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# Feasibility Analysis of International Sea–Air Transport on the Export Cargo from East Asia to North America

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**Abstract**: The realization of international sea and air intermodal transportation (SEA&AIR transportation) will improve the competitiveness of international transportation by responding to recent advanced logistics needs, such as shorter transportation days, cost reduction, and environmental load reduction. This study analyzes the feasibility of SEA&AIR transportation via Japan using a generalized cost model. We found that (1) the possibility of SEA&AIR transportation from Kaohsiung to New York via Japan is the highest, with a share of 3.51%; (2) the larger share of marine transportation and the farther destination is a critical issue in realizing SEA&AIR transportation; and (3) SEA&AIR transportation takes over the share of air transportation. SEA&AIR transportation captures the share of air transportation and presents solutions that reduce environmental impact and energy efficiency by reducing air transportation.

*Keywords*: Sea and air transportation, international and intermodal transportation, generalized cost model

## 1. INTRODUCTION

In recent years, logistics have become more sophisticated and in-depth, with shorter lead times, lower transportation costs, and reduced environmental impact. To meet these requirements and improve the international competitiveness of Japan's overall freight forwarding system, it is necessary to promote international sea and air intermodal transportation (SEA&AIR transportation), which is a type of international intermodal transportation that combines sea container transportation and air transportation. It requires fewer days than ocean transport alone and lowers costs compared to air transport alone. It is an intermediate service between ocean transportation and air transportation.

According to the Civil Aviation Bureau of the Ministry of Land, Infrastructure and Transport, the first service was provided by Air Canada in the 1960s from Japan to Europe via North America. Specifically, the service offers ocean transportation from major Japanese ports to the west coast of North America, land transportation from ports to airports, and air transportation from airports to Europe. The background was that the cost of air transportation from Japan to Europe and the U.S. was high, and ocean transportation was well established as a critical route. However, in 1988, Air Canada suspended SEA&AIR transportation from Japan via the west coast of North America. Furthermore, in the 1990s, the difference between air and ocean freight rates narrowed, making SEA&AIR transportation less affordable; the advantages of SEA&AIR transportation in terms of lead time became less apparent as the speed of ocean transportation increased; and there was a shift of cargo originating in Japan to cargo originating in Southeast Asia because of the overseas expansion of Japanese companies. Those three factors led to a slump in the demand for SEA&AIR transportation from Japan.

However, after the suspension of SEA&AIR transportation by Air Canada, SEA&AIR Transportation from China via Japan was temporarily used in the 2000s. The background to this was the difficulty in securing air cargo space from China and Hong Kong to Europe and the US amidst the rapid increase in cargo from China to Europe and the US. In contrast, air cargo fares from Japan to Europe and the US were less expensive. Currently, Dubai and Incheon are the representative transit points for SEA&AIR transportation. SEA&AIR transportation via Dubai is used for shipments from China to Europe. SEA&AIR transportation via Dubai can transport goods in about three weeks and can achieve smooth transportation to inland areas. In contrast, sea transportation usually takes about 40 days. SEA&AIR Transportation via Incheon is being promoted because Korean companies have moved their factory bases to Qingdao and Tianjin, and export demand from those regions to Europe and the US has increased.

There are two concepts of SEA&AIR Transportation. The first, in case the destination is inland for port-to-port transport or in case the time value of the cargo is somewhat high. The second is a means of transportation in a usual case, for instance there are capacity constraint of ocean transportation and air transportation caused by increased demand for imports and exports. The reason for going via Japan is that there are several places where ports and airports are adjacent to each other within a radius of 10 km. The internationalization of Japan's airports has been proceeded in recent years, for instance Tokyo Haneda Airport rapidly expanding the allocation of slots for international flights since 2010, and Kobe Airport will be internationalized in 2030.

This study applies a generalized cost model to investigate the feasibility of SEA&AIR transportation of containerized cargo from East Asia to North America via Japan, especially via the Kansai region. The analysis results will be used to consider the feasibility of SEA&AIR transportation, and scenarios will be developed regarding the services and policies required to make SEA&AIR transportation a reality, thereby expanding the potential of SEA&AIR transportation. In this study, SEA&AIR transportation has been explored as an overall intermodal transportation that combines sea transportation first and air transportation later, with sea transportation from the origin to the transit point and air transportation from the transit point to the arrival point. Figure 1 shows the locations of ports and airports in Kansai region. The ports of Kobe and Osaka have a prewar history of handling import and exporting cargo, and the port infrastructure is well-developed. SEA&AIR shipments from East Asia to the U.S. using Kansai International Airport after unloading at the ports of Kobe and Osaka are considered.

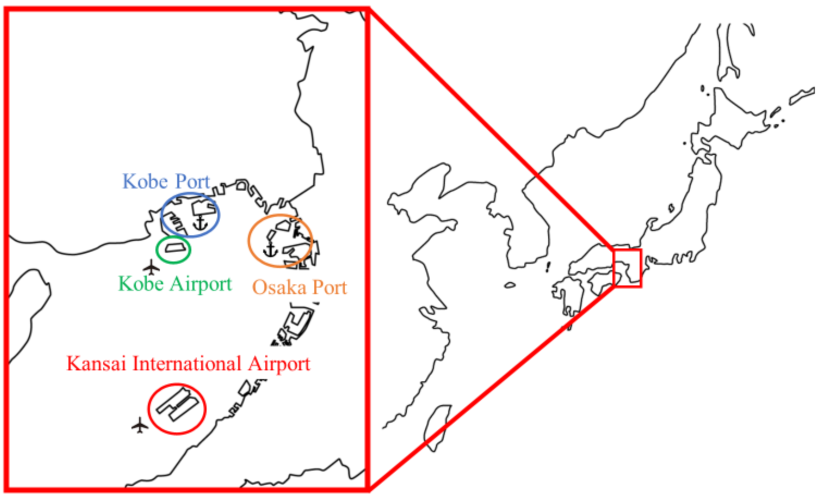

Figure 1. Location of ports and airports in Kansai

## 2. LITERATURE REVIEW

To analyze the significance of SEA&AIR transportation via Japan, this study addresses studies in our own country and SEA&AIR transportation efforts in other countries and intermodal transportation.

