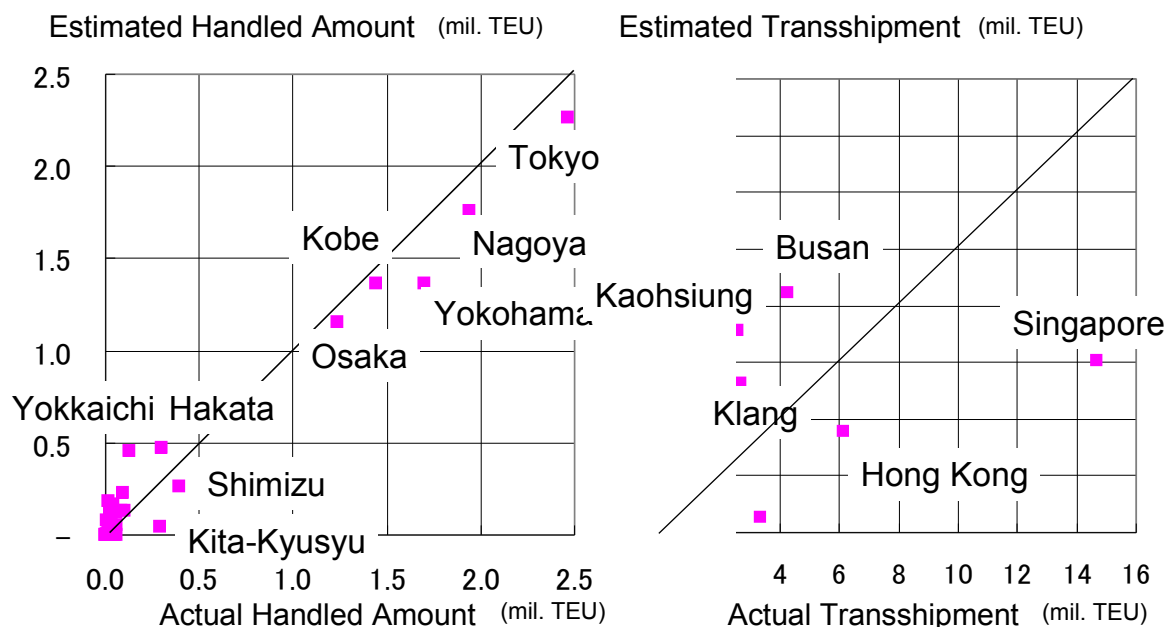


Figure 6. Reproducibility of the total and transshipped amount of containers

Basic Idea of Model Extension for Incorporating Cross Border Transport

The concept of model extension is almost similar in incorporating Chinese land transport network (Ma, et al., 2006). For the model extension, additional information as follows is needed;

- 1) Data on international land transport network in Southeast Asia, including transport length and cost by mode and resistance (time and cost) when crossing national border
- 2) Addition of OD information of cargo transported by international land transport means
- 3) Division of OD container cargo volume into several regions for each country of Southeast Asia and addition of OD data for the landlocked country (i.e. Laos)

4) Addition of several ports in Southeast Asia and related information

The unknown parameters shown in Table 1 can be estimated again for the entire network newly developed, according to the method described above. However, as in the case with incorporation of Chinese land transport network, it would not possibly obtain stable solutions, thus the estimated parameters shown in Table 1 would be used without modification. Concrete way to preparation of above data is shown below.

Data Preparation

International land transport network

As in the case when incorporating Chinese land transport network, we basically use ADC WorldMap™ database which works on GIS software, MapInfo, incorporating other data sources on international land transport network in Southeast Asian region such as a report by International Development Institute (2005). The developed network in Southeast Asian region is shown in Figure 7 and detailed example of Laos's network is shown in Figure 8. Please notice that in the Southeast Asian network railway and water transport are not included unlike Chinese land transport network. The cost function of land transportation is formulated as well as Japanese network (described in Shibasaki et al., 2005a) except links crossing national border, which cost function is defined in next section.

