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Intermodal Freight Simulation in Southern Mekong Region: Route Choice Model for International Container Shipping

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Abstract: Southern Mekong Region including Cambodia and South Vietnam is currently seeing not only economic growth but also increased investment in infrastructure such as seaports, river ports, and roads. There are four major routes for international container shipping between Cambodia (mainly her capital city, Phnom Penh) and partner countries such as China, USA and Europe; i) utilizing a barge on the Mekong River through Phnom Penh Port (and transshipped at Vietnamese ports including Cai Mep/Thi Vai and Ho Chi Minh), ii) land transport to Vietnamese ports across the national border by truck, iii) via Sihanoukville Port (and transshipped at hub ports such as Singapore), and iv) via Laem Chabang Port in Thailand by land transport across the national border. This paper develops a route choice model of Cambodian international container cargo on the intermodal network including both maritime and land shipping, and does several policy simulations to improve the condition of each shipping route such as improvement of river shipping and a bridge construction over the Mekong River.

Key Words: *Intermodal Transport, Greater Mekong Subregion(GMS), Route Assignment Model, International Shipping, Cross-border Transport*

1. INTRODUCTION

The Kingdom of Cambodia, one of ASEAN countries, is surrounded by Thailand, Vietnam, Lao PDR, and the ocean. She has a coastal line along Thailand Bay, although it is rather far from her capital city, Phnom Penh (PP), which is also the center of her economy. Sihanoukville (SV) Port, which is the most important seaport in Cambodia, is located about 240km away from the capital city.

On the other hand, PP is located along the Mekong River, the longest river in Southeast Asia which eventually meets the sea in southern Vietnam. It is connected by roads (Asian Highway No.1 road) with Ho Chi Minh (HCM), the major city of southern Vietnam, and Bangkok, the capital city of Thailand. Accordingly, international cargo which originates from or is destined to PP has several transport alternatives.

Viewed from another side, Cambodian cargo (mainly cargo from/to PP) has a handicap fin that PP does not have any seaports nearby. An additional shipping cost is required for the cargo to/from PP to connect with the seaports (such as SV, HCM, and Laem Chabang in Thailand) by land or river shipping for accessing the international market. This situation is not often observed in other countries. There are few Asian countries where the capital city is located far from the seaports but which have multiple options in accessing different seaports except for the landlocked countries such as Lao PDR, Mongolia, and Central Asian countries. New Delhi, the capital city of India, also has multiple access to different seaports (i.e. both on the east and west coast of the Indian subcontinent), which is a problem within the country. The problem facing Cambodia is more complicated because it includes the international hinterland transport crossing national borders on land or river (i.e. cross-border transport).

In other words, the international shipping of Cambodian cargo is one of the most complicated in Asian countries, in terms of the choice of the gateway port for export and import, including both her own seaports and neighboring countries' seaports, as well as including both road and river shipping as hinterland transport. Therefore, it is necessary to develop a route choice model for Cambodian international cargo in order to measure the impact of infrastructure improvement and other related policies on international logistics in Cambodia, because a policy which improves the condition on a specific route will also affect the transport volume on all the routes, not only the route in question.

Several papers and reports focus on the shipping routes and their competitive situation of Cambodian international cargo. Hanaoka (2013) described and analyzed the competitive situation of the SV and PP Ports. The PP Port is regarded as a feeder port of Cai Mep/Thi Vai (CMTV) Port, which is an outer port of the HCM city. Srivastava and Kumar (2012) and JETRO (2013) reported on the current situation of southern economic corridor of the Greater Mekong Subregion (GMS) which is mainly connecting Bangkok, PP and HCM, while fewer reports (e.g. Belgian Technical Corporation, 2006) are available on the current situation and issues to be tackled on river transport in Cambodia.

JICA (2012) developed a logit model for route choice of Cambodian international containers including the Mekong River route, cross-border route to CMTV Port by land, and the SV Port route, as well as forecasting the future shipping demand of the total Cambodian international cargo. JICA (2013) also developed a step-wise logit model in which the first step is a choice of the CMTV and SV Port and the second step is a choice of the land and river shipping if the CMTV route is selected. ADB (2006) developed an incremental assignment model on the intermodal transport network including road, railways, and water transport in the entire GMS. However, in these models, maritime shipping is not considered or simplified as a given condition. Also, the logit models considered by JICA focused on Cambodian international container cargo but the number of trade partners was limited due to the nature of the logit model. The authors (APEC, 2010) also developed a model for the international freight flow simulation on the intermodal transport network in the APEC member economies. In this simulation, the entire land shipping network and aggregated maritime shipping network in Southeast Asia are included, although it is not specifically focused on the Cambodian cargo, so does ADB (2006).

The authors (Shibasaki, et al., 2014) developed a container cargo assignment model on the intermodal international shipping network including worldwide maritime network and regional land network. It was applied in Central America including several countries sharing a border for simulating the impact of policies on the port maintenance and other related logistics. This paper aims to apply the same model by focusing on the Lower Mekong Region and route choice problem of the Cambodian international container cargo.

The paper is structured as follows: Section 2 summarizes the current situation of the four major shipping routes connecting Phnom Penh with gateway seaports. Section 3 describes a route choice model and data for input. Section 4 validates the model performance and the results of policy simulation. Finally, the achievements of the paper are summarized and further research issues are presented in Section 5.

2. CURRENT STATUS OF INTERNATIONAL SHIPPING ROUTE TO/FROM PHNOM PENH

There are four major routes for international cargo shipping to/from PP as shown in Figure 1; A. Mekong River Shipping Route via PP River Port connecting with Vietnamese Ports including HCM or Cai Mep/Thi Vai (CMTV), B. International Road Shipping Route directly connecting with Vietnamese Ports, C. Domestic Road Shipping Route to utilize SV Port, and D. International Road Shipping Route connecting with Laem Chabang (LC) Port in Thailand. Each route is outlined below. Also the major conditions for each shipping route are summarized in Figure 2.

2.1 Mekong River Route (via Phnom Penh River Port)

Most barges departing the PP River Port navigate the Mekong River, the Tien River (local name of the Mekong River in Vietnam), and the Chi Gao Canal to avoid navigating the ocean, heading to the Vietnamese ports including CMTV and HCM.

The PP New Port, which is a new container terminal, was opened in 2010. The new terminal is located about 24 km away from the city center of PP along the National Highway No.1 on the way to Neak Loeang and national border to Vietnam. The volume of containers handled in 2013 is about 110,500 TEU, which has been increasing in recent years and is expected to exceed the terminal capacity (150,000 TEU) within a few years; therefore, the second phase of the terminal is being developed. Cargo other than containers is still handled in the “old port” which is located in the city center of PP.

Another problem of the PP New Port is land access. A 4km section of the NH1 still needs to be widened and repaved. In addition, the government instituted a ban on heavy vehicles entering into the PP city center during the daytime from October 2013. This has had a large impact on container drayage because there are no detour routes to avoid the ban when entering into the city center as well as passing through the city to the suburban area in the north, west and south of PP during the daytime.

Table 1 shows a summary of regular container shipping service by barge connecting PP and Vietnamese ports. The number of regular service per week is fifteen as of 2010 according to the table, although more than twenty services per week are currently provided. The table also reveals that all barges call first at the CMTV Port then HCM Port after departing PP Port and that most of them leave PP Port from Friday to Saturday. This reflects the fact that most Cambodian export cargo utilizes the CMTV Port while most of her import cargo uses the HCM Port as described in detail later, as well as that most mother vessels leave the CMTV Port in the first half of the week.

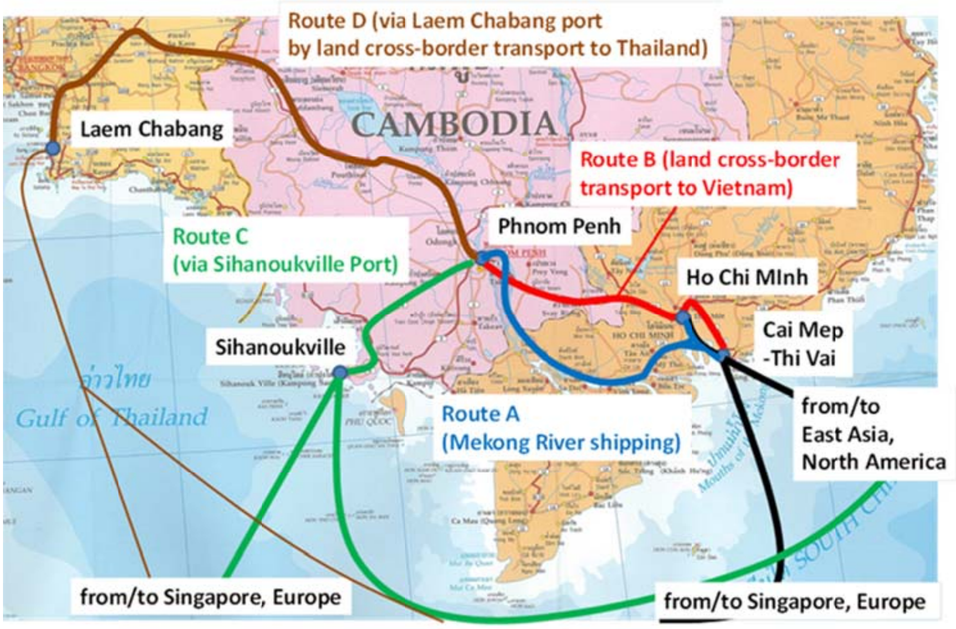


Figure 1 Major shipping routes of international cargo from/to Phnom Penh

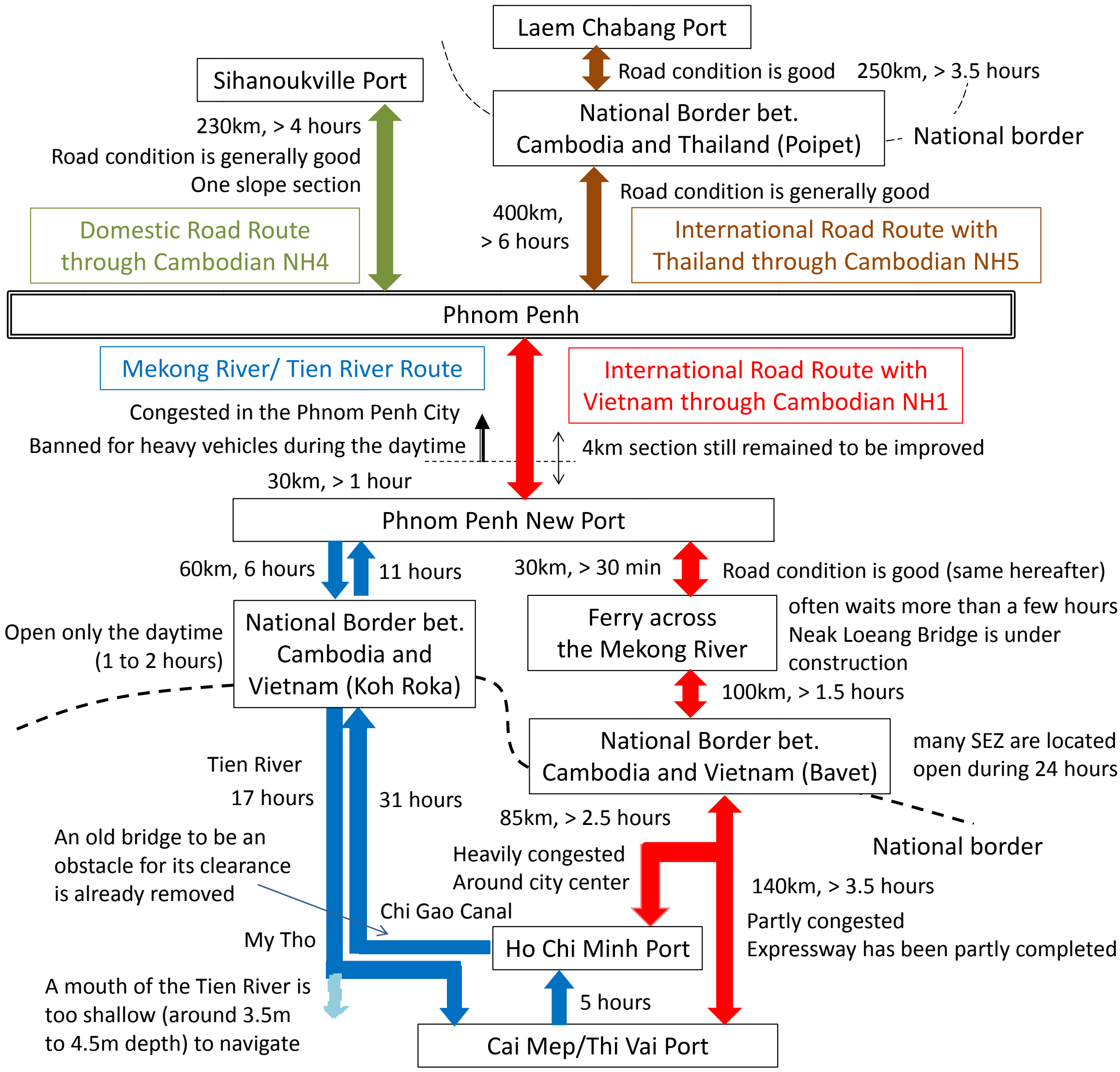


Figure 2 Major conditions for each international shipping route from/to Phnom Penh

Table 2 shows a typical schedule of barge for container shipping. After departing PP Port, a barge arrives at the national border (Koh Roka) between Cambodia and Vietnam in about six hours. The gates of the border only open during the daytime and their opening hours are slightly different on both sides of Cambodia and Vietnam. Although almost all the necessary procedures for customs clearance and international trade are completed before leaving the PP Port, the barges need to stop at the border and have the documents checked. It takes around two hours.