Yang (2010) analyzed the feasibility of SEA&AIR transportation via the Taiwan Strait. The volume of cargo demand for SEA&AIR transport from Xiamen to Kaohsiung by sea and from Kaohsiung to Los Angeles by air was forecasted. The results indicate that the forecasted cargo volume is much lower than initially expected in terms of lead-time and transportation cost reduction, government conflicts, inefficiency in customs clearance for ocean and air transportation, and uncertainty in timeliness as issues to be addressed. Chung et al. (2010) described the prospects for the Incheon area, where SEA&AIR transportation is practiced. They conducted a SWOT analysis based on data from a questionnaire survey of workers and the rate of change in cargo handling volume from 2001 to 2008. They indicated a high degree of uncertainty about the future. This is partly because the industry was significantly affected by the collapse of Lehman Brothers. Raguraman et al. (1994) described SEA&AIR transportation as "half the cost of air transport and half the time of marine transport" and introduced it as an epoch-making form of transport. As a feature of cargo when using SEA&AIR transportation, cargo prices should be limited to medium to high prices, and it is necessary to be sensitive to time so that shortened transportation time can be achieved. It explains the rise and fall of SEA&AIR transportation from the perspective of the historical background and declining service levels. Abid et al. (2020) used a Tunisian apparel manufacturer as a model to improve supply chain efficiency using SEA&AIR transportation. The variables and analysis consider financial costs and customer satisfaction, as the goal is to pursue profits for the company. From a supply chain perspective, SEA&AIR transportation is highly committed to trending apparel products. Okita et al. (2010) proposed the promotion of SEA&AIR transportation to resolve the disproportion between the capacity of China's airports and the volume of transportation, which was a bottleneck in transportation when manufacturing was concentrated in East Asia, and consumer demand was significant in the U.S., Japan, and Europe. The optimal allocation was obtained from a function determining the total profit considering inventory and transportation costs. However, in the choice of transportation method, instead of a realistic route service (flights/week), a hypothetical transportation mode allocation was created, and a sensitivity analysis was used to determine which transportation mode allocation would be the most profitable. As a result, they concluded that the maximum profit was obtained when air transportation was the most expensive mode and sea transportation was the least costly mode. Lee et al. (2011) studied SEA&AIR transportation routes between the Pacific and Asia using fuzzy SAW and fuzzy multiple criteria Q-analysis procedures as the analysis methods. The logistics perspective has been strongly emphasized. Performance satisfaction was also measured. The target regions were Singapore, Hong Kong, Taipei, Shanghai, and Seoul, and the questionnaires were sent to several major companies. The results showed that Shanghai, Singapore, and Hong Kong were superior, and ambiguity in route selection can be somewhat quantified.

Subsequently, we address studies on intermodal transportation other than SEA&AIR transportation. Wang et al. (2018) evaluated efficient transportation with Fuzzy Delphi and Fuzzy ELECTRE during intermodal transportation, focusing on rail services due to the increasing trade volume from Incheon to Central Asia (Kazakhstan). The five main factors (total cost, reliability, capacity, total time, and safety) were described based on the results when shippers choose transportation routes. Chen et al. (2008) proposed a decision-making model for freight forwarders' intermodal transportation route selection across the Taiwan Strait. The cargoes analyzed were textiles (low-value goods), and electrical appliances (high-value goods), and the model proves that low-value goods prefer low-speed transportation, and high-value goods prefer high-speed transportation. Although the superiority of air transportation has not been proven owing to the short route distance, the data of the companies and the market prices of sea and air transportation are clearly shown. Fan et al. (2019) showed the effectiveness of the objective optimization algorithm PMSS and used it to investigate the energy consumption of Sea & Rail transport. A sensitivity analysis using PMSS examined energy consumption over a combination of simple routes (Sea & Rail transport) and over time. It does not explicitly select actual routes or cargoes but proposes efficient transportation modes according to the transportation time. Sahin et al. (2014) conducted a cost analysis of intermodal transportation by combining road, rail, and sea transport. Using Turkey as a model case, the model equation uses the levelized cost analysis method to obtain and propose an economical transportation model by transportation distance when choosing between single- and combined-modal transport. The time value of the cargo was not considered. Gillen et al. (2018) investigated changes in the total dwell time of intermodal traffic at ports using a simulation model that utilized operational data from Canadian ports on the West Coast. They also predicted a correlation between the increase in vessel size and dwell time, resulting in a negative impact on port efficiency (in terms of dwell time) as vessel size increases owing to increased cargo demand. Sea & Rail transportation was assumed as the modes of intermodal transportation. Several vessel size patterns were set, and a sensitivity analysis was conducted to determine how port efficiency increases as demand increases. Increasing the frequency of operations is the most effective method because of elasticity and other limitations of demand growth. Chang (2008) attempted to solve this problem by formulating and developing a mathematical model (application of heuristics) because the optimal route selection in international intermodal transportation is complicated by multiple objectives, delivery times and modes, economies of scale, and other factors. As an example of the cargo to be analyzed, a route for transporting monitors from Taiwan to the U.S., with the number of monitors specified, was selected, formulated, and simulated using an algorithm.

Ohashi et al. (2005) applied a multinomial logit model to determine the critical factors in air cargo transshipment. The results state that reducing loading and unloading time is more effective than airport charges, implying time savings, improved service quality, and diversification are necessary for air cargo transshipments with a relatively high time value. Hanaoka et al. (2010) conducted a passenger volume forecast for air transport belly flights to control short-shipping due to unexpected increases in cargo and passengers on the Bangkok-London and Bangkok-Seoul routes. Kupfer et al. (2016) applied a multinomial logit model to analyze how shippers choose origin and destination airports when using European air transport for Freighter flights. The analysis results show that factors such as the presence of forwarders at the airport, experience in airport cargo handling, and airport charges were important. Choi (2023) states that emerging cargoes such as clothes, plastics, and cosmetics depend on air transport in the diversifying air transport cargo for South Korea and that these items will continue to dominate the air transport share and drive the air cargo market in the future.

