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Determination of Optimum Domestic Hub Port for Eastern Indonesia in Container Shipping

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Abstract

As a largest archipelagic country in the world, Indonesia has potential to become "the world's maritime axis". Consequently, the Blueprint of Development of National Logistics System (SISLOGNAS) was established in order to accomplish the objective. In line with the Masterplan for Acceleration and Expansion of Indonesia's Economic Development (MP3EI) 2011 – 2025, the vision and mission were set to create the national logistics hubs and to develop efficient connectivity inter-region and inter-islands. The "Sea Toll" program was thus be introduced to improve connectivity so that it can deliver goods efficiently and effectively across Indonesia. This study will find optimum domestic hub port in order to accommodate the container movement from the West to the East of Indonesia. This study uses integer linear programming to determine the most optimum domestic hub port and collects a total of 37 ports across Indonesia including 2 origin ports, 12 hub port candidates, and 23 destination (spoke) ports at the Eastern Indonesia. By using a mathematical method, this study finds the cheapest transportation cost for all container distribution system. Finally, this study results Samarinda port and Banjarmasin port with a cost of IDR 783.596.604.509, -. as the optimum domestic hub ports for the Eastern Indonesia.

Keywords: *Optimation, Hub and Spoke Network, Integer Programming, Hub Port Challenges*

1. Introduction

As the world's largest archipelago country in the world with more than 17.000 islands and a total coastal line of 81.000 kilometers (KM), Indonesia relies on its shipping to connect inter-region and inter-island economic activities. In the 7th until 14th century Indonesia with its two largest Kingdoms, Sriwijaya Kingdom and Majapahit Kingdom, were able to maximize shipping between islands as a bridge for unity [1]. These two kingdoms had built the Indonesian Maritime by controlling all forms of trade and shipping on the Asia Continent. Both Kingdoms were highly admired internationally due to their power across the Strait of Malacca, which was linked to international trade routes from East Asia to West Asia and Europe. In the face of the current global economic challenges Indonesian President Joko Widodo, Jokowi, has strongly committed to make Indonesia into a global maritime axis. His vision was therefore to develop a modern transport system, maritime highway or sea toll road to promote the development of the local economies.

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However, rejuvenating Indonesia as a global maritime hub is not an easy task. Despite its potential, Indonesia still faces many challenges including lack of connectivity, a lack of maritime infrastructure, inefficient port management, and price disparities between the islands. According to the World Bank report, shipping goods from Padang to Jakarta costs more than three times to compare shipping of the same container from Jakarta to Singapore [2]. The Logistics Performance Index (LPI) in 2018 also showed that Indonesia ranked 46th in the world and 4th place in Southeast region below Singapore (7th place), Thailand (32nd place), Vietnam (39th place), and Malaysia (41st place) [3]. The LPI evaluates countries based on a variety of variables such as customs, infrastructure, international shipments, logistics competence, and timeliness [3].

In response to the increase of national competitiveness, current Indonesian government introduced a Master Plan for the Acceleration and Expansion of Economic Development of Indonesia (MP3EI) 2011 – 2025. This MP3EI aims to make Indonesia one of the world's largest economic powers by 2025. The implementation of this MP3EI will include three main components including [4]: First, develop regional economic potential in six Indonesian economic corridors including Sumatra, Java, Kalimantan, Sulawesi, Bali - Nusa Tenggara, and Papua - Kepulauan Maluku Economic Corridors. Second, strengthen national connectivity national and international level. Third, strengthen human resources capacity and national science and technology to support the development of major programs in all economic corridors. With the introduction of MP3EI 2011 – 2025, the tasks were established to create the national logistics center (hub) as well as to develop connectivity around the six economic corridors which are commonly referred as a sea toll road program. Operated by Indonesia National Lines (PT. PELNI), according to the decree of the General of Sea Transportation Number A1.108/7/8/DJPL-2015 this sea toll program proposed an integrated logistic system using the concept of hub and spoke network. Figure 1 shows the concept of the sea toll program design including 24 strategic ports throughout Indonesia.