After navigating the Tien River near My Tho, the capital city of Tien Giang Province of Vietnam, most barges navigate the Chi Gao Canal which connects the Tien River and HCM/CMTV Port without navigating the ocean. Navigation of larger barges was hampered in the Chi Gao Canal due to insufficient clearance of a bridge until a new bridge was constructed and the old one removed last year.

The CMTV port has been developed in the deep water area near the ocean about 80km away from the HCM city, as an outer port of the HCM Port which is located along the Saigon River and Nha Be River with shallow berths. The first terminal was opened in 2009. Figure 3 shows the regular container shipping services which call at the CMTV Port as of May 2010. Seven services out of eight services in total are connecting with the United States or Europe with large containerships (their average capacity is 5,940 TEU), because the CMTV Port has the deep berths to accommodate them. On the other hand, the HCM Port still keeps many regular container services in intra-Asian routes connecting with Southeast and Northeast Asia including ports of Japan, China, Taiwan, Hong Kong, Singapore, and Malaysia, despite its shallow berths. According to the MDS database which provides information on the containership movements all over the world, forty-seven services were provided by various shipping companies as of May 2010. Their average capacity is 1,270 TEU.

Table 1 Summary of container shipping service (barge service) between Phnom Penh and Vietnamese Ports through the Mekong River as of 2010 (source: JICA, 2012)

Shipping line	Frequency	Turnround	Interval (days)	Vessels deployed	Fleet capacity (TEU/ service)	Average capacity/vessel (TEU)	Number of voyages /year	Fleet capacity /year (TEU)	Calling ports	Vessel name (capacity; TEU)	Departure day
Gemadept	weekly	7	0.8	9	728	81	469	37,960	Phnom Penh-Cai Mep-Ho Chi Minh-Phnom Penh	Gemadept 18 (112) Song Xanh 18 (112) Phuoc Long 16 (72) Phuoc Long 18 (72) Phuoc Long 20 (72) Phuoc Long 22 (72) Phuoc Long 24 (72) Phuoc Long 26 (72) Phuoc Long 28 (72)	Mon, Fri, Sat
Sovereign Base Logistics	weekly	7	2.3	3	312	104	156	16,269	Phnom Penh-Cai Mep-Ho Chi Minh-Phnom Penh	Golden Fortune 1 (96) Golden Fortune 2 (96) Golden Fortune 8 (120)	Thu, Sat
SNP-Cypress	weekly	7	3.5	2	168	84	104	8,760	Phnom Penh-Cai Mep-Ho Chi Minh-Phnom Penh	Tay Nam 08 (84) Cai Mep 06 (84)	Tue, Sat
Hai Minh	weekly	7	7.0	1	72	72	52	3,754	Phnom Penh-Cai Mep-Ho Chi Minh-Phnom Penh	Hai Minh 08 (72)	n/a
Mekong River Waterway Total				15	1,280	85	782	66,743			

Table 2 Typical schedule of container shipping service between Phnom Penh and Vietnamese Ports (source: JICA, 2012)

Sunday	01:00	ETD	Phnom Penh
Sunday	07:00	ETA	Border
	09:00	ETD	Border
Monday	02:00	ETA	Cai Mep
	05:00	ETD	Cai Mep
Monday	10:00	ETA	Ho Chi Minh
Wednesday	24:00	ETD	Ho Chi Minh
Friday	07:00	ETA	Border
	09:00	ETD	Border
Friday	20:00	ETA	Phnom Penh

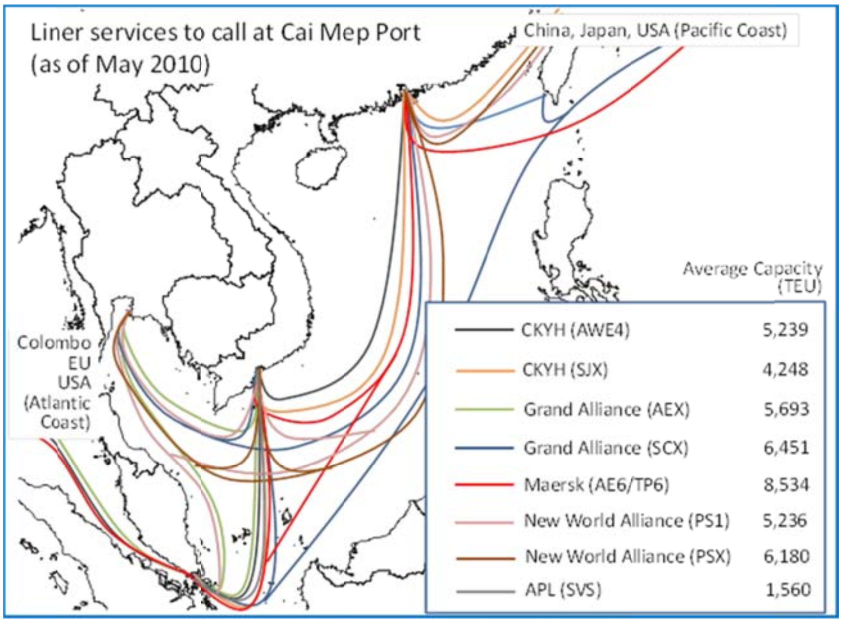


Figure 3 Regular container shipping service in the CMTV Port as of May 2010 (source: made by the authors from the MDS database)

2.2 International Road Route with Vietnam (via Ho Chi Minh or Cai Mep Port)

The distance between PP and HCM Port is around 240km along the Asian Highway No.1 (AH1) road, while that between PP and CMTV Port is around 300km. There is a ferry service to cross the Mekong River in Neak Loeang, which is located about 60km away from the PP city. Although the ferry service is frequent, a trailer with container has to wait about a few hours on average for boarding according to the authors' interview, because the ferry can accommodate only one large vehicle per navigation due to its size. A bridge is under construction near the ferry station, which is expected to open in early 2015.

Around the national border (i.e. Bavet) along the AH1 between Cambodia and Vietnam, a few special economic zones (SEZ) and dryports are located. Table 3 showing the number of vehicles to transit as well as the value and volume of cargo across a national border reveals that the origin and destination of many trucks entering/leaving Vietnam is Bavet. In particular, around 80% (3,895 unit) of trucks for Cambodian export cargo in 2011 originates from Bavet (most of them are considered to come from the factories located in the SEZs in Bavet), not from the PP city.

Table 3 Value and volume of cargo and number of vehicles transiting the national border between Cambodia and Vietnam in AH1 (source: JICA, 2013)

		2007	2008	2009	2010	2011
Import	Import Value (USD)	94,862,989	74,405,246	184,526,610	248,628,629	395,359,564
	Weight (Ton)	37,133	35,288	58,492	80,502	108,997
	Container Trucks to Bavet Area	2,097	2,856	2,200	3,085	4,773
	Non Container Trucks to Bavet Area	1,314	1,613	2,957	3,376	4,135
	Container Trucks to PP Area	-	1,478	3,673	10,974	15,243
	Bus	5,018	7,716	9,825	14,658	17,996
Export	Export Value (USD)	74,532,421	84,204,754	139,408,340	149,112,568	221,860,556
	Weight (Ton)	14,524	14,668	22,289	20,376	22,715
	Container Trucks from Bavet Area	1,923	2,198	1,901	2,591	3,299
	Non Container Trucks from Bavet Area	213	79	411	532	596
	Container Trucks from PP Area	-	-	161	736	951
	Bus	5,015	7,714	9,868	14,608	18,001

The road conditions for most of all sections are good, except for a few kilometers near the PP city (between the PP city and PP new port) as mentioned in 2.1. The road sections in Cambodia have been improved in recent years with assistance from JICA and ADB.

2.3 Sihanoukville Route (via Sihanoukville Port)

The distance between PP and SV Port is around 230km, which is similar to the distance between PP and HCM. The road condition of NH4 is generally good, although it passes through a mountainous area in one section. The railways connecting PP and SV Port have also been rehabilitated with the assistance of ADB. Since operations restarted last year, around 1,000 TEU containers per month, mainly containing rice, were transported by the railways.

The SV Port is the most important seaport in Cambodia. The amount of containers handled in the SV Port was around 260,000 TEU in 2012. Figure 4 shows the regular container shipping services which call at the SV Port as of May 2010. Five out of six services in total are the feeder service in the Thailand Bay connecting with the Singapore and Malaysian Ports (i.e. Tanjung Pelepas and Klang) with small vessels (their average capacity is 700 TEU), while the other one service is connecting with the ports in Japan, China, and Hong Kong.

2.4 International Road Route with Thailand (via Laem Chabang Port)

The distance between PP and LC Port in Thailand is around 650 km along Cambodian NH5 through the national border of Poipet/Aranyaprathet. The road condition is generally not bad, although there is only one lane for each direction in most sections. Although trucks have been able to cross the border of the two countries without any transshipment since June 2012, very few trucks have actually taken advantage of this arrangement and directly connect with PP and Thai cities such as Bangkok. The reason is that the quota is very small and transport over a long distance is needed in each country.

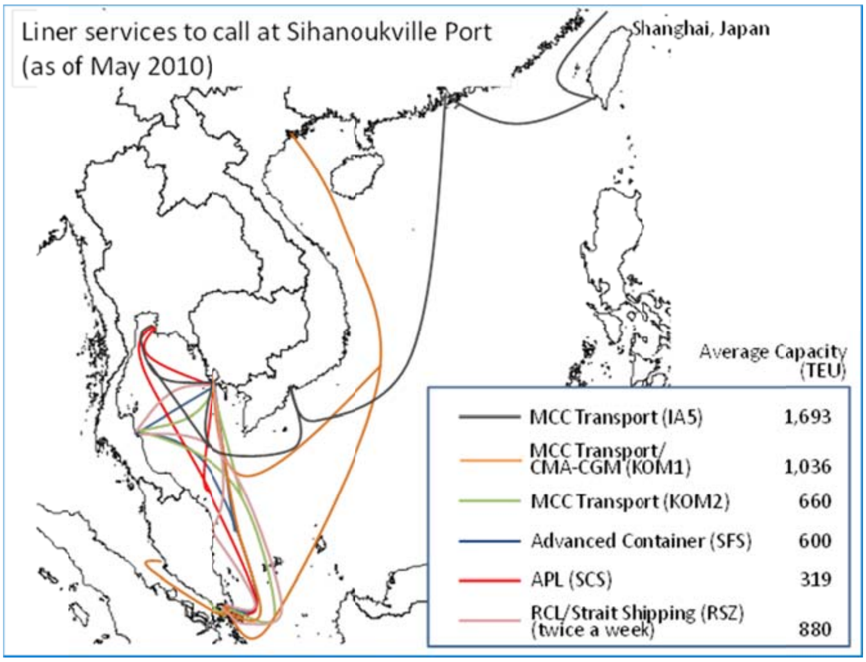


Figure 4 Regular container shipping service in the SV Port as of May 2010
(source: made by the authors from the MDS database)

According to the survey by JETRO (2013), there are still no examples of PP cargo utilizing the LC Port for export to or import from the third countries through this route. However, there are some examples in which cargo that originated from the border area in Cambodia (in the Poipet SEZ) utilized the LC Port as an export port to Europe. In addition, some Japanese companies utilize the route between PP and Bangkok as part of their international division of labor strategy; for example, the materials of auto parts are imported from Thailand to an assembly factory located near PP and the finished parts are returned back to Thailand through the route.

2.5 Share of each route

Figure 5 shows the amount of Cambodian international container cargo shipped in each route (gateway port); A: the Mekong River shipping via the PP Port, B: direct land transport connecting with Vietnamese ports (HCM and CMTV Port), and C: maritime shipping via the SV Port. The amount of containers utilizing D: the LC Port via national borders between Cambodia and Thailand on land are not shown in the figure due to lack of available data. Table 4 shows the share of these three routes for export/import by year.