We then discuss a study on intermodal transportation that includes generalized and logit models, which are non-aggregate analysis methods. Hanseen et al. (2012) analyzed the conditions under which intermodal transport is desirable for fresh fish from Norway to Central Europe, using a generalized cost model. Conditions that favor intermodal transport are (1) increased terminal handling costs, (2) increased total transport distance, (3) increased pre- and post-transport costs, and (4) distance dependence. (5) the distance-dependent marginal generalized cost of trucks decreases, and (6) the rest cost of truck drivers decreases. To promote intermodal transport compared to single truck transport, 1. standardization of cross-border intermodal transport, 2. reduction of transport costs for vehicles specializing in pre-post transport in urban areas, 3. prioritization of goods trains, 4. additional charges for road transport, 5. stricter rest regulations for truck transport over long distances. Although there are some differences from this study in that Sea & Rail transport is assumed as the form of intermodal transport, and the cargo target is fresh fish, similarities can be noted in that the conditions for the assumed realization of intermodal transport are considered. Jourquin et al. (2014) The cost elasticity of truck transport during Rail & Road transport is determined from a logit model for Europe. The elasticity is obtained when road and rail costs change and is analyzed using Antwerp to Bettenburg as a model route. The results show that Rail & Road intermodal transport is more sensitive than truck transport to changes in truck transport costs, but the demand itself does not change. This states that reductions in trucking costs benefit intermodal transport. Tavasszy et al. (2009) extend the generalized cost concept to create consistent future freight transport demand scenarios, aim to reduce costs for freight operators and shipper companies and provide an optimal framework. He states that generalized cost models are suitable for supply chain optimization but that issues such as choice of manufacturing and storage locations, frequency of replenishment shipments, and inventory issues remain.

Based on these considerations, this study applies a generalized cost model that represents the benefits of adding the value loss due to cargo time and the logistics costs for each mode of transport, such as sea and air transport. This enables comparisons between transport modes and the optimum means of transportation at a given time value to be found.

## 3. ANALYTICAL METHOD

### 3.1 Generalized Cost Model

Generalized cost models assume that a generalized cost volume, expressed in terms of time and cost, is set for each transportation route option and that the route with the lowest generalized cost volume is selected among the options. The logit model represents non-aggregate behavior models. The logit model can estimate the shipper's decision-making, such as transportation means and routes; however, as it deals with a utility function consisting of an observable fixed port and an unobservable stochastic term, it requires a large amount of data to create the model and, simultaneously, has many variables. In contrast, the generalized cost model has the advantage of being easy to handle because the only variables are time and cost, making it easy to set the level of service. Although fewer in number than the logit model, we applied it in this study because it has been applied in previous studies and hence is reliable. Iyama et al. (2010) stated that not only the benefits from reduced costs but also the benefits from reduced time are essential. They chose a generalized cost model consisting of cost and time benefits due to the variety of containerized cargo and the difficulty of obtaining detailed price data for each item. This study also targets containerized cargo from East Asia to North America, and it is assumed that costs and time values are incorporated into the benefits to analyze the feasibility of SEA&AIR Transportation via Japan. For this reason, a generalized cost model is applied, as in Iyama et al. Let $GC_r$ be the amount of generalized cost, $C_r$ the total transportation cost, α the time value, and $T_r$ the total transportation time. Then, the amount of generalized cost is expressed by the following equation:

$$GC_r = C_r + T_r \cdot \alpha \tag{1}$$

where,

$GC_r$ : amount of generalized cost of route r (JPY/ton)

$C_r$ : total transportation cost of route r (JPY/ton)
$T_r$ : total transportation time of route r (hour)
α : time value of cargo (JPY/ton/hour).

In SEA&AIR transportation, the total transportation cost is the sum of the ocean container transportation, land transportation, and air transportation costs. The total transportation time is the sum of the required days, cargo handling time, and waiting time for ocean transportation.

The concept of route selection using the amount of generalized cost is shown in Figure 2. Here, the vertical axis represents the generalized cost, and the horizontal axis represents the time value. Assuming, for example, that three routes can be selected, the amount of generalized cost for each route is represented by the three straight lines, $GC_1$, $GC_2$, and $GC_3$, respectively. The subscripts 1, 2, and 3 represent the number of each route. As shown in Figure 2, the straight line (route) with the minimum amount of generalized cost changes as the time value of cargo changes. In this case, route 1 is selected for the smallest amount of generalized cost when the time value of the cargo is between 0 and $\alpha_{12}$, route 2 is selected for time values between $\alpha_{12}$ and $\alpha_{23}$, and route 3 is selected for time values above $\alpha_{23}$. The graph below in Figure 2 shows the distribution curve of the time value with the probability density function P on the vertical axis and time value on the horizontal axis. For example, the probability P1 of the time value of cargo from 0 to $\alpha_{12}$ is the probability that route 1 is selected. Therefore, once the distribution of time value is known, the sharing ratio for each route can be determined.

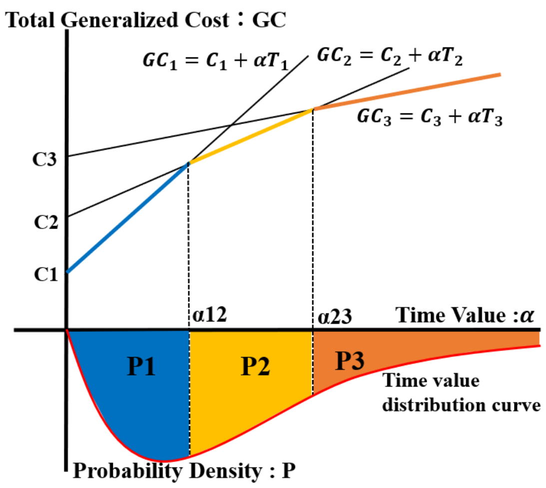

Figure 2. Example of generalized cost model

### 3.2 Time Value

The time value of cargo is an essential factor in selecting routes, considering transportation routes and the share of each transportation agency as well as a necessary item in the monetary conversion of transportation time savings and other benefits. The time value of money is the economic expression of the benefits that can be gained from time savings. The time value of cargo supposed in this study is based on data from the National Survey of Import/Export Container Cargo Flows conducted once every five years by the Ports and Harbors Bureau of the Ministry of Land, Infrastructure, Transport, and Tourism. Based on a previous study by Iyama et al. (2012), the time-value distribution in this study was assumed to be lognormal. As mentioned in Section 3.1, the lower graph in Figure 2 depicts a lognormally distributed probability density function with the probability density function P on the vertical axis and the time value α (JPY/ton/hour) on the horizontal axis. Iyama et al. (2012) built their model using the results of a 2013 container cargo flow survey, while Akakura et al. (2021) re-estimated the parameters of the lognormal distribution of the time value using the results of the same survey in 2018. In this study, we use Akakura et al.'s (2021) average of 8.03 and a standard deviation 2.31 for exports to North America and Europe, respectively. The time value of cargo from each origin to North America should be adopted. Still, in this study, the time value of cargo exported from Japan to North America was assumed to be the same as that of cargo from East Asia to North America due to data availability.