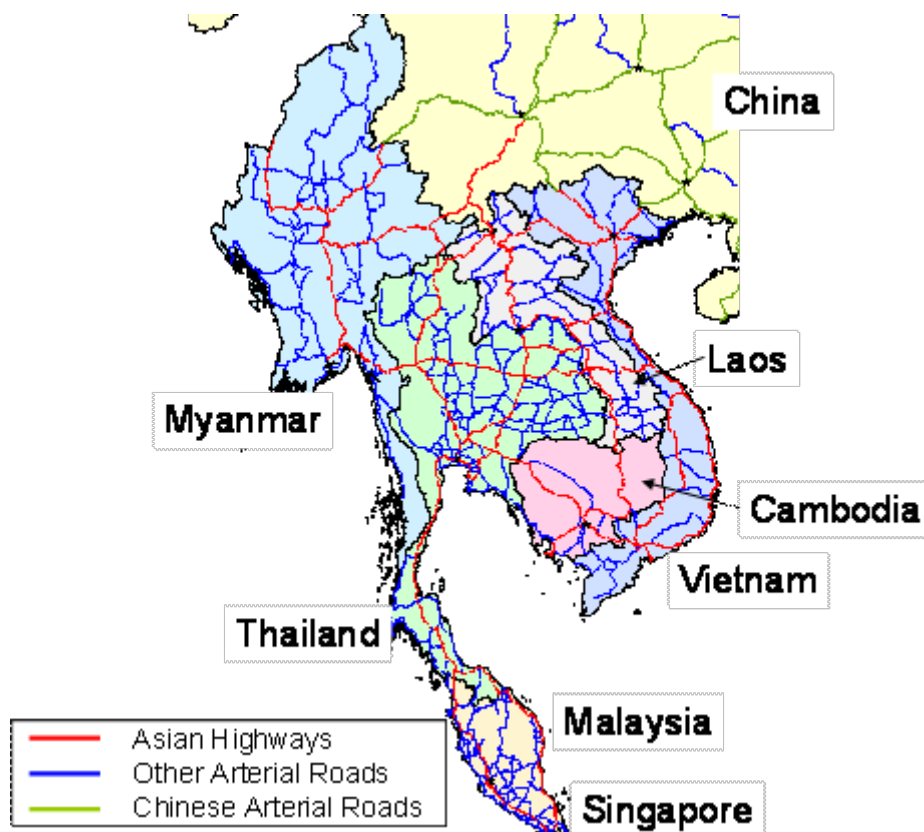


Figure 7. New added land transport network in Southeast Asia



Figure 8. An example of land transport network for each country: Laos

Resistance across national border

According to above developed network, there are totally 30 links which cross national border in Southeast Asian region (including borders between China and Southeast Asian country) as shown in Table 2. Thus, monetary cost and time cost needs to be set for all these “cross-border” links. Asian Development Bank (2005a and 2005b) had published several reports on cross-border transport in Southeast Asian region, especially focused on Mekong River Delta area. As referring these reports and other reports such as UN-ESCAP (2003), we assume the time and cost on these links. These estimation results are also shown in Table 2 and Figure 9.