More than half of Cambodian international containers utilizes the SV Port for both export and import, but the share of the SV Port is gradually decreasing. In particular, the share in export containers drastically decreased from 88% in 2007 to 55% in 2012. On the other hand, the share of river transport via the PP Port is rapidly increasing in export containers, while that in import containers keeps constant. In addition, the share of direct road transport connecting with the Vietnamese ports are increasing in both export and import containers. This is thought to be the result of the many policies introduced to improve the condition of the road and river transport between PP and HCM, including not only infrastructure investment such as the construction of new container terminal and road improvement, but also cross-border facilitation such as reducing protocol time and cost and increasing the quota of the number of trucks that can directly pass through without any transshipment at the border.

It can also be seen that the share of river shipping is larger than that of international road transport in export, while that the share of river shipping is smaller than that of international road transport in import. One possible explanation for this may be that import cargo is coming from various Northeast Asian ports by various shipping companies in the intra-Asian routes mainly via the HCM Port, while export cargo is mainly going to the United States or Europe via the CMTV Port; i.e., the destination ports and shipping companies providing the service are relatively limited, as will be discussed later in detail.

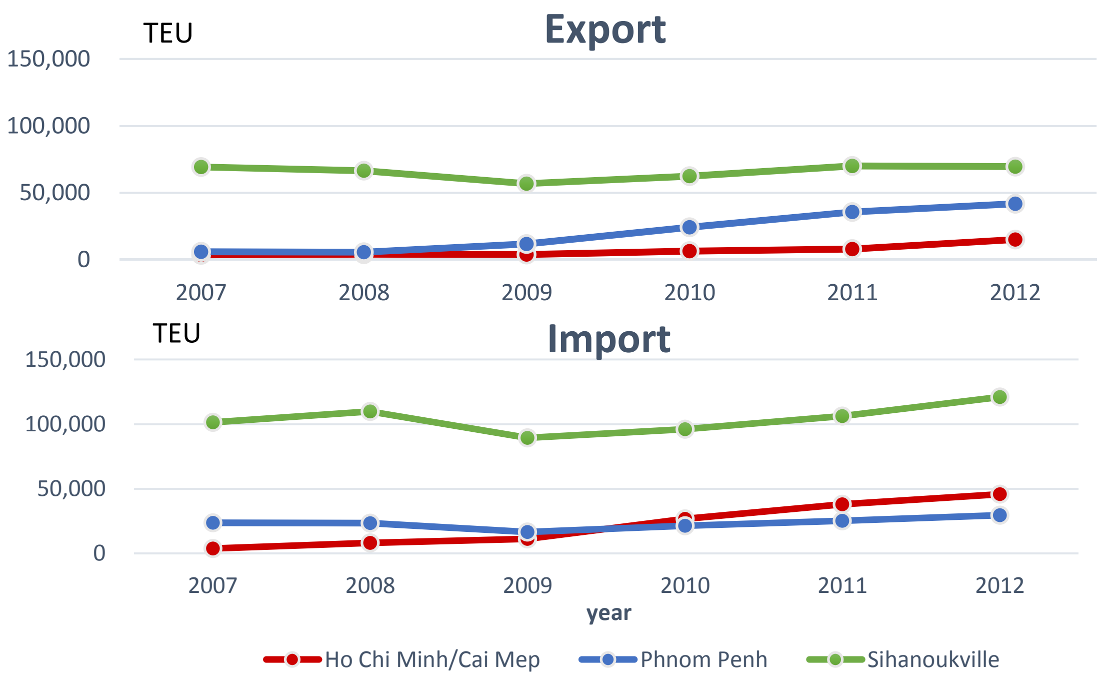


Figure 5 Amount of Cambodian international laden containers transported by route (gateway port) (source: IRITWG, 2012 and JICA, 2013)

Table 4 Share by shipping route (gateway port) of Cambodian international laden containers

年	Export			Import		
	Ho Chi Minh/ Cai Mep	Phnom Penh	Sihanoukville	Ho Chi Minh/ Cai Mep	Phnom Penh	Sihanoukville
2007	4.6%	7.5%	87.9%	3.1%	18.4%	78.5%
2008	5.5%	7.5%	87.0%	5.8%	16.7%	77.5%
2009	5.4%	16.2%	78.4%	9.5%	14.3%	76.2%
2010	6.8%	26.1%	67.1%	18.5%	14.8%	66.6%
2011	7.1%	31.3%	61.6%	22.4%	14.9%	62.7%
2012	11.9%	33.1%	55.0%	23.4%	15.1%	61.6%

3. ROUTE CHOICE MODEL OF CAMBODIAN INTERNATIONAL CONTAINER CARGO

The container cargo assignment model developed in Shibasaki, et al. (2014) is applied in the intermodal network of the Southern Mekong region. The rough structure of the model is described as follows.

3.1 Model Structure

The model is developed from a viewpoint of cargo owners (or shippers). Each shipper is assumed to choose the ports to be used for export and import, given the freight charges for maritime and land transport, and shipping time, on the intermodal network including both land and maritime shipping as shown in Figure 6. The inland waterway shipping in the Mekong River is basically included in the maritime shipping network, although a special treatment is considered which will be described in 3.5.

In this paper, a stochastic assignment model that can consider the influence of unobservable elements from the model developer is applied to describe the behaviour of shippers for port choice, since it usually has a good fitness to the reality despite the model formulation being quite simple.

When H_{ij} is the path choice set of cargo shipping demand Q_{ij} (TEU) from region i to region j ($ij \in \Omega$; Ω is the set of OD pair), a path h is chosen for a cargo m so as to maximize utility U_{ijhm}, including an error term ε_{ijhm}, that is,

$$U_{ijhm} > U_{ijh'm}, \quad \forall h \in H_{ij}, \forall h' \in H_{ij}, h \neq h', \forall ij \in \Omega, \tag{1}$$

$$s.t. \quad U_{ijhm} = -G_{ijh} + \varepsilon_{ijhm}, \tag{2}$$

where G_{ijh}: shipping cost (US\$/TEU) of path h from region i to region j. If the error term ε_{ijhm} follows Gumbel distribution, the choice of shipper is formulated as

$$F_{ijh} = Q_{ij} \cdot \frac{\exp(-\theta \cdot G_{ijh})}{\exp(-\theta \cdot G_{ijh}) + \sum_{h' \in H_{ij}} \exp(-\theta \cdot G_{ijh'})}, \tag{3}$$

where F_{ijh}: cargo volume on a path h from region i to region j, and θ: distribution parameter. The shipping cost G_{ijh} for each path is expressed by the equation below.

$$G_{ijh} = GL_{ir} + GPX_r + GM_{rs} + GPM_s + GL_{sj}, \qquad \forall r \in h, \forall s \in h \tag{4}$$

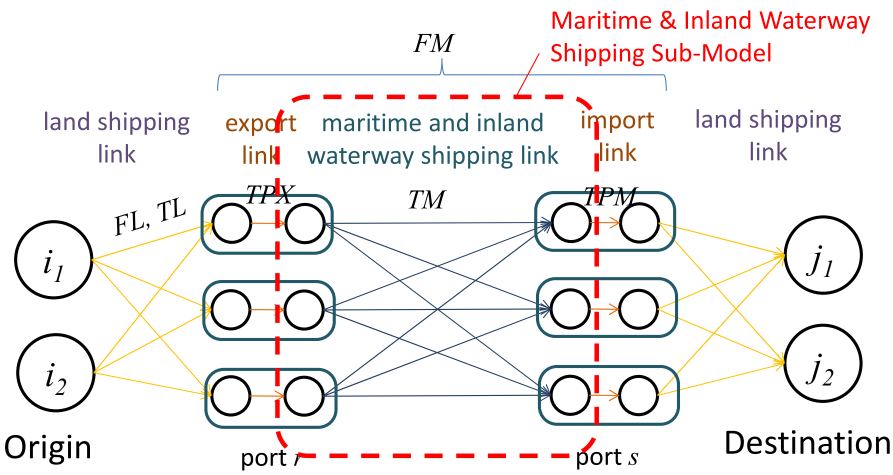


Figure 6 Shipping network of the model

where GL_{ri}, GL_{sj}: generalized land shipping cost from origin region r to port i and from port j

to destination region s, GPX_r: generalized port cost of export port r, GM_{rs}: generalized maritime and inland waterway shipping cost from export port r to import port s, and GPM_s: generalized cost of import port s.

The generalized cost of each link is expressed as the sum of freight charge and "time cost" which is defined by multiplying shipping time by value of time for shippers. Namely,

$$GL_{ir} = FL_{ir} + vt \cdot TL_{ir}, \quad GL_{sj} = FL_{sj} + vt \cdot TL_{sj}, \tag{5}$$

$$GPX_r = vt \cdot TPX_r \tag{6}$$

$$GM_{rs} = FM_{rs} + vt \cdot TM_{rs}, \qquad \text{and} \tag{7}$$

$$GPM_s = vt \cdot TPM_s, \tag{8}$$

where vt: value of time for shipper (US$/TEU/hour), FL_{ir}, FL_{sj}: freight charge of land shipping from origin i to port r and from port s to destination j (US$/TEU), TL_{ir}, TL_{sj}: land shipping time (hours) from origin i to port r and from port s to destination j, TPX_r: lead time when exporting in port r (hours), FM_{rs}: ocean freight charge from port r to port s (US$/TEU) including inland waterway shipping and port charges, TM_{rs}: maritime and inland waterway shipping time (hours) from port r to port s, and TPM_s: lead time when importing in port s (hours). Note that any monetary costs are not considered in the port links (i.e. export and import link), since we assume the ocean freight charge, FM_{rs}, includes all port charges, not only for export and import port but also transhipment port on the way of shipping.

3.2 Maritime and inland waterway shipping submodel

The maritime and inland waterway shipping time, TM_{rs}, shown in Equation (7) are estimated from the output of the maritime and inland waterway shipping submodel. The submodel was developed by the Shibasaki, et al. (2013), which basic concept is shown as follows.

The model is defined as a problem to allocate container cargo on the worldwide liner shipping network made from the containership movement data (the MDS database). Each liner shipping network is structured as shown in Figure 7. Each container of the shipper will choose an "optimum" link from origin node (O node) of an export port to destination node (D node) of an import port. In this submodel, every container of each OD pair is assumed to choose a route to minimize its total transit time. The shipper chooses a carrier with consideration of only transit time, not freight charge at all. This assumption is based on the idea that the international maritime container shipping market is oligopolistic but a freight charge for an OD pair is the same among carriers if the service is provided and utilized.

Since vessels of each service have their own capacities, there is diseconomy of scale by concentrating into a specific service. Therefore, the congestion of the link is considered and a User Equilibrium (UE) assignment is applied as network assignment methodology.

$$\min_x z(x) = \sum_{a \in A} \int_0^{x_a} t_a(x_a) dx, \tag{9}$$

subject to

$$x_a = \sum_{(r,s) \in O \times D} \sum_{k \in K_{rs}} \delta_{a,k}^{rs} \cdot f_k^{rs}, \qquad \forall a, \tag{10}$$

$$\sum_{k\in K_{rs}} f_k^{rs} - q_{rs} = 0, \quad \forall r,s, \quad \text{and} \tag{11}$$

$$f_k^{rs} \geq 0, \quad \forall k,r,s, \tag{12}$$

where a: link, A: set of link, x_a: flow of the link a, $t_a(.)$: cost function of the link a, $z(.)$: objective function, r: origin, s: destination, O: set of origin, D: set of destination, k: path, K_{rs}: set of path for OD pair rs, δ_{krs}: Kronecker delta, f_{krs}: flow on the path k, and q_{rs}: cargo shipping demand from r to s. Kronecker delta, δ_{krs}, is written as

$$\delta_{a,k}^{rs} = \begin{cases} 1 \text{ if } a \in k \\ 0 \text{ if } a \notin k \end{cases}. \tag{13}$$

For a detailed description of the cost function for each link, please see Shibasaki, et al. (2013) except for an inland waterway shipping link. The shipping time of the inland waterway shipping link is written as

$$t_w(x_a) = \frac{l_a}{v_a} + TW_{a'} \cdot b1\left(\frac{x_a}{cap_a \cdot freq_a}\right)^{b2} \tag{14-1}$$

if the link does not pass through a national border, where t_w: cost of the inland waterway shipping link (hour), x_a: container cargo flow of the link a (TEU/year), l_a: distance of the link a (NM), v_a: vessel speed of the link a (knot), a': loading link in the departure port of the inland waterway shipping link a, $TW_{a'}$: expected waiting time for the loading of the loading link a' (hour), cap_a: average vessel capacity of the service (TEU/vessel), $freq_a$: frequency of the service (vessels/year), and $b1$, $b2$: parameters related to the congestion, which are set to $b1$ = 2.309 and $b2$ = 1.017 as estimated in Shibasaki, et al. (2013). This formulation is exactly the same as the maritime shipping time described in Shibasaki, et al. (2013)..