## 4. SEA&AIR TRANSPORTATION AREAS AND TRANSPORTATION ROUTES

### 4.1 Overview of Data

Data from the 2021 edition of the International Transport Handbook were used for the number of days required for sea transport and the ports covered in the feasibility analysis of SEA&AIR transportation, and transport costs were obtained from the Container Freight Rate and Sea & Air Shipper Insight. Costs were obtained on a per-ton basis.

### 4.2 Selection of Target Region

This study considered the feasibility of SEA&AIR transportation via Japan in East Asia. First, the effectiveness of SEA&AIR transportation via the ports of Kobe and Osaka was examined using a generalized cost model. From the International Transport Handbook 2021; we identified all services from North America, Europe, East Asia, Southeast Asia, and Oceania that call at the Ports of Kobe and Osaka and selected the target ports from all the previous ports. The nine ports in Table 1 are targeted as the departure points because all ports have direct flights to Kobe and Osaka, with the minimum number of these flights at five. In addition, there is at least one direct flight to one of the destinations, Los Angeles, Chicago, or New York, and the number of sailing days and flights is specifically indicated in the International Transport Handbook 2021. Considering the geographical distance from Incheon, Korea, a competitor for SEA&AIR transportation, the ports are located south of Shanghai. The three destinations were set as Los Angeles (LA), Chicago (CHI), and New York (NY), owing to geography, covering West Coast, Mid-West, and East Coast. Each of these cities often handles ocean containerized cargo and serves as a destination because of the large number of international air shipments from Japan.

Table 1. Target Ports for SEA&AIR Transportation

| Place | Port/City |
|---|---|
| **Origin** | Shanghai, Ningbo, Xiamen, Shenzhen, Hong Kong, Kaohsiung, Haiphong, Laem Chabang, Singapore |
| **Transit point** | Osaka, Kobe |
| **Destination** | Los Angeles (LA), Chicago (CHI), New York (NY) |

### 4.3 Setting Up Time and Cost

#### 4.3.1 Time setting

In this study, five types of times were assumed: (1) ocean transport time, (2) air transport time, (3) land transport time, (4) cargo handling time (port and air), and (5) average waiting time for ocean transport. The ocean transport time and average waiting time for ocean transport in (1) and (5) were set based on actual transport schedules using the International Transport Handbook

2021. For ocean transit time in (1), the number of days required for each service to call at the ports of Kobe and Osaka from all previous ports was examined after checking the availability of direct services to Kobe and Osaka. Only practical days were selected by employing less than half of the rotation days (the number of days required for a ship to complete one round trip) for each service. As for the average waiting time for marine transportation in (5), we obtained the number of services from each port by ascertaining the number of direct services to Kobe and Osaka ports from all previous ports. Using this information, we calculated the average waiting time per week. The formula is as follows:

$$T_w = \frac{7}{F_l} \cdot \frac{1}{2} \cdot 24 \tag{2}$$

where,
$T_w$ : Average waiting time (hour)
$F_l$ : Number of flights (flights per week)

Regarding the air transport time for (2), as it is not possible to determine an exact transport time with the currently available data, we set the time for any route to 24 hours. Regarding the land transportation time for (3), the land transportation time in the U.S. was set to 96 hours from the Port of Los Angeles to Chicago (Matsuda et al. 2015). In Japan, the transportation time was estimated from the land transportation distance at a speed of 60 km/h. Regarding the cargo handling time for (4), the Port Policy Council (2007) and the Ministry of Finance (2018) established 48 hours for cargo handling at ports and 8 hours for cargo handling by air, respectively. Thus, the values for (1) and (5) ocean transportation time and waiting time for ocean transportation are precise because they are derived from actual data. In contrast, air transportation time, land transportation time, and cargo handling time are estimated.

#### 4.3.2 Establishment of costs

Four costs were assumed: (1) ocean freight, (2) air freight, (3) land freight, and (4) cargo handling—all of which were set using freight rates per ton. First, for (1) ocean transportation costs, we calculated the costs from the figures described for the route to be analyzed from the Drewry container freight rate of December 2021 by Drewry Maritime Research. According to Sasaki et al. (2017), the ocean freight cost per ton of cargo is shown below, given that the ratio of container types is 20-foot pieces:40-foot pieces = 10:12, and the amount of cargo per container is approximately 23.3 tons.

$$\frac{C_{20ft} \cdot 10 + C_{40ft} \cdot 12}{(10+12) \cdot 23.3} \tag{3}$$

where,
$C_{20ft}$ : Sea freight cost per 20 ft Dry
$C_{40ft}$ : Sea freight cost per 40 ft Dry

The data used in this study are the latest container freight rates available, which differ from regular times because container freight rates have risen sharply in recent years owing to the coronavirus. However, in ocean container transport, container freight rates often fluctuate monthly, and transport routes are frequently changed. Considering this impact, we selected more up-to-date freight rates and routes. Subsequently, (2) air transportation costs are based on data from the Sea & Air Shipper Insight, which consists of three components: buy rate (US$/kg), fuel surcharge, and security surcharge.

For the sea transportation costs in (1) and air transportation costs in (2), the data available on Drewry did not disclose the costs for all the routes analyzed. Therefore, in this study, non-data section costs were calculated based on the ratio of the linear distance between the non-data section and the section for which the data existed. The reference data for the non-data segments are those for the segment with the closest distance. Data from Ho Chi Minh City to LA and NY were used as references for Haiphong to LA and NY. Japan's land transportation costs in (3) were first calculated from the distance ratio based on actual truck freight rates from the LOGI-BIZ APRIL 2020. Then, (4) refers to the additional cargo handling costs that arise only when SEA&AIR transportation is used compared to ocean and air transportation. As there are no exact values for this, we assumed 30,000 JPY/ton. Regarding costs, the sea transportation cost was collected from the current data; however, it was difficult to predict that the data were precise because they were estimated based on the distance ratio for some sections. Air and land transportation costs were also estimated; therefore, they cannot be considered clear values.

## 5. RESULTS OF SEA&AIR TRANSPORTATION

### 5.1 Results of Analysis of SEA&AIR Transportation

We analyzed ocean transportation, air transportation, Kobe SEA&AIR transportation, and Osaka SEA&AIR transportation using a generalized cost model. The vertical axis is the total generalized cost GC (JPY/ton), and the horizontal axis is the time value α (JPY/ton/hour). SEA refers to marine transportation, AIR to air transportation, Kobe SEA&AIR to SEA&AIR transportation via Kobe, and Osaka SEA&AIR to SEA&AIR transportation via Osaka.