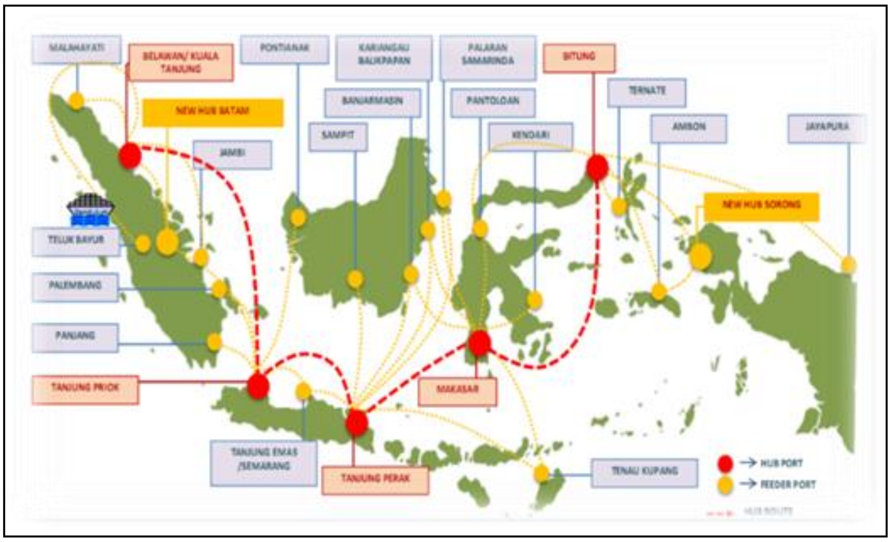

Figure 1. The Sea Toll Program in 2015 – 2019 [5]

The implementation of the sea toll program in 2015 – 2016 found that the logistics cost for freight distribution were still relatively high [6]. One of the main reasons was due to the inefficiency of routing in which the sea toll programme of 2015 - 2016 still used the concept of direct connection hub port to feeder port or multi-port calling network [7]. As a result, this study attempts to improve by implementing a network of hubs and spokes. A previous study by Keceli and Choi (2008) argued that the concept of hub and spoke network shipped cargo or containers to a large hub port with ultra-large container ships and was transshipped by feeder ships to smaller ports. The location of the logistic center (hub) will determine the efficiency of urban freight transport systems and sufficiently support supply chain activities [8].

Based on an interview with the Indonesian Ministry of Transportation in 2016, this study chose Tanjung Priok Port in Jakarta and Tanjung Perak Port in Surabaya as original ports for the delivery of goods to the Eastern part of Indonesia. The Tanjung Priok Port is chosen since it is the most advanced port in Indonesia which handles more than 50% of all Indonesian domestic traffic while the Tanjung Perak Port is selected due to its strategic posititive to meet the needs of the shipping activities in the Eastern part of Indonesia. In addition, these two ports play an important role in connecting West Indonesia with East Indonesia including Sulawesi, Borneo, Maluku, Nusa Tenggara, West Papua and Papua [4]. Table 1 shows the 12 selected hub port candidates and 23 destination (spoke) ports and Figure 2 illustrates the location of all ports used in this study.

Table 1. All Selected Ports for This Study

Origin Port	Hub Port Candidates		Destination (Spoke) Ports			
T.Priok	Ambon	Pontianak	Merauke	Donggala	Labuanbajo	Tanjung Selor
T.Perak	Balikpapan	Samarinda	Tarakan	Ende	Lembar	Tobelo
	Banjarmasin	Sampit	Amamapare	Fakfak	Luwuk	Tolitoli
	Jayapura	Sorong	Atapupu	Gorontalo	Maumere	Tual
	Kendari/Bungkutoko	Tenau/Kupang	Badas	Kalabahi	Nabire	Wini
	Pantoloan	Ternate	Baubau	Kumai	Parepare	Tanjung Selor