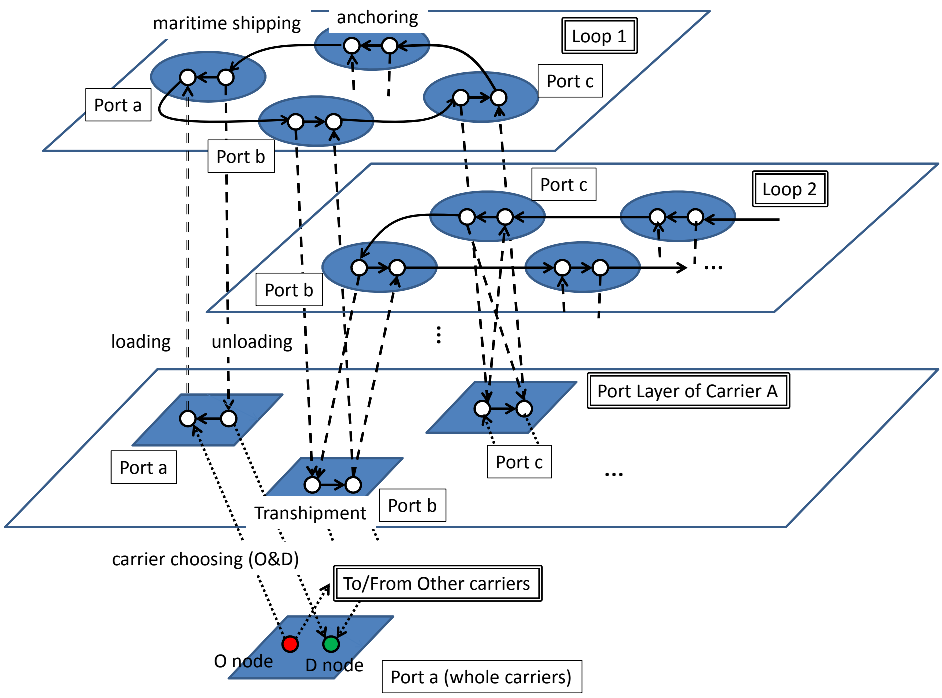


Figure 7 Network structure of the maritime shipping submodel
(source: Shibasaki, et al., 2013)

However, if the inland waterway link passes through a national border, the border-crossing time should be considered because some additional time is actually needed when crossing the border by the inland waterway shipping as well as the land shipping, which is different from the maritime shipping. Therefore, the formulation of the inland waterway shipping time described in Equation (14-1) is rewritten as

$$t_w(x_a) = \frac{l_a}{v_a} + TW_{a'} \cdot b1\left(\frac{x_a}{cap_a \cdot freq_a}\right)^{b2} + \alpha^w \cdot TB_a \,, \tag{14-2}$$

if the link passes through a national border, where TB_a: border-crossing time of the link a (hour), and α^w: coefficient on bonded transport for inland waterway shipping. The coefficient on bonded transport, α^w, is an adjustment unknown parameter, since TB_a is defined as the time for documents preparation in export and import, not transit, from a “doing-business database” provided by the World Bank. The results will be compared later for the several settings of α^w.

Of the networks, only the navigating link has a flow-dependent cost function. The cost functions of other links are flow-independent. Therefore, the UE problem defined in Equation (9) will be solved in the algorithm shown by Sheffi (1985). According to the UE assignment definition, maritime and inland waterway shipping time, TM_{rs}, in Equation (7) is defined as

$$TM_{rs} = \min_k \left\{ \sum_{a \in k} t_a(x_a) \right\} . \tag{15}$$

3.3 Ocean freight charge

The ocean freight charge (including inland waterway shipping) on each maritime and inland waterway shipping link, FM_{rs}, in Equation (7) provided by carrier is generally different from the monetary cost of the route for the carrier, reflecting the balance of demand and supply on the market. In particular, since the maritime container shipping industry has an oligopolistic market in which surplus of supplier may exist, it should be carefully examined. First, the maritime and inland waterway shipping cost is calculated, and then the methodology to estimate freight charge from the cost information is shown.

(1) Cost of maritime and inland waterway shipping

Shipping cost of each link included in the maritime and inland waterway shipping submodel is defined per TEU as follows.

1) Navigating link

Cost of navigation in the maritime shipping, c_m, consists of the fuel cost, capital cost, operation cost, and canal toll as

$$c_m(x_a) = \left\{ \left(FC_a + CC_a + OC_a\right) \cdot \frac{l_a / v_a}{24} \right\} \Big/ \frac{x_a}{freq_a} \tag{16-1}$$

if the link does not pass through the Suez Canal or Panama Canal, or

$$c_m(x_a)=\left\{(FC_a+CC_a+OC_a)\cdot\frac{l_a/v_a}{24}+CT_a\right\}\Big/\frac{x_a}{freq_a} \tag{16-2}$$

if the link passes through the Suez Canal nor Panama Canal, where x_a: container cargo flow of the link a (TEU/year), FC_a: fuel cost of container vessel (US$/vessel/day), CC_a: capital cost of container vessel (US$/vessel/day) , OC_a: operation cost of container vessel (US$/vessel/day), CT_a: canal toll for the Panama and Suez Canal of container vessel (US$/vessel), l_a: distance of the link a (NM), v_a: vessel speed of the link a (knot), and , $freq_a$: service frequency of the loop (vessels/year). The term $x_a/freq_a$ represents the average amount of containers transported in one vessel. The details of each cost item are omitted in this paper.

Also, the cost of navigation in the inland waterway shipping, c_w, is defined as

$$c_w(x_a)=\left\{(FC_a+CC_a+OC_a)\cdot\frac{l_a/v_a}{24}\right\}\Big/\frac{x_a}{freq_a} \tag{17-1}$$

if the link does not pass through a national border, or

$$c_m(x_a)=\left\{(FC_a+CC_a+OC_a)\cdot\frac{l_a/v_a}{24}\right\}\Big/\frac{x_a}{freq_a}+\alpha^w\cdot CB_a \tag{17-2}$$

if the link passes through a national border, where CB_a: border-crossing cost of the land shipping link a (hour), as the similar consideration of the inland waterway shipping time described in Equation (14-1) and (14-2).

2) Loading, unloading, transhipment and carrier choosing link

In these links, port charge (terminal handling charge, THC_a) should be considered. In order to reflect an empirical fact that handling charge for the transhipment is less than double of that for the loading or unloading, cost of each link is defined as

$$c_l(x_a)=SSN, \tag{18}$$
$$c_u(x_a)=SSN, \tag{19}$$
$$c_r(x_a)=0.75\cdot(CHX_a+CHM_a), \tag{20}$$
$$c_{cx}(x_a)=CHX_a \text{ , and} \tag{21}$$
$$c_{cm}(x_a)=CHM_a, \tag{22}$$

where c_l: cost function of loading link (US$/TEU), c_u: cost function of unloading link (US$/TEU), c_r: cost function of transhipment link (US$/TEU), c_{cx}: cost function of carrier choosing export link (US$/TEU), c_{cm}: cost function of carrier choosing import link (US$/TEU), SSN: sufficient small number (in this model, we assume SSN = 0.01 US$), and CHX_a, CHM_a: container handling charge when container cargo is loaded and unloaded respectively of port a (US$). Note that in order to avoid giving a negative link cost in the transhipment link, the handling charges are imposed in the carrier choosing link, not in the loading and unloading link.

(2) Ocean freight charge

Since the maritime container shipping industry is an oligopolistic market, generally the freight charge is not equal to the marginal shipping cost. However, if we assume the market is in Bertrand competition in which companies compete over prices rather than the capacities, it is well known that price is equal to the marginal cost. Hereinafter, it is assumed that the market of maritime and inland waterway container shipping is individually established for each combination of origin and destination port, although each market is related with each other (Note that the inland waterway container shipping market which is not connected with any maritime shipping services is not considered in this model). Individual maritime container shipping market connecting specific export and import port may be relatively easy to enter and leave for the shipping companies that already operate container vessels in the region; therefore, equilibrium price (i.e. ocean freight charge) is considered to approximate the price reached in the perfect competition.

Another point is that the marginal shipping cost may be different from each shipping company in the equilibrium price, mainly because the vessel size and shipping route are different among companies. Some shipping companies may want to set their price to be lower than the marginal cost of other shipping companies so that they should leave from the market (the theory of "limit price"). However, since the maritime container shipping market is easy to enter and leave as mentioned above, the strategy of limit price may not be the best for the companies.

From the above discussion, equilibrium price (ocean freight charge), FM_{rs}, in each market is uniquely set to be equal to the highest marginal shipping cost in the companies that participate the market (from export port r to import port s); namely,

$$FM_{rs} = \max_{g \in G} MC_{grs}, \tag{23}$$

where MC_{grs}: marginal cost of shipping company g from export port r to import port s, G: set of shipping company. The marginal shipping cost is defined as

$$MC_{grs} = \sum_{a \in k_g} \frac{d}{dx_a} c_a(x_a) \quad \text{if} \;\; TM_{grs} = TM_{rs}, \text{ or} \tag{24}$$

$$MC_{grs} = 0 \qquad \text{if} \;\; TM_{grs} > TM_{rs}, \tag{25}$$

where k_g: path to minimize the shipping time from export port r to import port s of shipping company g, TM_{grs}: minimum shipping time from export port r to import port s of shipping company g. Namely,

$$k_g = \arg\left[\min_{k'}\left\{\sum_{a \in k'} t_a(x_a)\right\}\right], \;\; \forall k' \in K_g^{rs}, \tag{26}$$

$$TM_{grs} = \sum_{a \in k_g} t_a(x_a), \tag{27}$$

where K_{rsg}: path set from export port r to import port s of shipping company g.

3.4 Land shipping time and freight charge

The shipping time, TL_{ir} and TL_{sj} (hour), and the freight charge, FL_{ir} and FL_{sj} (US$/TEU), in the land shipping link, are defined as sum of time or cost for driving and border-crossing, respectively. In addition, the freight charge can approximate the shipping cost, since the truck industry in this area is sufficiently competitive to be able to assume the perfect market competition. Therefore,

$$TL_{ir} = TD_{ir} + \alpha^{l} \cdot TB_{ir} \text{ (also, } TL_{sj} = TD_{sj} + \alpha^{l} \cdot TB_{sj} \text{), and} \quad (28)$$

$$FL_{ir} = CD_{ir} + \alpha^{l} \cdot CB_{ir} \text{ (also, } FL_{sj} = CD_{sj} + \alpha^{l} \cdot CB_{sj} \text{),} \quad (29)$$

where TD_{ir}, TD_{sj}: driving time of the land shipping link (hour), CD_{ir}, CD_{sj}: driving cost of the land shipping link (hour), and α^{l}: coefficient on bonded transport for land shipping. The coefficient on bonded transport for land shipping, α^{l}, is an adjustment unknown parameter as well as α^{w} in the inland waterway shipping.

4. INPUT DATA

4.1 Ports

The liner shipping network all over the world is covered in this model. In principle, all the container ports where throughput was more than 500,000 TEU per year (2010, domestic and empty containers are included) are considered. After adding and eliminating several ports due to data availability and other reasons, 156 ports of the world are included in the model. Details were described in Shibasaki, et al. (2013). Furthermore, two Cambodian ports (SV and PP) and two neighboring countries' ports (Songkhla in Thailand and Kuantan in Malaysia) located along the Thailand Bay are added, because the model focuses on the Low Mekong region. Finally, the number of ports included in the model is 160 in total as shown in Figure 8.

Parameters set by each port are shown in Table 5 (Due to the paper limitation, only parameters in the ports of Cambodia and neighbor countries are shown in the table). The container handling charge, CHX_r and CHM_r (included in Equation (18) to (20)), and lead time for export, TPX_r (in Equation (6)), and for import, TPM_r (in Equation (8)) are basically acquired from the "ports and terminal handling" cost and time which are shown by country in both exports and imports on the Doing-Business website provided by the World Bank. The transshipment time, TR_r (in maritime shipping submodel), is estimated as 12, 24, or 48 hours by port according to various sources and the authors' interviews.

4.2 Maritime shipping network

Maritime shipping network is basically developed by the MDS database. Details of the database are explained in Shibasaki, et al. (2013). From the MDS database, not only the data for making network, but also vessel speed, v_a (knot), average vessel capacity, cap_a and $Vcap_a$ (TEU/vessel), and frequency, $freq_a$ (vessels/year) for each service is acquired.

The distance between ports, l_a (NM), is acquired from Toriumi's work (2010) as in the previous model. The distance is calculated from an assumption that every containership passes through the shortest route on the sea out of the preset navigation routes. Also, whether each link a passes through the Panama and Suez Canal or not can be judged from the calculation.