The results of the analysis are summarized in Table 3 (divided into three items): preferred transportation mode, gap (JPY/ton) at the first crossing point (via Kobe and Osaka), and the minimum time value at the first crossing point. Figure 3 shows the concept of the first crossing point and gap. The first crossing point refers to the intersection between SEA and AIR, Kobe SEA&AIR, and Osaka SEA&AIR with the smallest time value.

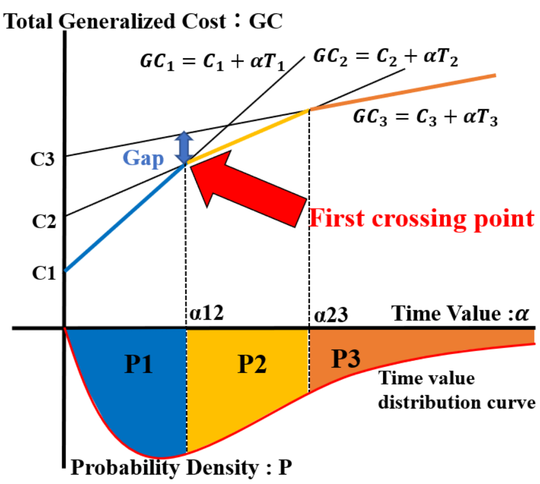


Figure 3. First crossing point and gap

The gap (JPY/ton) is the difference in the generalized cost at the first crossing point (AIR: Kobe, Osaka SEA&AIR). If this value is negative, there is no possibility of SEA&AIR transportation through Japan, and the generalized cost must be reduced by a negative amount to realize it. Meanwhile, if the value is positive, there is a possibility of SEA&AIR

transportation; however, if the generalized cost of AIR is lowered by the gap, the feasibility of SEA&AIR transportation is diminished.

Table 2 shows that the only possible SEA&AIR destinations via Japan are Hong Kong to NY (12) and Kaohsiung to NY (18). For the Kaohsiung to NY route, SEA&AIR via Kobe is also possible because the gap value for SEA&AIR via Kobe is positive. This indicates that the Port of Osaka is superior to the Port of Kobe in SEA&AIR transportation via Japan. As the main difference between the ports of Kobe and Osaka is the time required from the point of origin to the ports of Kobe and Osaka, this study, which applies a generalized cost model, suggests that time value has a significant impact.

Looking at the gap by destination, the negative values are more significant in the order NY < CHI < LA, indicating that LA < CHI < NY are the destinations with the highest potential for SEA&AIR transportation. This means that the greater the distance to the destination, the greater the possibility of SEA&AIR transportation.

Table 2. Analysis results for each route

| No. | Origin and destination | Potential of SEA&AIR | Gap (JPY/ton) via Kobe SEA&AIR | Gap (JPY/ton) via Osaka SEA&AIR | First crossing point minimum time value |
|---|---|---|---|---|---|
| 1. | Shanghai to LA | No | -550,456 | -496,662 | 3,572 |
| 2. | Shanghai to CHI | No | -426,504 | -385,955 | 2,667 |
| 3. | Shanghai to NY | No | -273,480 | -247,921 | 1,644 |
| 4. | Ningbo to LA | No | -964,107 | -902,282 | 4,120 |
| 5. | Ningbo to CHI | No | -693,918 | -648,882 | 2,974 |
| 6. | Ningbo to NY | No | -371,175 | -346,281 | 1,599 |
| 7. | Xiamen to LA | No | -855,294 | -749,291 | 4,060 |
| 8. | Xiamen to CHI | No | -601,329 | -523,547 | 2,964 |
| 9. | Xiamen to NY | No | -222,973 | -170,276 | 1,989 |
| 10. | Hong Kong to LA | No | -475,092 | -369,814 | 3,964 |
| 11. | Hong Kong to CHI | No | -330,454 | -252,895 | 2,905 |
| 12. | Hong Kong to NY | Yes (Osaka) | -44,533 | 10,126 | 2,031 |
| 13. | Shenzhen to LA | No | -690,070 | -522,514 | 4,667 |
| 14. | Shenzhen to CHI | No | -445,931 | -328,791 | 3,250 |
| 15. | Shenzhen to NY | No | -90,333 | -12,843 | 2,136 |
| 16. | Kaohsiung to LA | No | -499,774 | -423,981 | 4,185 |
| 17. | Kaohsiung to CHI | No | -334,124 | -278,942 | 3,024 |
| 18. | Kaohsiung to NY | Yes (Osaka) | 28,501 | 62,225 | 1,816 |
| 19. | Haiphong to LA | No | -606,052 | -502,308 | 3,896 |
| 20. | Haiphong to CHI | No | -437,369 | -362,354 | 2,802 |
| 21. | Haiphong to NY | No | -122,719 | -69,414 | 1,975 |
| 22. | Laem Chabang to LA | No | -336,178 | -288,579 | 2,966 |
| 23. | Laem Chabang to CHI | No | -283,264 | -245,458 | 2,337 |
| 24. | Laem Chabang to NY | No | -188,144 | -152,500 | 2,198 |
| 25. | Singapore to LA | No | -550,862 | -627,858 | 2,683 |
| 26. | Singapore to CHI | No | -419,369 | -482,166 | 2,197 |
| 27. | Singapore to NY | No | -444,360 | -519,012 | 2,602 |

When the difference between the LA and NY values of the first crossing point minimum time value is significant, the gap is also large, and the possibility of SEA&AIR transportation tends to increase. Based on this, we propose the following two conditions for the realization of SEA&AIR transportation, which is an intermediate transportation mode: (1) the time value range of LA-bound ocean transportation from the point of origin is large, which means that the share of ocean transportation is significant; and (2) the time value range of NY-bound air transportation is expanding as air transportation has reduced the share of ocean transportation.

### 5.2 Possible Routes

Based on the results in Section 5.1, we discuss the three routes from Hong Kong and Kaohsiung to NY, which have the potential for SEA&AIR transportation, and the following three routes from Shenzhen to NY, which have the highest potential for SEA&AIR transportation, considering the cost and other conditions involved in the routes.