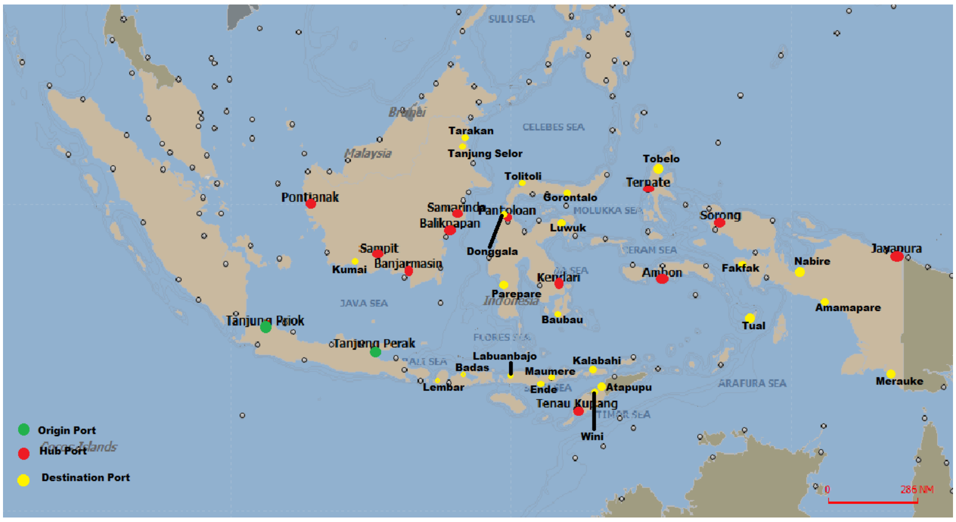

Figure 2. The Location of All Ports Used in This Study

1.1 Port to Port Network, Multi-Port Calling Network, and Hub and Spoke Network

In the earlier phase the container shipping route adopted port-to-port network. Due to the economic growth and the increasing size of the ship, a multi-calling port network was then introduced [9]. With this multi-calling port network, shipping companies were able to reduce transport costs and achieve the economies of scale of large ships. However, as cargo demand is continuously growing, this multi-calling port network concept leads to an inefficiency sailing time and the decrement of the operation [9]. If the container movement growths between the ports cannot be synchronized with the growth of the ship's size, in order to ensure that ships are fully loaded, the port operators must usually decide whether to add up the number of calling ports and keeping the network remains unchanged or reducing the number of calling ports and changing the network. As a result, the hub and spoke network was created to accommodate mega-container ships.

In a hub and spoke network, import of goods are first delivered to a main hub port then continues to its final destination (spoke) network whether by sea, rail, road or inland waterways. Similar to the import of goods, the export of goods is first connected to the main hub port and secondly transported to the final destination (spoke) port. The main hub port is often developed to accommodate a quick turnaround time of ships. Therefore, the main port is usually located in the center of the region [10]. Figure 3 illustrates the different service networks among port-to-port, multi-calling port, and hub and spoke network.

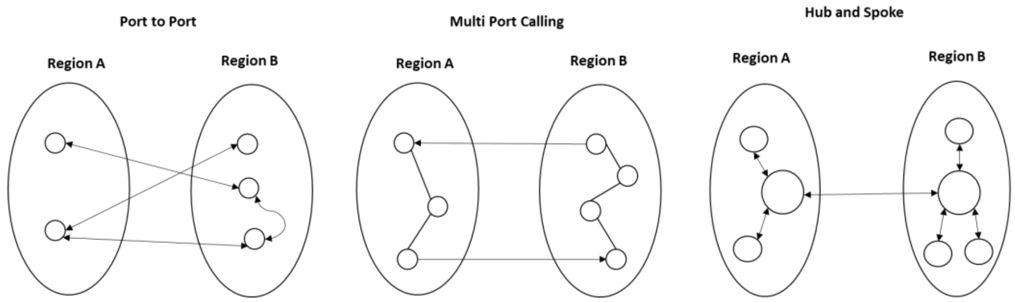

Figure 3. Service Network

The selection of the above networks is mainly based on those affected by size of the ships and the demand for cargo, besides distances, freight rates and shipping costs between ports in the same area. As a result, ship size and cargo demand directly determine the optimal selection of route structure forms and the optimization of other specific elements on routes.

1.2 Integer Linear Programming

In order to accommodate the container movement from the West to the East of Indonesia. This study uses integer linear programming to determine the optimal domestic hub port. Linear programming is defined as a mathematical model technique that aims to help manager for maximizing profit and minimizing resources in an organization [11]. It becomes integer since all the variables are restricted to be integer. Campbell (1994) explained the application of the integer programming method in the transport and telecommunication sector [12]. Here, integer programming formulations were created to solve five main types of discrete hub location problems including P-Hub Median problem (P-HM), Uncapacitated Hub Location Problem (UHLP), Capacitated Hub Location Problem (CHLP), and P-Hub Center Problem (P-HCI, P-HC2), and Hub Covering Problem (HCV). From the mentioned hub location problems, each origin port to the destination port is carried out via at least one port and no single origin port to the destination ports is through more than two hubs. In relation to the case present in this study, the P-HM is matched with the objective of this study since it is aimed to reduce the total operation cost [13].