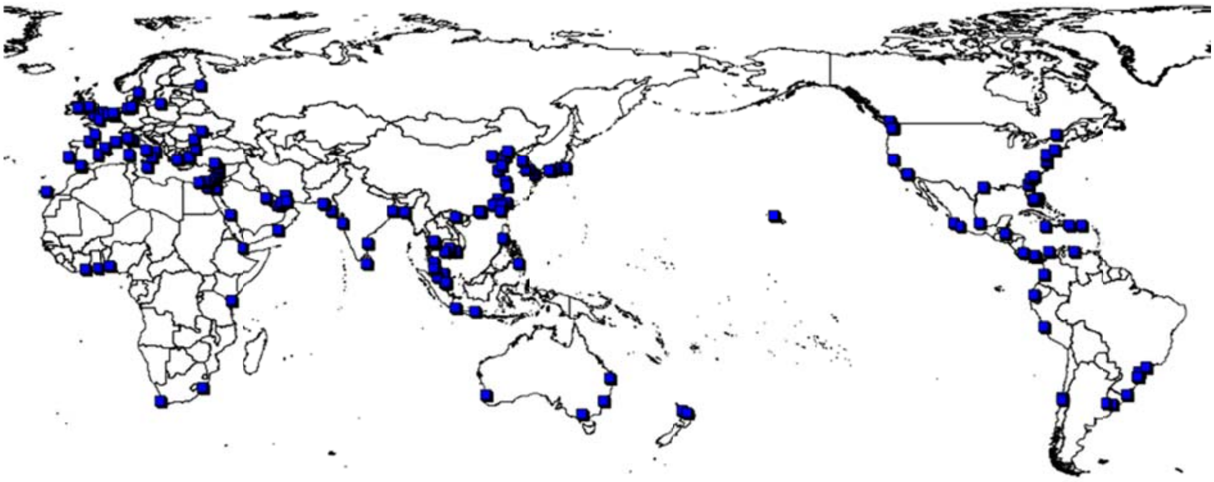


Figure 8 All container ports (160 ports) included in the model (source: authors)

Table 5 Settings of level of service in the selected ports (source: World Bank and others)

Port			Lead Time (Export) TPX_r	Lead Time (Import) TPM_r	Transship ment Time TR_r	Container Handling Charge (Export) CHX_r	Container Handling Charge (Import) CHM_r
No.	Port Name	Country	(hours)	(hours)	(hours)	(US$/TEU)	(US$/TEU)
30	Ho Chi Minh	Vietnam	72	96	48	150	175
31	Cai Mep/Thi Vai	Vietnam	72	96	24	150	175
311	Phnom Penh	Cambodia	72	96	48	100	225
312	Sihanoukville	Cambodia	48	48	48	100	225
32	Laem Chabang	Thailand	72	48	24	160	160
33	Bangkok	Thailand	72	48	24	160	160
331	Songkhla	Thailand	72	48	24	160	160
332	Kuantan	Malaysia	48	48	48	120	120
35	Tanjung Pelepas	Malaysia	48	48	12	120	120
36	Klang	Malaysia	48	48	24	120	120
38	Singapore	Singapore	24	24	12	150	150

The network is made for the 20 largest container shipping companies of the world (as shown in Shibasaki, et al., 2013) plus ten additional companies for middle and small class which have liner service networks in Southeast Asia including Heung-A (South Korea), Hub Line (Singapore), KMTC (South Korea), Nam Sung (South Korea), RCL (Thailand), SinoKor (South Korea), SITC (China), STX (South Korea), TS Lines (Taiwan), and Wan Hai (Taiwan). The liner services or capacities that are not included in any of these 30 companies as operators, partners or slot charters are excluded. In addition, ports which are not included in the model are eliminated. As a result, out of 2857 services from MDS database (as of May 2010), 892 services are included in the model. Although the number of loops included in the model is about one-third of the total, 67.0% of the annual vessel capacity of the world is covered by the model because larger companies provide more significant and heavy services across the world.

In addition, any container shipping services calling at the PP Port are not included in the MDS database; therefore, one hypothetically integrated service calling at PP, CMTV, HCM, and returning to the PP is added. The frequency and average vessel capacity of the hypothetical service are assumed to 15 per week and 82 TEU respectively based on data from Table 1. Also, the vessel speed is assumed to be 8.2 knots based on the actual shipping time described in Table 2. Since all shipping companies shown in Table 1 only provide the feeder service in this area and are not included in the 30 companies of the model as described above, the authors assume that every shipping company (i.e. 27 companies out of the above 30 companies) which calls at the HCM or CMTV Port provides the same capacity of the feeder service in the Mekong River; namely, the capacity of each company per vessel is 82 * (1 /27) = 3.0 TEU or that per week is 82 * (1 /27) * 15 = 45.6 TEU.

4.3 Land shipping network and cross-border transport

The land shipping network is only considered in Cambodia and neighbouring countries as shown in Figure 14. This network is structured based on APEC (2010). Note any railway links as well as future road links are not included in the calculation network of the model this time due to lack of data, although they are also included in the figure.

The driving time, TD_{ir} from origin zone *i* to export port *r*, and TD_{sj} from import pot *s* to destination zone *j*, which are included in Equation (28), is calculated from the shortest path search based on the land shipping network shown in Figure 9. The land shipping network provides information of each link on its distance as well as road type such as primary route, motorway, and important route. According to the road type provided, the average speed is set from 20 km/h to 60 km/h; thus, shipping time of each link is calculated by dividing link distance by the average speed.

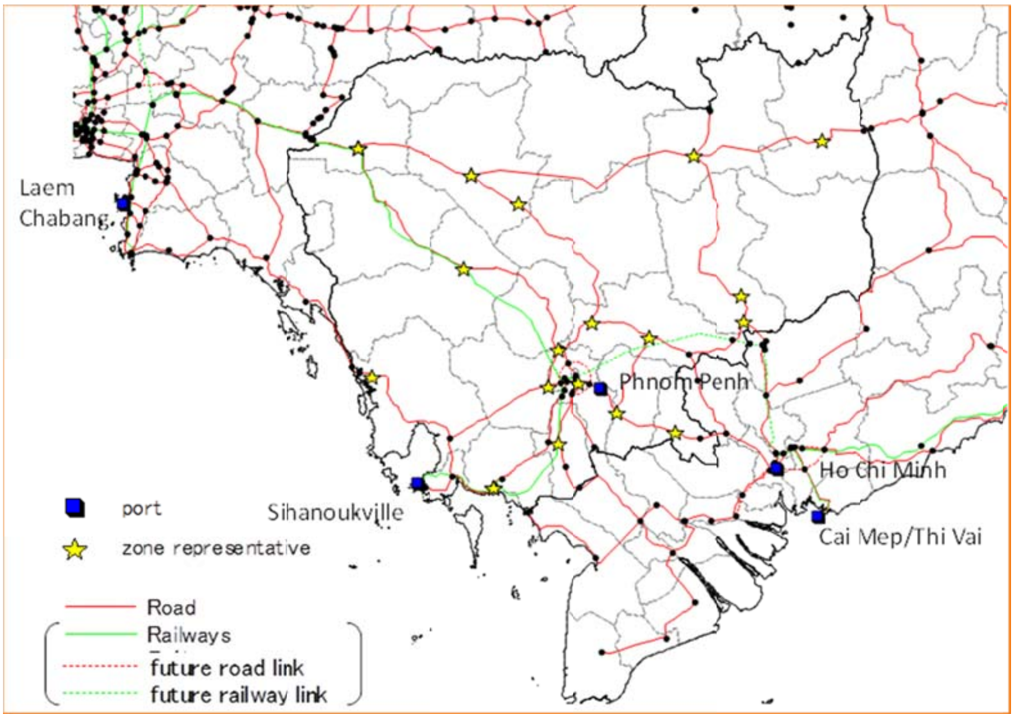


Figure 9 Land shipping network included in the model (source: APEC, 2010)

Table 6 Border-crossing time and cost for each country (source: World Bank)

	Time (Days)				Cost (US$)			
	Export		Import		Export		Import	
country	documents preparation	customs clearance and technical control	documents preparation	customs clearance and technical control	documents preparation	customs clearance and technical control	documents preparation	customs clearance and technical control
Vietnam	12	4	12	4	160	100	130	95
Thailand	8	1	8	2	175	50	135	255
(Cambodia)	14	3	15	3	220	275	225	280

The driving cost, CD_{ir} and CD_{sj}, which are included in Equation (29), is, calculated from the total distance of land shipping from the departure point (i.e. origin zone or import port) to the arrival point (i.e. export port or destination zone), which is acquired from the result of the shortest path search to minimize the shipping time. The land shipping cost is assumed as 1.0 US$/km which is acquired from JETRO's survey (2008) on the trucking industry in Southeast Asia. Note that the total shipping distance should be doubled in the shipping cost calculation because the land shipping of international maritime container cargo is normally contracted in a round-trip basis including a reposition of an empty container.

The border-crossing time, *TB*, included in Equation (14-2) and Equation (28) is acquired from the summation of the time for "documents preparation" and "customs clearance and technical control" on the Doing-Business website provided by the World Bank. The border-crossing cost, *CB*, in Equation (17-2) and Equation (29) is also acquired from the summation of the cost for both indices. Both indices in terms of time and cost for both exports and imports by country are shown in Table 6. Note that this model focuses on the border-crossing time and cost only in the transit country (i.e. Vietnam or Thailand) by land and river shipping, not Cambodia. Since, the cost and time for the "document preparation" and "customs clearance and technical control" in Cambodia are necessary for any international cargo to/from Cambodia, they are ignored in the model calculation.

4.4 Shipping demand of container cargo (container OD cargo)

The shipping demand of container cargo (container OD cargo), Q_{ij}, from region i to j is estimated basically as the similar way in Shibasaki, et al. (2014).

First, container OD cargo between countries or regions in a TEU-basis is available from the World Trade Service (WTS) database provided by IHS Inc. However, the container OD cargo to/from "Other Asia" in the WTS database includes not only the cargo to/from Cambodia, but other Asian countries such as Myanmar, Lao DPR, Brunei Darussalam, Mongolia, North Korea, and Papua New Guinea; therefore, it needs to be divided into each country. For the sake of more precise division, it is divided according to the trade value data by commodity (in a WTS commodity classification basis); the share of each country by partner country by commodity in a value basis is calculated from the UN comtrade data.

Second, the country-basis container OD cargo as acquired above is divided into a port-basis container OD cargo according to the share of the port out of the country/region in terms of the laden, local container cargo throughput, which is estimated by a Drewry Maritime Research (2013) and other related sources.

Third, the container OD cargo that will be shipped by carriers not among the 30 container carriers included in the model is eliminated, in order to take a balance between the vessel capacity and the amount of containers shipped in each service. It is used as a model input of initial container OD cargo, $q_{rs}^{(0)}$.

Forth, since the Cambodian cargo is considered to include hinterland (i.e. land and river) transport as discussed while other cargos of the world are only considered for the maritime shipping, the container OD cargo to/from Cambodia which is estimated in the first step is once again divided into 24 provinces according to the index which represents a regional economy. Due to limited available data, the amount of sales in each province as shown in Table 7 is utilized as an index for the regional division. The container OD cargo between other regions than Cambodia is not changed from the third step. This is how the shipping demand of container cargo (container OD cargo), *Qij*, is estimated.

Figure 10 shows the share of partner regions for Cambodian international container cargo in a TEU basis which is estimated in the first step. The figure shows the partner regions in export from and import into Cambodia are significantly different; the export cargo from Cambodia is mainly heading to North America and Europe, while the import cargo into Cambodia is mainly coming from Northeast and Southeast Asia. The main commodity for export is "wearing apparel" (which shares 54.4% of Cambodian exports in terms of value) and "postcards, calendars, and other printed materials" (31.8%), while that for import is "textiles" (which shares 38.2% of Cambodian imports in terms of value).