As for transportation from Hong Kong to NY, shown in Figure 4, where only SEA&AIR transportation via Osaka is possible, it uses Container Freight Rate and Sea & Air Shipper Insight values from Drewry Maritime Research for both ocean and air transportation. Ocean freight costs from Hong Kong to Kobe and Osaka were calculated using distance ratios based on freight rates from Hong Kong to Yokohama to obtain more exact values. As the destinations are the same in Japan, and the difference in distance is approximately 400 km, the difference between the actual fares can be slight. However, air transportation from Kansai International Airport to NY is calculated based on the distance ratio from Shanghai to NY, which can cause errors. Additionally, the air transportation time was assumed to be 24 hours. For ocean freight, the values for Hong Kong to NY and Hong Kong to Kobe and Osaka were taken from the International Freight Handbook 2021; therefore, the difference would be negligible. This seems realistic because we have limited data on the four routes. The results show that the possible routes for SEA&AIR transportation via Osaka require a time value from 2031 to 2080 (JPY/ton/hour), with a small share of 0.40%. However, a 0.40% share indicates that 4 of 1,000 containers are transported by SEA&AIR transportation, which is reasonable, given the characteristics of intermediate transportation modes. Thus, SEA&AIR transportation is feasible.

As for transportation from Shenzhen to NY, shown in Figure 5, ocean transportation costs from Shenzhen to NY could be obtained directly from Drewry. Air transportation costs were calculated as the distance ratio from Hong Kong to NY data. The ocean transportation costs from Shenzhen to Kobe and Osaka were also obtained by the distance ratios from Shenzhen to Yokohama costs, as was the case for Hong Kong. For NY from Kansai International Airport, as in Hong Kong, the costs for Shanghai to NY were calculated using the distance ratio from Kansai International Airport to NY. As in Hong Kong, only air transportation is assumed to take 24 hours, whereas other times are obtained from the International Transportation Handbook 2021. Compared to Hong Kong, there are many places where transportation costs are estimated, and there is a possibility that there is a large discrepancy with the actual transportation costs. The gap for SEA&AIR transportation via Osaka is -12843 (JPY/ton), and additional analysis in the next section focuses on how this gap changes. The minimum time value of the first crossing point is also more significant than that of Hong Kong, so we will also focus on how this crossing point changes.

For the Kaohsiung to NY route shown in Figure 6, which is feasible for both routes, Drewry's values are used for ocean transportation costs, which are calculated based on the distance ratio from Hong Kong to NY, and the distance ratios for Kaohsiung to Kobe and Osaka are obtained from Kaohsiung to Yokohama. As in Hong Kong, only air transportation was assumed to take 24 hours, and the rest was based on the International Transportation Handbook 2021. Therefore, the reliability of the data is comparable to that of Shenzhen. However, it has the highest potential for SEA&AIR transportation among the three routes, with a wide time value range of 1816–2134 (JPY/ton/hour) and a share of 2.73%, making it the most notable route. Therefore, this is the basis for confirming the credibility of the conditions for realizing SEA&AIR transportation, as described in Section 5.1.

Following the discussion in Section 5.1, we can state that Osaka SEA&AIR transport has an advantage over Kobe SEA&AIR transport. To determine the factors, the slopes of the generalized cost model were tabulated for each mode of transportation. As mentioned in Section 4, the generalized cost model can be expressed as a linear equation; thus, the slope and y-intercept exist, and these slopes are summarized.