2. Methods

This study uses both primary and secondary data about container shipping in the Eastern Indonesia. The primary data was collected directly from the interview while secondary data was obtained from the Indonesia Ministry of Transportation data and reports, international journal, papers, and publications from related topic. The secondary data was mostly obtained from the data and reports published by the Indonesia Ministry of Transportation, Netpass data, and company's websites such as PELINDO IV and Directorate General Sea and Transportation website. Consequently, data and information about distance information among ports, container flow information, ports, ships, total operating cost, and the cargo handling cost of each ports were obtained from this secondary data. In addition, there were 35 ports to accommodate container shipping in the Eastern Indonesia. Once all related information was collected, the interview was conducted with the Indonesia Ministry of Transportation to validate the collected data information. Next, mathematical model and the scenario were developed. Three scenarios were created = **Scenario 1:** One hub port to cover one origin port. This first scenario means that every origin port have their own dedicated hub port to served them. **Scenario 2:** One hub port to cover two origin ports. **Scenario 3:** Two hub ports to cover two origin ports while there is no condition hub 1 only for origin port 1. This scenario means that every container from origin port can move to any hub ports open that close to their destination port. All results were calculated with Microsoft Excel and finally the optimal domestic hub port was selected taking into account the lowest total transportation cost.

3. Result and Discussion

A mathematical model of this study is adopted from the model introduced by [12] and [13]. This mathematical model aims to separate the difference of port and shipping cost on main and feeder lines and the cost for delivering cargo in hub port from origin port. The following paragraphs will demonstrate the formulation of the model including parameters, objective function, decision variables, and constraints:

I = Origin Port
K = Hub Port
J = Destination Port (Major Port)
j = Destination Port (Feeder Port)

$$St_{IKJ} = St_{IK} + St_{KJ} = \frac{DIS_{IK}+DIS_{KJ}}{(Sp^{V}\times 24)} \quad (1)$$

$$St_{IKj} = St_{IK} + St_{Kj} = \left[\frac{DIS_{IK}}{Sp^{V}\times 24}\right] + \left[\frac{DIS_{Kj}}{Sp^{v}\times 24}\right] \quad (2)$$

Whereas,
St_{IKJ} = Streaming time from major port I to major port J via hub port K (days)
St_{IKj} = Streaming time from major port I to feeder port j via hub port K (days)
St_{IK} = Streaming time from major port I to hub port K (days)
St_{KJ} = Streaming time from hub port K to major port J (days)
St_{Kj} = Streaming time from hub port K to feeder port j (days)
DIS_{IK} = Distance between major port I and hub port K (Nautical Mile)
DIS_{KJ} = Distance between hub port K and major port J (Nautical Mile)
DIS_{Kj} = Distance between hub port K and feeder port j (Nautical Mile)
Sp^{V} = The speed of large vessel V (knots)
Sp^{v} = The speed of feeder vessel v (knots)

$$SC_{IK} = CV_{IK}^{V} \times St_{IK} \quad (3)$$

$$SC_{KJ} = CV_{KJ}^{V} \times St_{KJ} \quad (4)$$

$$SC_{Kj} = CV_{Kj}^{V} \times St_{Kj} \quad (5)$$

Whereas,
SC_{IK} = Sailing cost from major port I to hub port K (IDR/TEU)
SC_{KJ} = Sailing cost from hub port K to major port J (IDR/TEU)
SC_{Kj} = Sailing cost from hub port K to feeder port j (IDR/TEU)
CV_{IK}^{V} = Vessel daily operating cost from major port I to hub port K by large vessel V (IDR/TEU/DAY)
CV_{KJ}^{V} = Vessel daily operating cost from hub port K to major port J by large vessel V (IDR/TEU/DAY)