Table 7 Sales amount by province in 2010 (source: Statistical Yearbook of Cambodia 2011)

No.	Province	Amount (1000US$)	Share	No.	Province	Amount (1000US$)	Share
1	Banteay Meanchey	217	1.3%	13	Preah Vihear	68	0.4%
2	Battambang	304	1.8%	14	Prey Veng	125	0.7%
3	Kampong Cham	3,338	19.8%	15	Pursat	59	0.4%
4	Kampong Chhnang	64	0.4%	16	Ratanak Kiri	166	1.0%
5	Kampong Speu	197	1.2%	17	Siem Reap	984	5.8%
6	Kampong Thom	147	0.9%	18	Preah Sihanouk	243	1.4%
7	Kampot	163	1.0%	19	Stung Treng	8	0.05%
8	Kandal	870	5.2%	20	Svay Rieng	309	1.8%
9	Koh Kong	56	0.3%	21	Takeo	275	1.6%
10	Kratie	78	0.5%	22	Otdar Meanchey	23	0.1%
11	Mondul Kiri	17	0.1%	23	Kep	7	0.04%
12	Phnom Penh	8,966	53.3%	24	Pailin	143	0.8%
					Total	16,827	100.0%

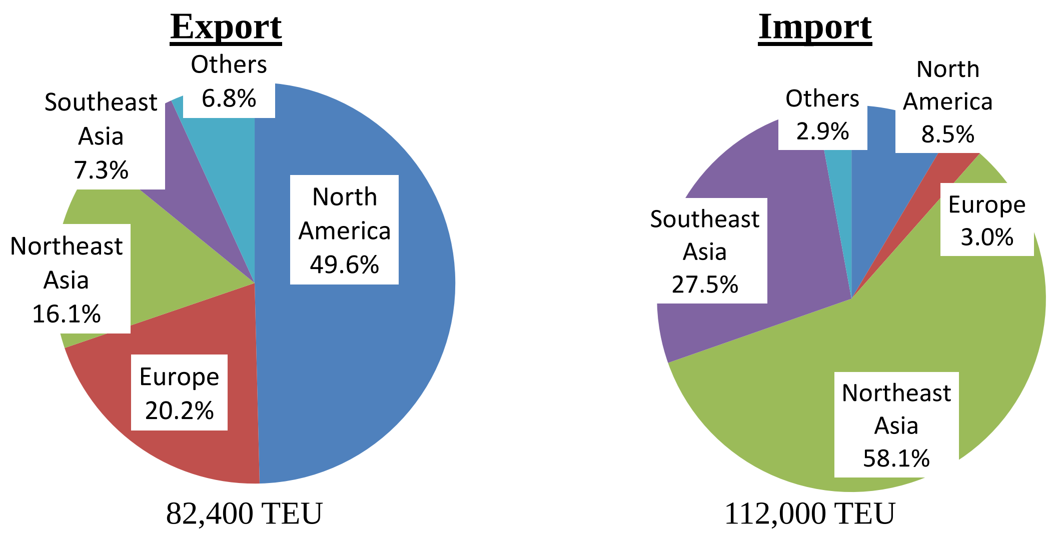


Figure 10 Shares by partner regions for Cambodian international container cargo in 2010

5. MODEL CALCULATION AND OUTPUT

5.1 Calculation procedure

The actual calculation process of the model is as follows.

(1) Initial calculation

i) Maritime and inland waterway shipping submodel is calculated and the initial maritime and inland waterway shipping time, $TM_{rs}^{(0)}$, is estimated as described in 3.2, by inputting the initial port-basis container OD cargo, $q_{rs}^{(0)}$.

ii) The initial ocean freight charge $FM_{rs}^{(0)}$, is estimated as described in 3.3, based on the maritime and inland waterway shipping network.

iii) By inputting these estimated variables and the container OD cargo, Q_{ij}, the path flow of container cargo, $F_{ijh}^{(0)}$, on the intermodal network (see Equation (3) in 3.1) and container cargo throughput for each port (by aggregating F_{ijh} by port) are estimated based on the stochastic network assignment methodology.

(2) *m*-th iterative calculation and convergence check

i) In the calculation of the previous (m-1)th iteration, port-basis container OD cargo, $q_{rs}^{(m)}$, which denotes the maritime and inland waterway link flow on the intermodal network, is estimated from the path flow, $F_{ijh}^{(m-1)}$.

ii) According to the similar procedure of initial calculation (i.e. (1) i) to iii)), path flow of container cargo, $F_{ijh}^{(m)}$, is calculated by inputting port-basis container OD cargo, $q_{rs}^{(m)}$, and the total container OD cargo, Q_{ij}. However, ocean freight charge, FM_{rs}, severely fluctuates if it is calculated by Equation (23), depending on which shipping company enters into the market to provide the liner service. It is not considered to appropriately reflect the actual change of ocean freight charge which should continuously change from that in the previous period. In addition, the authors would like to focus on its change of the cargo to/from Cambodia Therefore, that of m-th iteration (in case that m is larger than one), $FM_{rs}^{(m)}$, is estimated as following equation using the previous freight charge, $FM_{rs}^{(m-1)}$.

$$FM_{rs}^{(m)} = \left\{ \frac{q_{rs}^{(m)}}{q_{rs}^{(m-1)}} \right\}^{\gamma_e} \cdot FM_{rs}^{(m-1)} \quad \text{for export cargo from Cambodia,} \qquad (23'\text{-a})$$

$$FM_{rs}^{(m)} = \left\{ \frac{q_{rs}^{(m)}}{q_{rs}^{(m-1)}} \right\}^{\gamma_m} \cdot FM_{rs}^{(m-1)} \quad \text{for import cargo to Cambodia, and} \qquad (23'\text{-b})$$

$$FM_{rs}^{(m)} = FM_{rs}^{(m-1)} \quad \text{for other cargoes,} \qquad (23'\text{-c})$$

where γ_e, γ_m: parameters for price elasticity of demand for export and import cargo, respectively. These parameters are set to be 0.00207 and 0.0394 respectively as well as Shibasaki, et al. (2014).

iii) If the path flow of container cargo, $F_{ijh}^{(m)}$, converges by comparing that in the previous iteration, $F_{ijh}^{(m-1)}$, the iterative calculation ends. Otherwise, back to i) after $m = m + 1$.

5.2 Unknown parameter estimation

The model contains four unknown parameters vt, θ, α^l, and α^w. All other parameters are preliminarily set as exogenous variables and have already been explained until the previous section. vt is value of time for shipper (US$/TEU/hour) included Equation (5) to (8); θ is a distribution parameter included Equation (3) in which probability that each route is chosen is defined; and α^l and α^w are adjustment parameters on bonded transport in road and river shipping respectively, which is multiplied by border-crossing time, *TB*, and cost, *CB*, as described in Equation (14-2), (17-2), (28), and (29).

An optimal combination of coefficients of unknown parameters is selected to reproduce the actual container cargo flow well. Trial-and-error-basis calculation and grid search is conducted for estimation of unknown parameters by changing each parameter with the range of ($2.0 < vt < 10.0$), ($0.001 < \theta < 0.01$), ($0.0 < \alpha^l < 0.5$), and ($0.0 < \alpha^w < 0.5$). Also, adjustment parameters on road bonded transport, α^l, should be larger than that on river bonded transport, α^w. As a result, it is estimated that (vt, θ, α^l, α^w) = (5.0, 0.003, 0.4, 0.1) is an optimal combination of coefficient for both export and import cargo.

5.3 Model reproducibility and validation

Figure 11 shows the shares estimated from the model in terms of shipping route (or gateway port) in 2010 for Cambodian international laden containers. Different from the actual shares shown in Table 4 in 2.5, the model can estimate the shares of two Vietnamese ports (i.e. HCM and CMTV) separately; also, it includes the share of LC Port.

Compared with the actual and estimated share, the shares of SV Port are underestimated in both export and import by about 10 percentage points, while the shares of PP Port (i.e. Mekong River shipping) are both overestimated. The share of Vietnamese ports (i.e. sum of HCM and CMTV Ports) is overestimated in export, while that in import is underestimated. As discussed in 2.5, the shares of SV Port are decreasing in recent years and those in 2012 (shown in Table 4) are quite similar to the estimated shares from the model as below. In other words, the model seems to accurately predict the share in near future in the case that cargo owners is more sensitive to choose the more cost-effective shipping route.

The difference between the actual and estimated shares of Vietnamese ports implies that the model does not sufficiently describe the difference in feature of export and import compared with the actual. However, the model can describe the difference in feature of HCM and CMTV Port as discussed in 2.1; namely, CMTV Port is mainly utilized for export, while HCM Port is mainly for import. One reason why the model cannot sufficiently describe the difference in export and import may be that the model does not consider the difference of vessel speed between downriver (for export) and upriver (for import). If the difference of the vessel speed is considered, the river shipping in import will be less utilized.

Figure 12 shows the estimated truck flow of Cambodian international laden container in 2010. The greatest traffic volume is estimated between PP and SV on the NH4, followed by the section between PP and HCM on the NH1. Also, the traffic volumes on the NH6 (between PP and Siem Reap) and NH7 (between PP and Kampong Cham) are significant, because the container OD cargo to/from these two provinces is assumed to share some portion as shown in Table 7.

Figure 13 shows the estimated shares in terms of shipping route (or gateway port) in 2010 for international laden containers by five regions in Cambodia. The figure shows the shares of each shipping route are different among regions, especially in imports; for example, the shares of PP port in Central region are larger than those in other regions for both export and import due to its closest location to PP Port, while the shares of SV Port in Coastal region are larger than those in other regions for both export and import due to the similar reason.

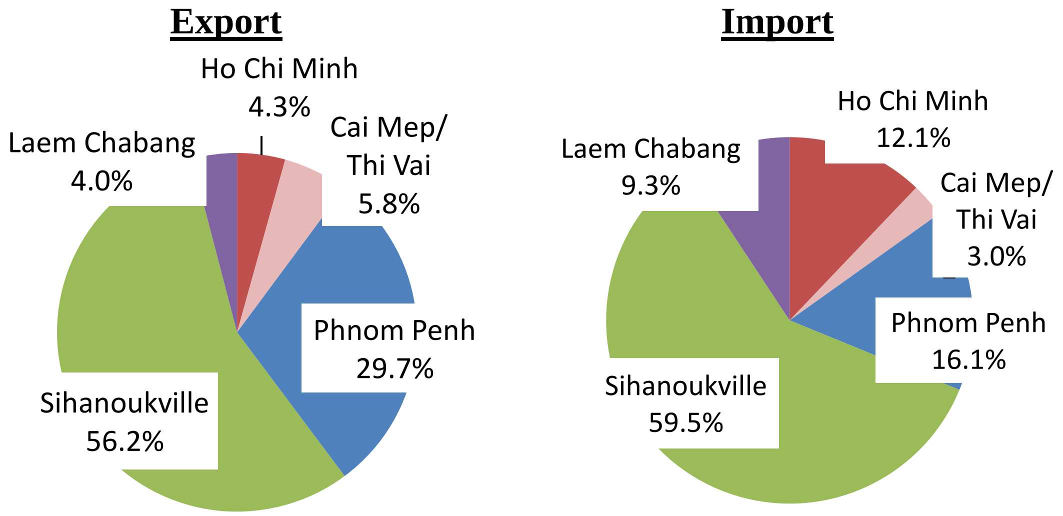


Figure 11 Estimated share of shipping route (gateway port) for Cambodian international laden container in 2010