Table 2 Cross-border links in Southeast Asian region and its time and cost

No	Country 1	City 1	Country 2	City 2	Time Required in Crossing (hour)	Cost Required in Crossing (1000JPY)	Gate Open Hours of Border per day (hour)	Mode	Asian Highway No.
1	China	Ping Xiang	Vietnam	Dong Dang	3	11.8	15	Road	1
2	China	Ping Xiang	Vietnam	Dong Dang	3	11.8	15	Rail	
3	China	Hekou	Vietnam	Lao Kai	3	11.8	15	Road	14
4	China	Mohan	Laos	Bung Nua	3	11.8	15	Road	
5	China	Mohan	Laos	Boten	3	11.8	15	Road	3
6	China	Daluo	Myanmar	Keng Tung	3	11.8	15	Road	3
7	China	Ruili	Myanmar	Muse	3	11.8	15	Road	
8	Laos	Vantao	Thailand	Chong Mek	7.75	15.46	16	Road	
9	Laos	Savannakhet	Thailand	Mukdahan	7.75	15.46	16	Road	16
10	Laos	Thakhek	Thailand	Nakhon Phanom	7.75	15.46	16	Road	15
11	Laos	Tanaleng	Thailand	Nong Khai	7.75	15.46	16	Road	12
12	Laos	Houay Xay	Thailand	Cheng Khong	7.75	15.46	16	Road	3
13	Vietnam	Dien Bien Phu	Laos	Muang Khoua	2	11.8	16	Road	
14	Vietnam	Tin Tio	Laos	Nam Kahn	2	11.8	16	Road	
15	Vietnam	Keo Neua	Laos	Nam Phao	2	11.8	16	Road	15
16	Vietnam	Lao Bao	Laos	Deng Savan	2	11.8	16	Road	16
17	Laos	Veun Kam	Cambodia	Stoeng Treng	2	11.8	16	Road	11
18	Vietnam	Ban quan su mien	Cambodia	Snuol	2	11.8	16	Road	
19	Vietnam	Tay Ninh	Cambodia	Suong	2	11.8	16	Road	
20	Vietnam	Moc Bai	Cambodia	Bavet	2	11.8	16	Road	
21	Vietnam	Chau Doc	Cambodia	Kompong Chery	2	11.8	16	Road	
22	Thailand	Hat Lek	Cambodia	Koh Kong	4	15.46	16	Road	
23	Thailand	Aranyaprathet	Cambodia	Poipet	4	15.46	16	Road	
24	Thailand	Mae Sai	Myanmar	Tachilek	4	15.46	16	Road	
25	Thailand	Mae Sot	Myanmar	Myawadi	4	15.46	16	Road	1
26	Thailand	Phra Chedi Sam Ong	Myanmar	Maulamyaing	4	15.46	16	Road	
27	Thailand	Sungai Kolok	Malaysia	Rantau Panjang	4	15.46	16	Road	18
28	Thailand	Betong	Malaysia	Pengkalan Hulu	4	15.46	16	Road	
29	Thailand	Sa Dao	Malaysia	Bukit Kayu Hitam	4	15.46	16	Road	2
30	Malaysia	Johor Bahru	Singapore	Singapore	4	15.46	16	Road	