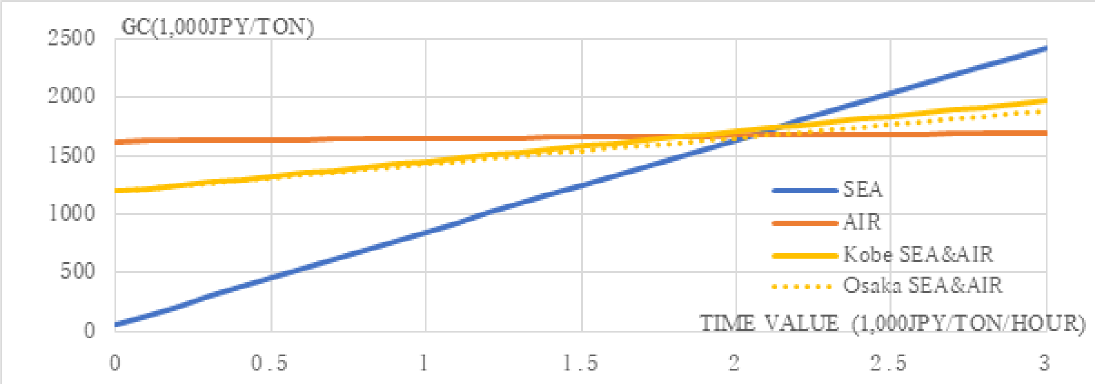

Figure 4. Hong Kong to NY generalized cost model

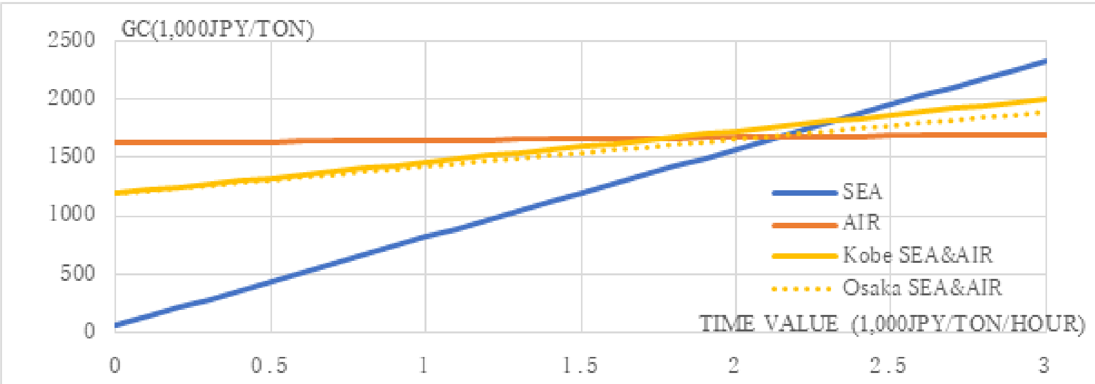

Figure 5. Shenzhen to NY generalized cost model

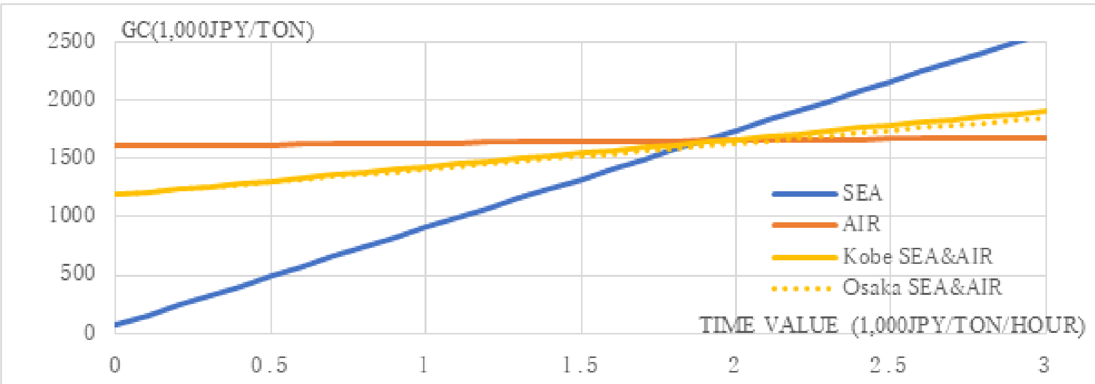

Figure 6. Kaohsiung to NY generalized cost model

Comparing Kobe SEA&AIR and Osaka SEA&AIR in Table 3, Kobe SEA&AIR > Osaka SEA&AIR, except for items 25–27. The items that cause the difference between Osaka and Kobe SEA&AIR are, by setting, truck transportation time and cost, the average number of days required for sea transportation from the point of origin, and the average waiting time depending on the number of flights. The land transportation cost is approximately 1,500 JPY higher via Kobe due to the difference in distance, as it is approximately 60 km from the Port of Kobe to

Kansai International Airport and approximately 45 km from the Port of Osaka to Kansai International Airport and in terms of time, Kobe gives a value 0.25 hours longer than Osaka. Furthermore, in sea transportation, Kobe took approximately one day longer than Osaka. The results of this analysis show that the superiority of the Osaka and Kobe ports does not change even when land transportation costs differ by about 1,500 JPY, suggesting that the time value, mainly the number of sea transportation days, significantly impacts superiority.

Table 3. Analysis results for each route (slope)

| No. | Origin and destination | Slope (Sea) | Slope (Air) | Slope (Kobe SEA&AIR) | Slope (Osaka SEA&AIR) |
|---|---|---|---|---|---|
| 1 | Shanghai to LA | 357.6 | 24 | 205.94 | 191.29 |
| 2 | Shanghai to CHI | 501.6 | 24 | 205.94 | 191.29 |
| 3 | Shanghai to NY | 726.8 | 24 | 205.94 | 191.29 |
| 4 | Ningbo to LA | 316.0 | 24 | 285.00 | 270.35 |
| 5 | Ningbo to CHI | 460.0 | 24 | 285.00 | 270.35 |
| 6 | Ningbo to NY | 759.0 | 24 | 285.00 | 270.35 |
| 7 | Xiamen to LA | 388.2 | 24 | 330.60 | 304.85 |
| 8 | Xiamen to CHI | 532.2 | 24 | 330.60 | 304.85 |
| 9 | Xiamen to NY | 788.8 | 24 | 330.60 | 304.85 |
| 10 | Hong Kong to LA | 412.0 | 24 | 257.16 | 230.97 |
| 11 | Hong Kong to CHI | 556.0 | 24 | 257.16 | 230.97 |
| 12 | Hong Kong to NY | 789.0 | 24 | 257.16 | 230.97 |
| 13 | Shenzhen to LA | 354.8 | 24 | 268.34 | 232.75 |
| 14 | Shenzhen to CHI | 498.8 | 24 | 268.34 | 232.75 |
| 15 | Shenzhen to NY | 756.0 | 24 | 268.34 | 232.75 |
| 16 | Kaohsiung to LA | 378.0 | 24 | 237.44 | 219.68 |
| 17 | Kaohsiung to CHI | 522.0 | 24 | 237.44 | 219.68 |
| 18 | Kaohsiung to NY | 834.0 | 24 | 237.44 | 219.68 |
| 19 | Haiphong to LA | 444.0 | 24 | 315.80 | 289.55 |
| 20 | Haiphong to CHI | 588.0 | 24 | 315.80 | 289.55 |
| 21 | Haiphong to NY | 828.0 | 24 | 315.80 | 289.55 |
| 22 | Laem Chabang to LA | 612.0 | 24 | 365.10 | 349.55 |
| 23 | Laem Chabang to CHI | 756.0 | 24 | 365.10 | 349.55 |
| 24 | Laem Chabang to NY | 786.0 | 24 | 365.10 | 349.55 |
| 25 | Singapore to LA | 572.8 | 24 | 367.50 | 396.75 |
| 26 | Singapore to CHI | 716.8 | 24 | 367.50 | 396.75 |
| 27 | Singapore to NY | 636.0 | 24 | 367.50 | 396.75 |

In the 25–27 Singapore departures, the slopes of Kobe SEA&AIR and Osaka SEA&AIR are reversed, with Kobe SEA&AIR < Osaka SEA&AIR. The Port of Kobe has an advantage in these three sections, as shown in Figure 7. This slope is determined by the sea transportation time from the port of origin to the port of Kobe or Osaka, the average waiting time, the truck transportation time from the port of Kobe or Osaka to Kansai International Airport, and the air transportation time from Kansai International Airport to the destination, including the cargo handling time. The items that differed the most were sea transportation time and the average waiting time. Kobe has much more direct liner services from Singapore. A higher frequency contributes to a shorter average waiting time. These results suggest that the time required for sea transportation and the average waiting time significantly impact the superiority of the ports of Kobe and Osaka. Kobe takes approximately one day longer than Osaka in terms of sea transportation because, in most sea transportation, the direct routes from East Asia to Kobe and Osaka are often formed by the port call to Osaka, followed by the port call to Kobe. In cases where the number of services is greater at the Port of Kobe than at the Port of Osaka, the average waiting time in the case of Kobe is shorter. Thus, this suggestion helps us understand the nature of establishing SEA&AIR services.