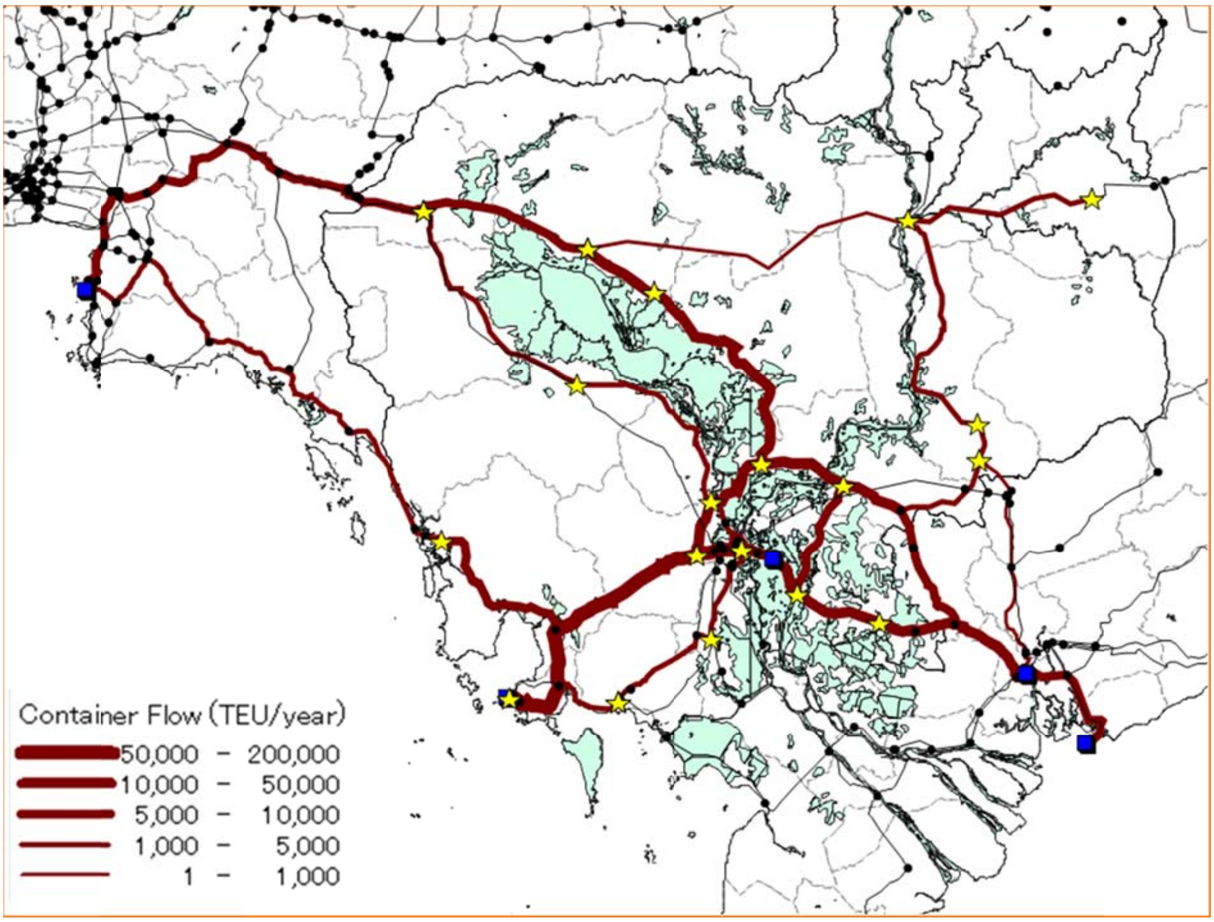
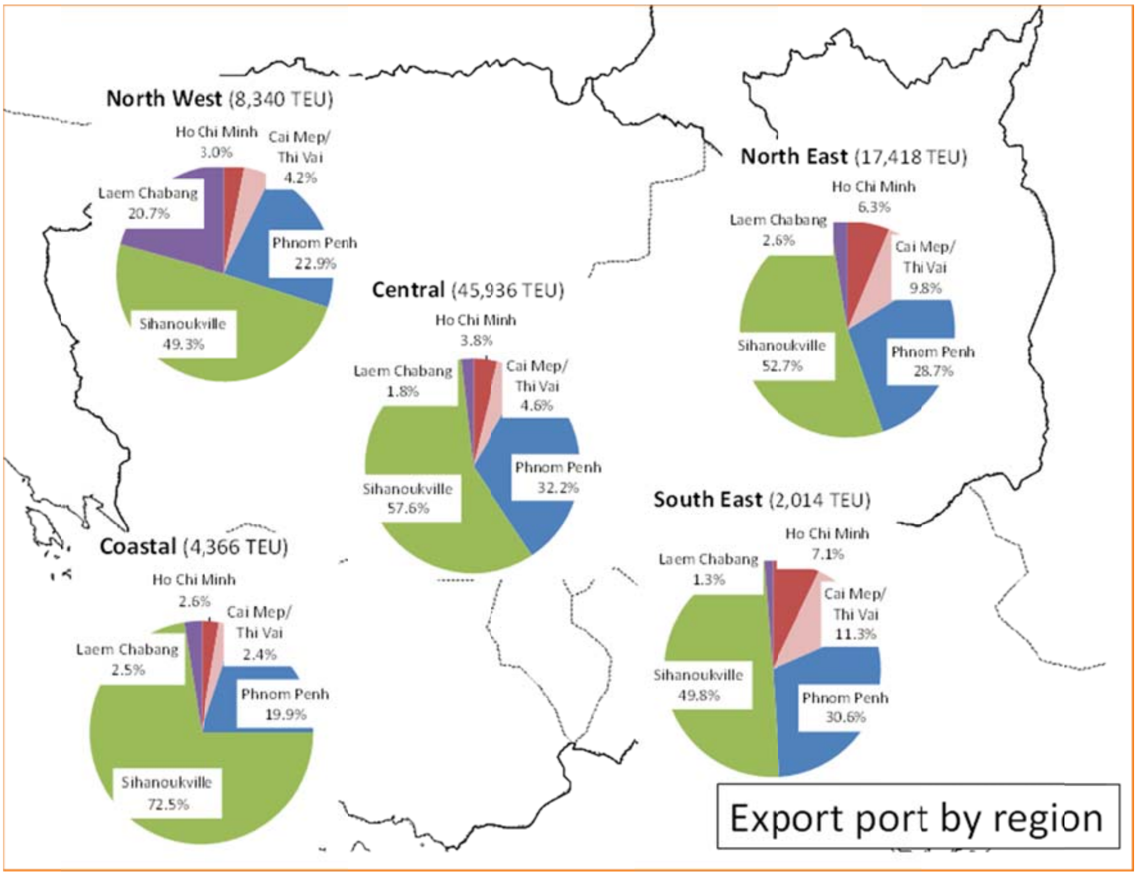


Figure 12 Estimated truck flow of Cambodian international laden container in 2010



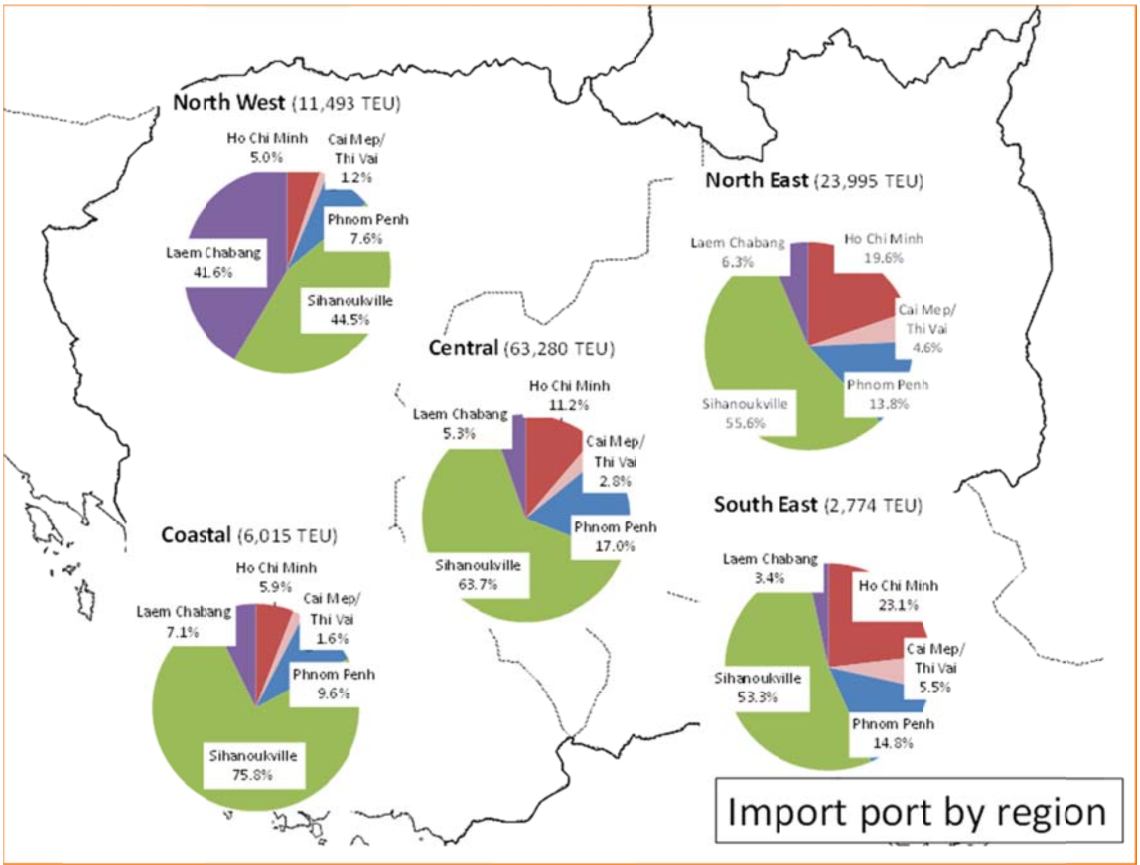


Figure 13 Estimated share of gateway port for international laden container by regions in Cambodia in 2010

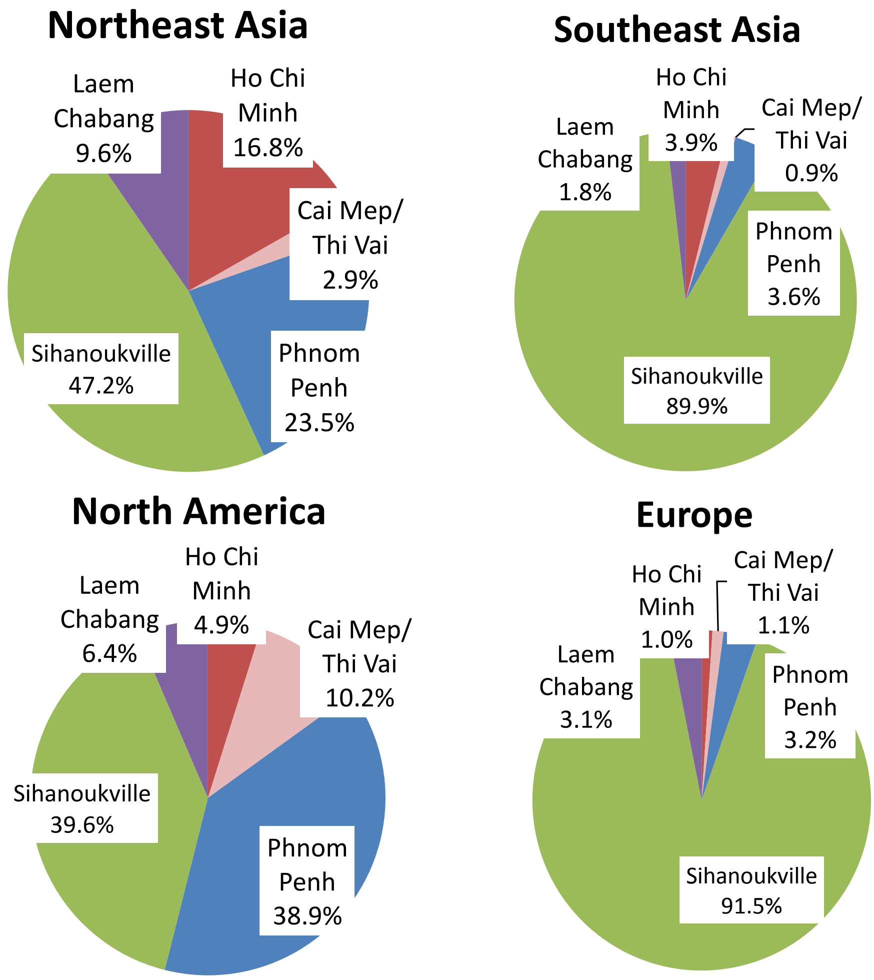


Figure 14 Estimated share of gateway port for international laden container by partner regions in 2010 (sum of export and import)

Figure 14 shows the estimated shares in terms of shipping route (or gateway port) in 2010 for international laden containers by partner regions in the total amount of export and import. The figure shows the shares of each shipping route are significantly different for each partner region. For example, the share of SV Port is quite large (about 90 percent of the total amount) for the container OD cargo between Cambodia and Southeast Asia or Europe. This implies that SV Port has a significant advantage for the southbound or westbound shipment from Cambodia by the strong connection with Singapore and other hub ports in Southeast Asia through the feeder services (see Figure 4 shown in 2.4). On the other hand, for the container OD cargo between Cambodia and North America, the sum of CMTV and PP Port shares about half of the total amount. Since most cargo to North America utilizing PP Port are considered to be transshipped in CMTV Port into mother vessels which directly connect with North America on the trunk route as shown in Figure 3 in 2.1, CMTV Port virtually functions as a gateway of Cambodian container cargo to North America. As well, the share for the container OD cargo between Cambodia and Northeast Asia reveals that HCM Port functions as a gateway of Cambodian container cargo from Northeast Asia based on the strong connection with Northeast Asian ports through many liner services as mentioned in 2.1, if the share of PP Port is included (which is utilized as a feeder port mainly coming from HCM Port), not only the share of HCM Port itself.

Figure 14 also reveals the reason why the share of PP Port (i.e. Mekong River shipping) in export containers is larger than that in import containers, while the share of Vietnamese ports (i.e. international land shipping) in export is smaller than that in import, as mentioned several times such as Table 4 and Figure 11. Since the export containers are mainly heading for North America as shown in Figure 10, CMTV Port is a main gateway of Cambodian containers as discussed above. On the other hand, since the import containers are mainly coming from Northeast Asia, HCM Port is a main gateway. Note that the share of river shipping against land (truck) shipping generally becomes larger as the shipping distance is longer due to the structure of the cost function. In addition, as described in 2.1, the feeder services in the Mekong River is directly heading for CMTV Port after leaving PP Port without calling at HCM Port on the way, which becomes more advantageous against the truck transport to CMTV Port. Therefore, the share of river shipping connecting with CMTV Port is quite larger than that connecting with HCM Port.

5.4 Policy simulation using the model

At the end of the paper, three scenarios on the policies which affect the competitive environment of shipping route for Cambodian international container cargo are considered and simulated by the developed model. The estimated results based on the current situation as shown in 5.3 are regarded as the result of “Scenario 0”.

(1) Scenario 1: improvement of Mekong River shipping

In the first scenario, improvement of Mekong River shipping is assumed; concretely, the average vessel capacity becomes doubled from 85 TEU to 170 TEU, due to the river dredging and removal of obstacle. The enlargement of barge size can reduce the shipping cost as well as the freight charge. Additionally, the vessel speed is also assumed to increase from 8.2 knots to 10.0 knots mainly due to the reduction of waiting time at the national border.

The estimated shares in terms of shipping route (or gateway port) in this scenario are shown in Figure 15. Compared with the share in Scenario 0 as shown in Figure 11, the share of PP Port is increased by 11.4 percent point in export, as well as 8.7 percent point in import. The shares of all other ports are decreasing in both export and import; about half amount of the increased containers in PP Port is shifted from SV Port, while another half amount is shifted from land shipping connecting with Vietnamese pots.