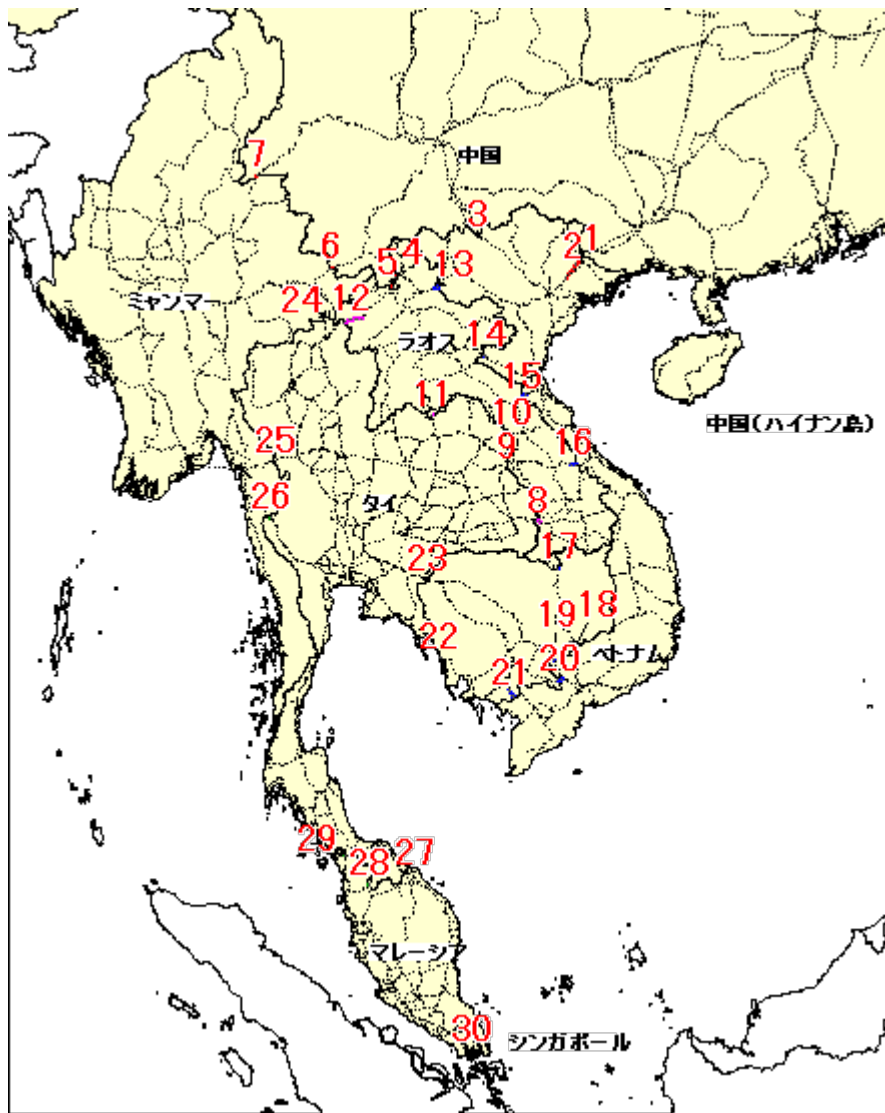


Figure 9. Cross-border points in Southeast Asia

OD volume of international container cargo in regional basis

As shown in Shibasaki, et al. (2005b), OD volume of international container cargo is basically estimated bilateral trade flow acquired from several data sources such as Global Trade Atlas. For countries where the trade amount cannot be available, we refer individual country's statistics such as "Direction of Trade Statistics Yearbook 2005" published by International Monetary Fund for trade amount on Laos. Then, these trade amount data are i) divided by transport mode (i.e. air, land and maritime) according to World Trade Service Data published by Global Insight Inc., ii) transformed to cargo volume (tonnage basis) from monetary amount according to the same data source, iii) multiplied containerized ratio for maritime cargo according to the same data, and iv) transformed to unit basis from tonnage basis according to the same data and other sources. For maritime container cargo, its unit is defined by TEU (twenty-equivalent unit). By following above procedures and adding the volume of land and maritime cargo, we can estimate OD volume of international container cargo in country basis. As an example of World Trade Service Data, land transport cargo flow in Southeast and South Asia is shown in Figure 10. As shown in the figure, transport cargo flows on smaller countries are unknown individually from this database, thus the modal share of land transport out of international cargo transport for these countries should be estimated by referring "other countries" data in the data source or neighbor countries' data.

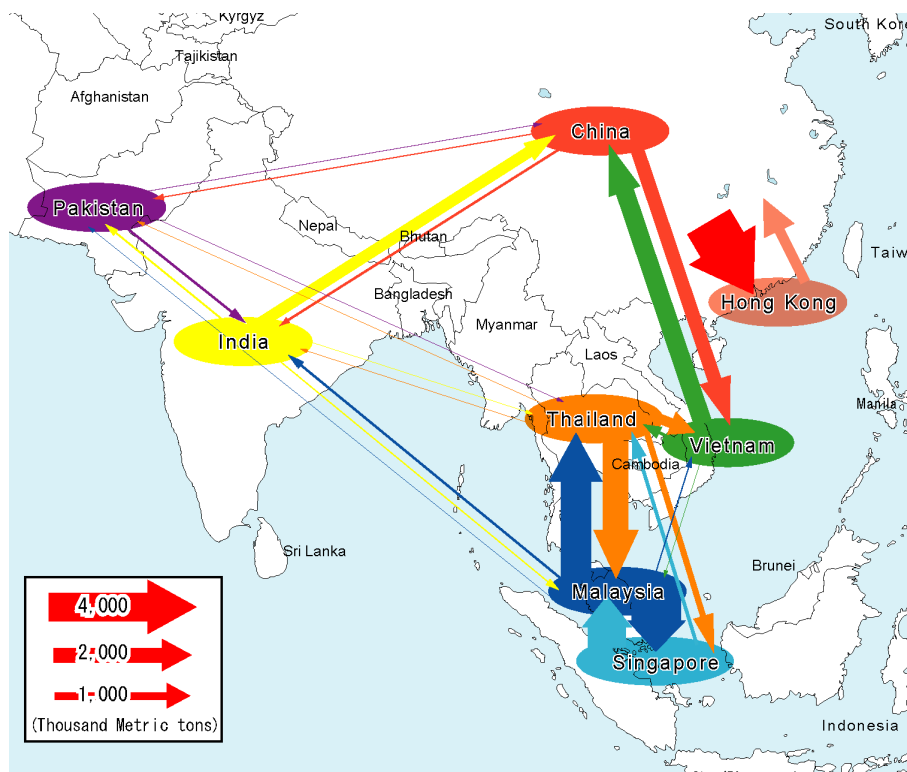


Figure 10. Land transport cargo flow in Southeast and South Asia

After above procedures, OD volume of international container cargo in country basis needs to be divided into regional basis (i.e., several regions in a country), especially larger countries within Southeast Asia, that is to say, Vietnam, Thailand, Malaysia, and Indonesia. So far, regional base OD volumes are estimated only for Japan and China. As mentioned in Shibasaki, et al. (2005b), for OD containers between Japan and China, gravity model is used to estimate, for OD containers between Japan and other countries, existing data according to Survey Report of International Container Cargo Flow is used, and for OD containers between China and other countries, country base OD containers is divided according to the share of trade amount to the country in question by each Chinese region, from China Customs Statistics data.