CV_{Kj}^{v} = Vessel daily operating cost from hub port K to feeder port j by feeder vessel v (IDR/TEU/DAY)

$$PC_{IK} = HC_I + HC_K \tag{6}$$
$$PC_{KJ} = HC_K + HC_J \tag{7}$$
$$PC_{Kj} = HC_K + HC_j \tag{8}$$

Whereas,
PC_{IK} = Port cost from major port I to hub port K (IDR/TEU)
PC_{KJ} = Port cost from hub port K to major port J (IDR/TEU)
PC_{Kj} = Port cost from hub port K to feeder port j (IDR/TEU)
HC_I = Cargo-handling charge at major port I (IDR/TEU)
HC_K = Cargo-handling charge at hub port K (IDR/TEU)
HC_J = Cargo-handling charge at major port J (IDR/TEU)
HC_j = Cargo-handling charge at feeder port j (IDR/TEU)

$$MC_{IK} = PC_{IK} + SC_{IK} \tag{9}$$
$$MC_{KJ} = PC_{KJ} + SC_{KJ} \tag{10}$$
$$FC_{Kj} = PC_{Kj} + SC_{Kj} \tag{11}$$
$$TC_{IKJ} = \left(MC_{IK} + MC_{KJ}\right) \times Q_{IJ} \tag{12}$$
$$TC_{IKj} = (MC_{IK} + MC_{Kj}) \times Q_{Ij} \tag{13}$$

Whereas,
MC_{IK} = Mainline cost from major port I to hub port K (IDR/TEU)
MC_{KJ} = Mainline cost from hub port K to major port J (IDR/TEU)
FC_{Kj} = Feeder line cost from hub port K to feeder port j (IDR/TEU)
Q_{IJ} = The container flows from major port I to major port J (TEU)
Q_{Ij} = The container flows from major port I to feeder port j (TEU)
TC_{IKJ} = Total cost from major port I to major port J via hub port K (IDR)
TC_{IKj} = Total cost from major port I to feeder port j via hub port K (IDR)

The objective function:

$$Min \sum_{I\in N_I}\sum_{K\in N_K}\sum_{J\in N_J} TC_{IKJ}X_{IKJ} + \sum_{I\in N_I}\sum_{K\in N_K}\sum_{j\in N_j} TC_{IKj}X_{IKj} + \sum_{I\in N_I}\sum_{K\in N_K} MC_{IK}Q_{IK}X_{IK} \tag{14}$$

Subject to:

$$\sum_{K\in N_K} Y_K = N \tag{15}$$
$$\sum_{K\in N_K} X_{IKJ} = 1 \quad \forall I \in N_I, \forall J \in N_J \tag{16}$$
$$\sum_{K\in N_K} X_{IKj} = 1 \quad \forall I \in N_I, \forall j \in N_j \tag{17}$$
$$\sum_{K\in N_K} X_{IK} = 1 \quad \forall I \in N_I, \tag{18}$$
$$X_{IKJ} \le Y_K \quad \forall I \in N_I, \forall K \in N_K, \forall J \in N_J \tag{19}$$
$$X_{IKj} \le Y_K \quad \forall I \in N_I, \forall K \in N_K, \forall J \in N_j \tag{20}$$
$$X_{IK} \le Y_K \quad \forall I \in N_I, \forall K \in N_K \tag{21}$$
$$Y_K \in \{0,1\} \tag{22}$$

Whereas,
Y_K : Binary variable that is equal to one if the location of hub port K is selected and zero otherwise.
X_{IKJ} : Flow fraction from major port I to major port J via hub port K
X_{IKj} : Flow fraction from major port I to feeder port j via hub port K
X_{IK} : Flow fraction from major port I to hub port K
N : The exact number of hub ports that must be open
N_I : The set of major ports I in the total ports
N_K : The set of hub ports K in the total ports
N_J : The set of major ports J in the total ports

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N_j : The set of feeder ports j in the total ports
Q_{IK} : The container flow from major port I to hub port K (TEU)

3.1 Data

This study uses data including ports information, container flow information, ships information, total operating cost, and cargo handling cost of each ports. Table 2 explains total container flow from origin port to destination port and vice versa.