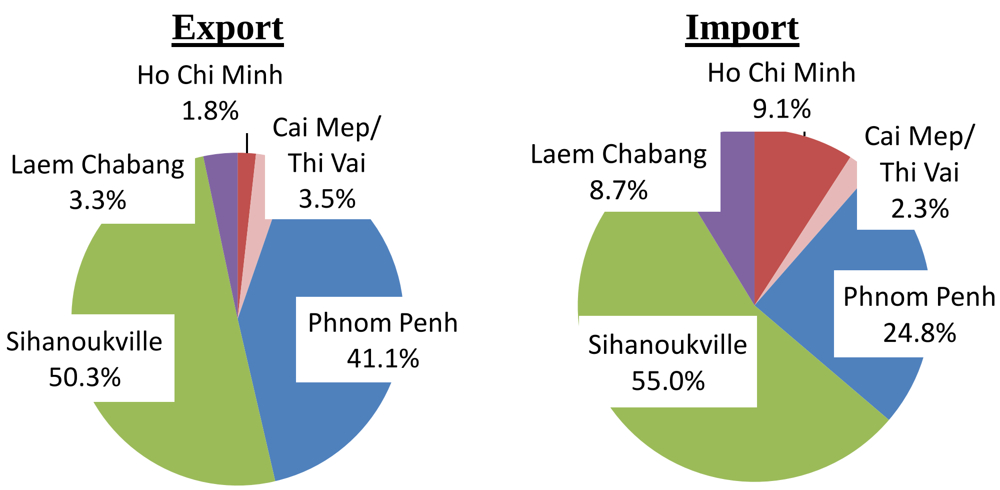


Figure 15 Estimated share by gateway port in Scenario 1
(the improvement of Mekong River shipping)

(2) Scenario 2: improvement of road infrastructure between PP and HCM

The second scenario assumes an improvement of road infrastructure on the Cambodian NH1 connecting with PP and HCM, in which the 4km section near PP (see 2.1) is widened and repaved and the Neak Loeang Bridge (see 2.2) is opened. Concretely, the truck speed of the link which includes the section in question is assumed to be increased from 20 km/h to 50 km/h; consequently, the shipping time is shortened about 30 minutes in the road improvement section as well as about one hour by the bridge construction. Note that the road improvement is also expected to positively affect to the river shipping because the section that needs to be improved is located between the center of PP city and PP Port as mentioned in 2.1.

Figure 16 shows the estimated shares in terms of shipping route (or gateway port) in Scenario 2. Compared with the shares in Scenario 0, the change of shares is very slight; in export containers, the share of land shipping with Vietnamese ports (i.e. sum of shares of HCM and CMTV Port) is not changed, while a small amount of containers (about 2 percent point of the total amount) is shifted from SV Port to PP Port (river shipping). In import containers, the share of land shipping with Vietnamese ports and that of PP Ports are both increasing by 1.6 percent point and 0.9 percent point, which are also shifted from SV Port. These results imply that the road improvement positively affects to the Mekong River shipping as expected, as well as that the import cargo is more sensitive than the export cargo in terms of the competitive environment between road and river shipping.

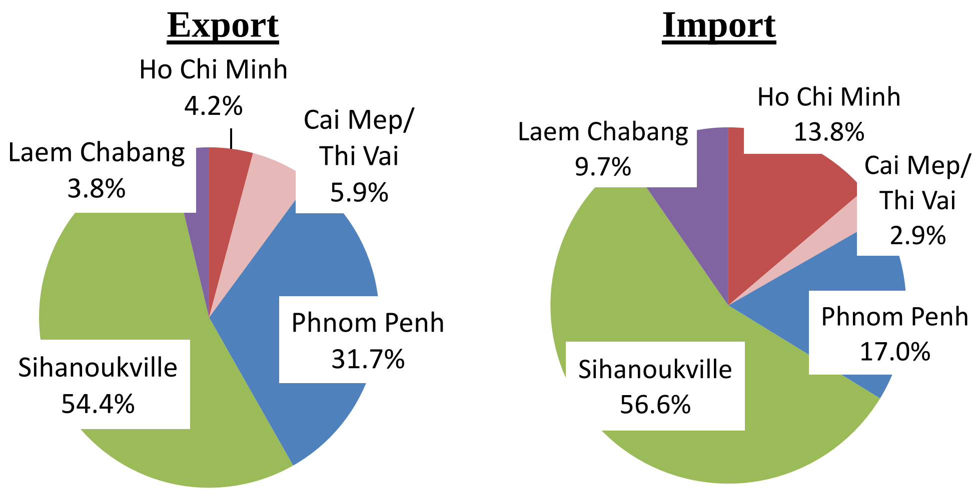


Figure 16 Estimated share by gateway port in Scenario 2
(the improvement of road infrastructure on the NH1)

(3) Scenario 3: improvement of efficiency in SV Port

The third scenario assumes an improvement of efficiency of cargo handling in SV Port; concretely, the lead time is decreased from three days (for export) and four days (for import) respectively to two days for both export and import. In addition, the coastal road (NH48) connecting SV with Thai border (Koh Kong) is assumed to be improved by some investment, resulting in decreasing the shipping time by about 1 hour 40 minutes.

Figure 17 shows the estimated shares in terms of shipping route (or gateway port) in Scenario 3. Compared with the shares in Scenario 0, the share of SV Port in export is not changed, while that in import increases by 11.9 percent point. The possible reason why the sensitivity to the policy is very different between export and import is that the reduced hours by efficiency improvement in import (i.e. 2 days) is likely larger than those in export (1 day). Another reason is the difference in the competitive environment as discussed in (2).

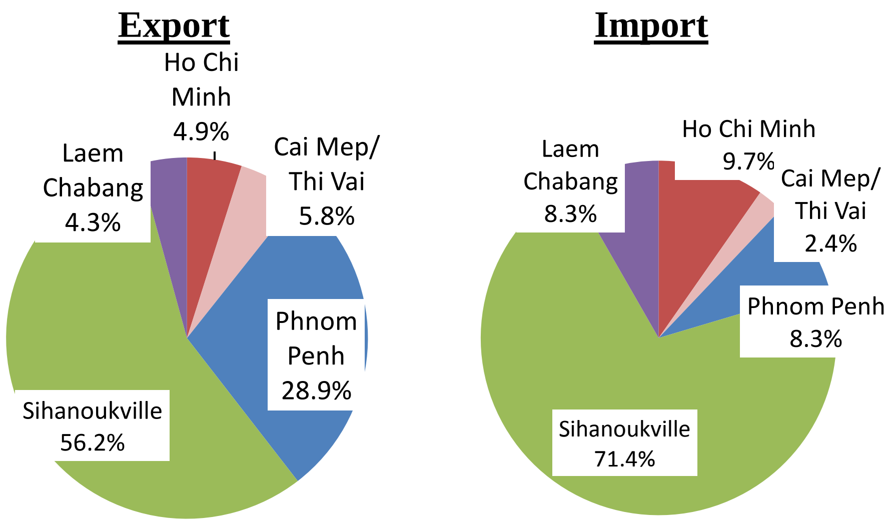


Figure 17 Estimated share by gateway port in Scenario 3
(the improvement of efficiency in Sihanoukville Port)

(4) Decreased shipping cost by policy implementation

The model can estimate the shipping cost of each container in the calculation process. Table 8 summarizes the total generalized shipping cost of all Cambodian international container cargo for each scenario. Note that the shipping cost shown in the table also includes the time cost (multiplied shipping time by value of time).

The table reveals that all three scenarios can reduce the amount of shipping cost for Cambodian cargo. As discussed above, each scenario changes the share of each shipping route; in other words, any policies to give a positive impact to some route inevitably give a negative impact to the other routes. However, the competitiveness of Cambodian cargo in the international market will be certainly improved due to these policies, from the viewpoint of the shipping cost.

As shown in the table, the expected amount of reduced shipping cost for each scenario is between three and thirty million US$ per year, which is equal to from 0.3 to 2.6 percent of the total generalized shipping cost of all Cambodian international container cargo.

Table 8 Total generalized shipping cost of all Cambodian international container cargo for each scenario and their differences

Scenarios	Total shipping cost (including time cost) (million US$/year)	Difference from (thousand US$/year)	Decreasing rate of shipping cost
0: current situation	1,067.99	-	-
1: improvement of Mekong River shipping	1,048.11	-19,872.1	-1.86%
2: improvement of NH1	1,064.60	-3,387.2	-0.32%
3: improvement of SV Port efficiency	1,039.66	-28,331.4	-2.65%

6. CONCLUSION

This paper focuses on Cambodian international container shipping and develops their route choice model on the intermodal transport network including Mekong River shipping via Phnom Penh Port, international road transport with neighbor countries (Vietnam and Thailand), and domestic road transport to Sihanoukville Port. The model can well describe the actual shares of the route of hinterland transport (or gateway port) for Cambodian international laden containers. The model developed is applied to simulate the impacts of policies on the infrastructure improvement including river and road transport. The expected impacts by the simulation are reasonable and explainable as a whole.

One of the major faults of the model is that the capacity constraint is only considered in the maritime and inland waterway (i.e. river) shipping, not in road transport as well as in the port. When predicting the change of the share for each shipping route in future, consideration of the capacity constraint is quite important because the total amount of Cambodian container cargo is expected to steadily increase. Another element to be considered is railway transport. As mentioned in 2.3, the railway transport connecting Phnom Penh with Sihanoukville Port started last year, and handled a certain amount of cargo despite the pessimistic expectations of some experts. Also, utilization of inland waterway shipping as a network in the whole country, not only between Phnom Penh and Vietnamese ports, is expected to be encouraged and needs to be simulated by the model.

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REFERENCES

Asian Development Bank (ADB) (2006) **GMS Transport Sector Strategy Study, Final Report**

Asia-Pacific Economic Cooperation (APEC) (2010) **Impacts of Trade and Transport Policy on International Cargo Shipping and Economic Activities**, presented at the 33rd Transportation Working Group Meeting (TPTWG), Tokyo, final version is available at http://www.apec-tptwg.org.cn/new/Archives/tpt-wg34/Maritime/Final/draft_final_ report_revised%20(2).pdf, last accessed on March 31, 2014.

Belgian Technical Corporation (2006) **Master Plan for Waterborne Transport on the Mekong River System in Cambodia, Final Report**.

Drewry Maritime Research (2013) **Annual review of the global container market**.

Hanaoka, S. (2013) Port competition in Cambodia, **Journal of Maritime Researches, Kobe University**, Vol.3, No.1, 31-38.

Infrastructure and Regional Integration Technical Working Group (IRITWG), Kingdom of Cambodia (2012) **Overview on Transport Infrastructure Sectors in the Kingdom of Cambodia (4th Edition)**

Japan External Trade Organization (JETRO) (2008) **ASEAN logistics network map 2008**. (in Japanese)

Japan External Trade Organization (JETRO) (2013) **Current situation of Logistics and Customs in the Mekong Region**, available at https://www.jetro.go.jp/world/asia/asean/reports/07001403, last accessed on March 30, 2014. (in Japanese)

Japan International Cooperation Agency (JICA) (2012) **Final report for the project for the study on strengthening competitiveness and development of Sihanoukville port in the Kingdom of Cambodia**, available at http://libopac.jica.go.jp/images/report/P1000005179.html (final access on 30/03/2014)

Japan International Cooperation Agency (JICA) (2013) **The preparatory survey on Phnom Penh autonomous port new container terminal's special economic zone and associated facilities construction project in Kingdom of Cambodia: final report**, available at http://libopac.jica.go.jp/images/report/P1000013602.html , last accessed on March 30, 2014.

Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (2012) **Report on enhancement of project formation on the ports in the Mekong Region** (in Japanese)

Shibasaki, R., Azuma, T., Watanabe, T., and Toriumi, S. (2013) A container cargo assignment model on a real international maritime shipping network and application to the Suez Canal transit analysis, **Proceedings of International Association of Maritime Economists Annual Conference (IAME 2014)**, Marseille, France.

Shibasaki, R., Iijima, T., Kawakami, T., Kadono, T, and Shishido, T. (2014) Integrated model of maritime and hinterland container shipping considering both freight and shipping time and application to Central America, **Proceedings of International Association of Maritime Economists Annual Conference (IAME 2014)**, Norfolk. (accepted)

Srivastava, P. and Kumar, U., eds. (2012) **Trade and trade facilitation in the Greater Mekong Subregion**, ADB Publishing, Mandaluyong City, Philippines. available at http://www.adb.org/sites/default/files/pub/2012/trade-and-trade-facilitation-gms.pdf, last accessed on March 31, 2014.

Toriumi, S. (2010) Pattern Analysis of Containerships using Maritime Shipping Network, **Journal of the Operations Research Society of Japan**, 55(6), 359-367. (in Japanese)