In a similar way, at this time, by using each country's statistics on regional economic indices, OD volume of international container cargo in country basis is divided into regional base OD data. Concretely,

- 1) Vietnam: Based on "Trade (Retail sales of domestic economic sector / Direct export of the local)" data published by Statistical Publishing House Ha Noi, it is divided into 8 regions,
- 2) Thailand: Based on "Gross Regional and Provincial Product at 1988 Prices (2001)" data published by National Statistical Office, it is divided into 7 regions,
- 3) Malaysia: Based on "Value of gross output (2001)" data published by Department of Statistics Malaysia, it is divided into 13 regions, and
- 4) Indonesia: Based on "Gross Regional Domestic Product Without Oil and Gas At Constant 1993 Market Prices by Province (2003)" data by Statistical Yearbook of Indonesia (2004), it is divided into 6 regions,

as shown in Figure 11. The estimation results of OD containers will be shown in presentation.

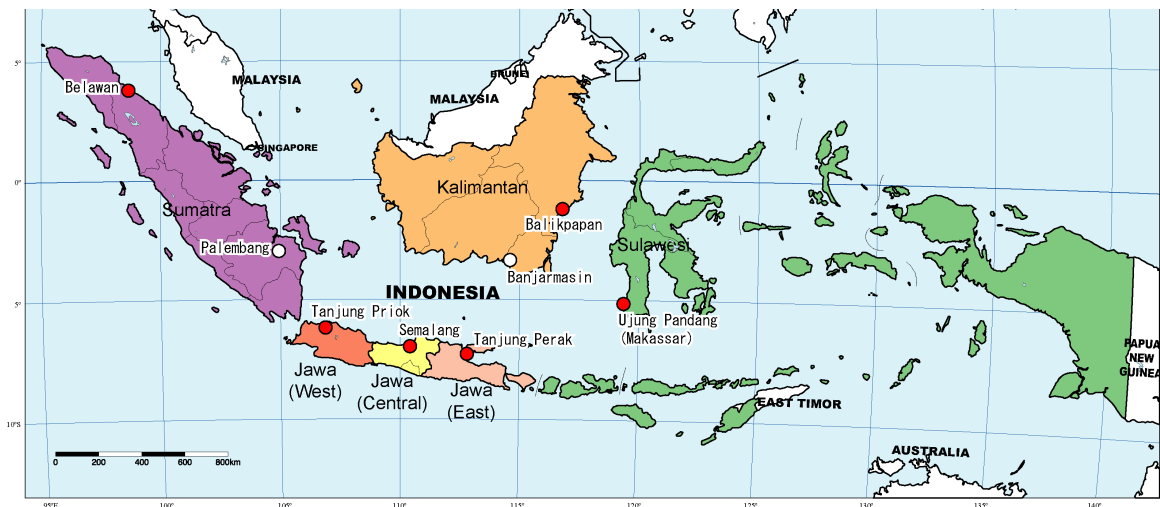
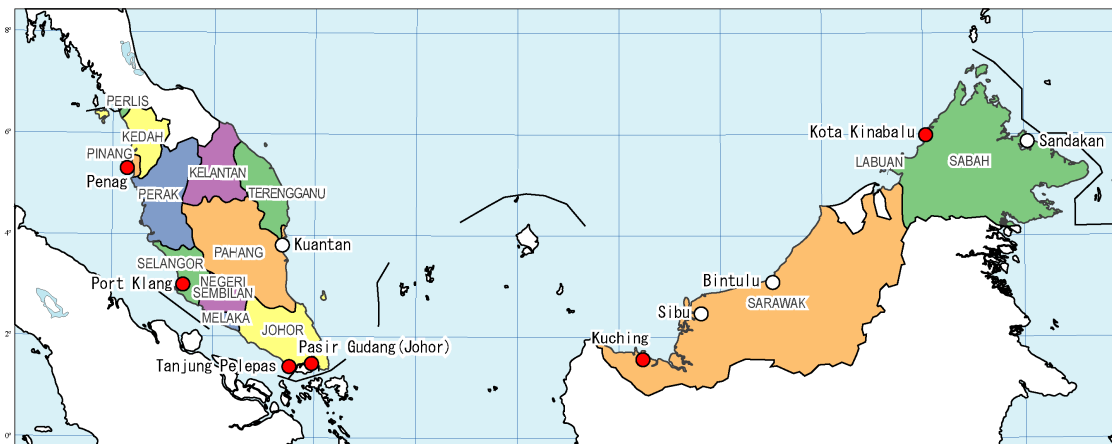
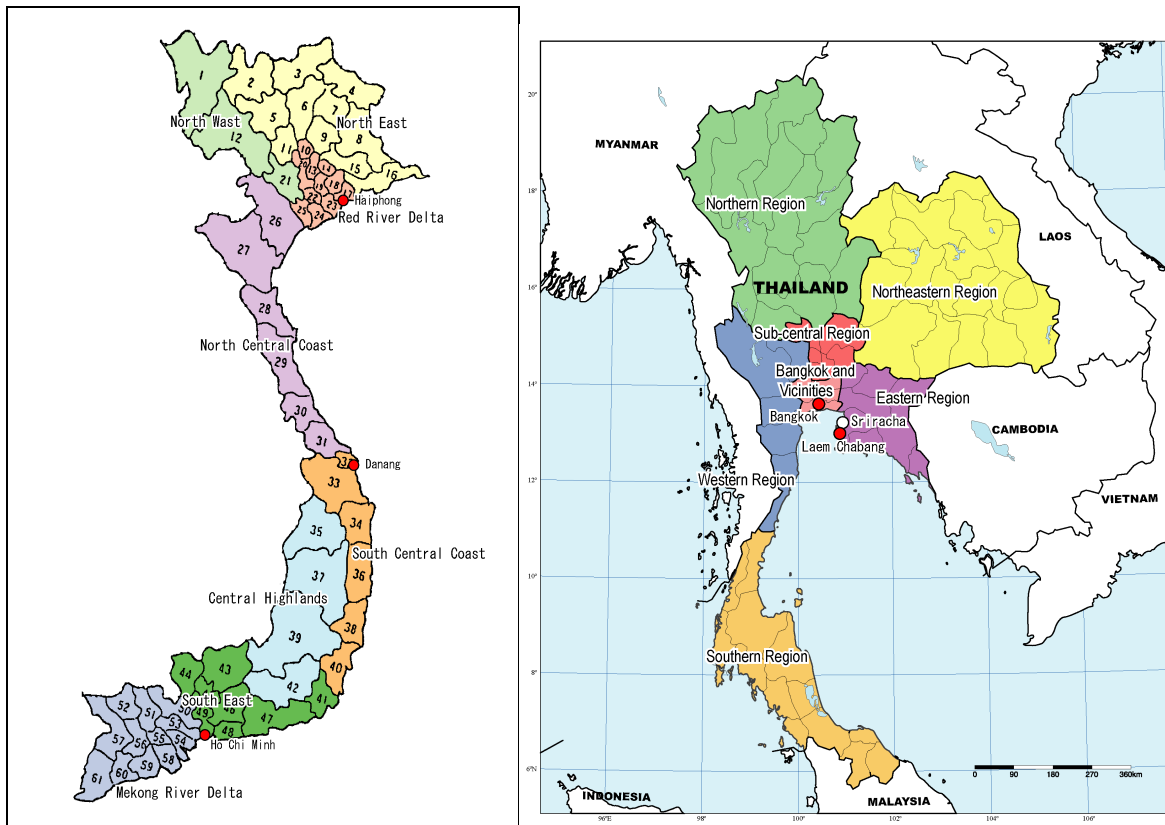


Figure 11. Regional division for larger Southeast Asian countries

(Vietnam, Thailand, Malaysia, and Indonesia)

Calculation and Simulation Results of Model

Calculation results of the model that is extended to Southeast Asia with international land transport network including cross-border and some simulation results of the policies on infrastructure improvement using the extended model will be shown at the presentation time.

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