Table 2. The Container Flow to the Eastern Indonesia

Destination Port	Origin Port	
	Tanjung Priok	Tanjung Perak
Merauke	0	9932
Tarakan	0	2399
Amamapare	214	3630
Atapupu	0	150
Badas	46	988
Baubau	0	4256
Donggala	200	400
Ende	0	230
Fakfak	0	170
Gorontalo	0	29488
Kalabahi	0	190
Kumai	0	398
Labuanbajo	0	314
Lembar	100	5171
Luwuk	0	4735
Maumere	0	193
Nabire	0	3765
Parepare	0	2685
Tanjung Selor	0	430
Tobelo	0	2013
Tolitoli	0	147
Tual	0	8033
Wini	236	0
Ambon	0	14071
Balikpapan	11931	39876
Banjarmasin	22389	42813
Jayapura	616	5697
Kendari	0	4871
Pantoloan	3708	4261
Pontianak	26904	4300
Samarinda	20762	37160
Sampit	111	1910

Sorong	0	8619
Tenau/Kupang	0	14430
Ternate	330	13342

In order to determine the distance between ports, this study uses Netpass software. With regard to the type of vessels, feeder vessel and large vessel are both used in this study. Table 3 shows the vessel characteristics include the capacity, the speed, and the daily operating cost for each vessels. While table 4 summarizes the cost of cargo handling in Tanjung Perak Port, Tanjung Priok Port, Pelindo II, Pelindo III, and Pelindo IV.

Table 3. Vessel Characteristics

	Capacity (TEUs)	Speed (knots)	Operating Cost (IDR/TEU/DAY)
Large Vessel	700 - 1000	14	IDR 14.234,-
Feeder Vessel	300 - 500	11	IDR 22.338,-

Table 4. Cargo Handling Cost (IDR)

Tanjung Perak	Tanjung Priok	Pelindo II	Pelindo III	Pelindo IV
IDR 728.000	IDR 650.000	IDR 650.000	IDR 600.000	IDR 623.000

3.2 Computational Results

Table 5 shows the computational results.

Table 5. Cost Classification of Optimal Domestic Hub Solution

Scenario	Origin Port	Optimum Domestic Hub Port	Main Line (IDR)	Feeder Line (IDR)	Hub Cost (IDR)	Total Transportation Cost (IDR)
1	T.Priok	Samarinda	161,457,152,418	1,461,624,972	31,996,862,761	194,915,640,151
	T.Perak	Banjarmasin	416,762,537,192	177,626,312,577	57,341,733,241	651,730,583,009
2	T.Priok & T.Perak	Banjarmasin	606,198,547,219	179,058,452,756	72,509,700,717	857,766,700,692
3	T.Priok & T.Perak	Samarinda & Banjarmasin	448,981,501,886	179,058,452,756	155,556,649,867	783,596,604,509

From table 5, one can see that only Banjarmasin port is appeared in every scenarios. In scenario 1, there are two selected hub ports, Samarinda port with Tanjung Priok Port as an origin port and Banjarmasin port with Tanjung Perak port as an origin port. Table 5 also shows that more containers are distributed via Tanjung Perak port than Tanjung Priok port to serve the container movement to the Eastern Indonesia. Further, in comparison among 3 scenarios, one can conclude that the cheapest transportation cost is appeared from scenario 3 with IDR 783.596.604.509, -. In this scenario, the origin ports are coming from Tanjung Priok port and Tanjung Perak port and both Samarinda port and Banjarmasin port are selected as the most optimum domestic hub to serve container distribution to the Eastern Indonesia.

4. Conclusion

This study concludes that both Samarinda port and Banjarmasin port as the most optimal hub ports with a cost of IDR 783.596.604.509, -. One can conclude that Indonesia can have multiple hubs since it is proven by scenario 3 where from 2 origin ports the container can be distributed via 2 hub ports. Samarinda port and Banjarmasin port are designated as the most optimum domestic hub ports since comparing to the other scenario, these two ports resulted in the cheapest transportation cost. This study has several limitations. First, although this study uses primary data with interviewing Indonesian Ministry of Transportation, the data that is given to this study can be subjected to bias. Second, since the data calculation is done with Microsoft Excel, human error can be occurred on the calculating progress. Therefore, this study recommends to include more accurate data, and more parameters to be taken into account in mathematical model, and finally it is also recommended that for further study can include international routing.

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