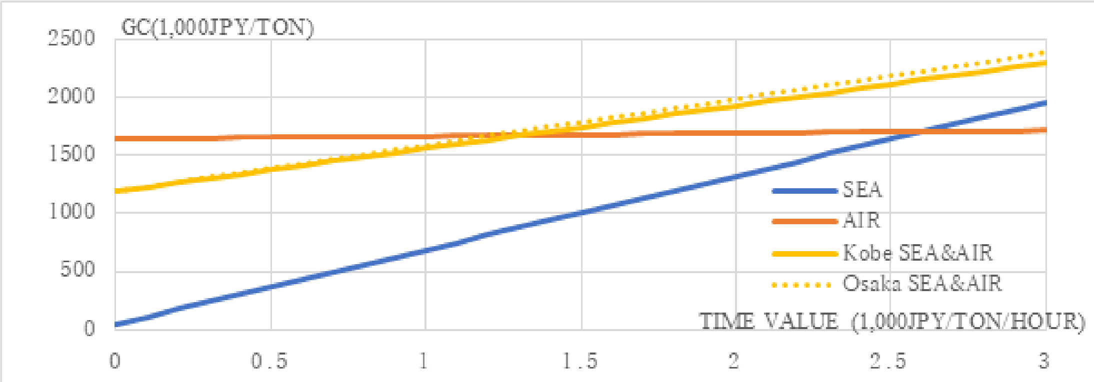


Figure 7. Singapore to NY generalized cost model

## 6. SCENARIOS ANALYSIS AND THE KOBE PORT POTENTIAL ADVANTAGES

### 6.1 Scenario 1

As described in Section 5, the time required for sea transportation significantly impacts the superiority of the ports of Kobe and Osaka. Therefore, if import demand to Kobe increases and the ports of Kobe and Osaka are called in that order, the time required for sea transportation from the point of origin to the ports of Kobe and Osaka in SEA&AIR transportation is replaced in scenario 1. The route will be from Hong Kong, Shenzhen, and Kaohsiung to NY, identified in the previous section as having a high possibility of SEA&AIR transportation. Below is an analysis of the Kaohsiung–NY route, the most feasible of the three routes.

Scenario 1 shows that the superiority of the ports of Kobe and Osaka in SEA&AIR transportation was switched by replacing the time required for sea transportation, proving that the sea transportation time from the point of origin to the port is a more significant factor in SEA&AIR transportation than is the average waiting time.

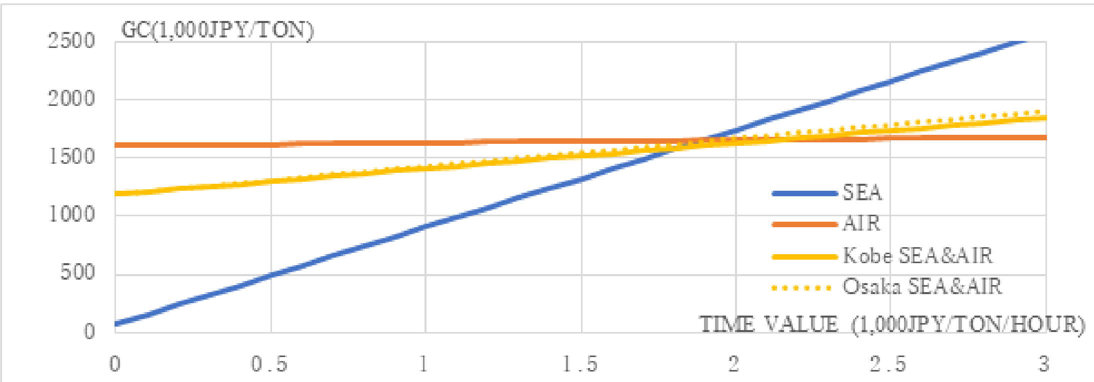


Figure 8. Kaohsiung to NY generalized cost model for scenario 1

Comparing the time value range and share of SEA&AIR transport based on the analysis results of Scenario 1 and Section 5, Table 4 shows that the time value range for Hong Kong to NY is 2,033–2,075 (JPY/ton/hour), and the share is 0.35%, which is lower than the result in Section 5. The optimal mode is the order of SEA, Kobe SEA&AIR, and AIR, with the Port of

Kobe having an advantage. Shenzhen to NY shows that the Port of Kobe was dominant, but the potential for SEA&AIR transport did not appear, as in Section 5. In Figure 8, Kaohsiung to NY, the time value range is 1,814–2,142 (JPY/ton/hour), and the share is 2.82%, slightly higher than that in Section 5.

Table 4. Comparison of Scenario 1 and Section 5 for SEA&AIR transportation

| | Time Value (JPY/ton/hour) | Share (%) |
|---|---|---|
| Hong Kong to NY in Chapter 5 | 2,031~2,080 | 0.40 |
| Hong Kong to NY in Scenario 1 | 2,033~2,075 | 0.35 |
| Shenzhen to NY in Chapter 5 | — | — |
| Shenzhen to NY in Scenario 1 | — | — |
| Kaohsiung to NY in Chapter 5 | 1,816~2,134 | 2.73 |
| Kaohsiung to NY in Scenario 1 | 1,814~2,142 | 2.82 |

### 6.2 Scenario 2

Kobe Airport, located adjacent to the Port of Kobe, currently serves only domestic flights, but the 12th Kansai Airports Roundtable Meeting held in 2022 considering regular international flights by 2030. Considering this, the analysis in Section 6 used Kansai International Airport as the base for air transportation, whereas Kobe Airport was used as the base in Scenario 2. The distance from the Port of Kobe to Kobe Airport was approximately 5 km, and from the Port of Osaka to Kobe Airport was approximately 35 km. The conditions set up in Scenario 1 (i.e., sea transportation time from the point of departure to the ports of Kobe and Osaka is replaced) are retained in Scenario 2.1, and the conditions set up in Section 5 (not replacing sea transportation time) are included in Scenario 2.2.

#### 6.2.1 Scenario 2.1

The results of the analysis for scenario 2.1 are presented in Table 5. The results show that changing the airport for SEA&AIR transportation from Kansai International Airport to Kobe Airport did not create possibilities for Shenzhen. Still, it expanded the potential of SEA&AIR transportation by reducing the share of air transportation compared to sea transportation due to the extent of the time value range. In addition, it can be inferred that trucking time and cost impact SEA&AIR transportation via Japan.

Table 5. Comparison of scenarios 2.1 and 1 for SEA&AIR transportation

| | Time Value (JPY/ton/hour) | Share (%) |
|---|---|---|
| Hong Kong to NY in Scenario 1 | 2,033~2,075 | 0.35 |
| Hong Kong to NY in Scenario 2.1 | 2,016~2,121 | 0.87 |
| Shenzhen to NY in Scenario 1 | — | — |
| Shenzhen to NY in Scenario 2.1 | — | — |
| Kaohsiung to NY in Scenario 1 | 1,814~2,142 | 2.82 |
| Kaohsiung to NY in Scenario 2.1 | 1,799~2,192 | 3.35 |

#### 6.2.2 Scenario 2.2

The results of the analysis for scenario 2.2 are presented in Table 6. The results show that the share does not appear in the Shenzhen to NY section and that the shares of both Hong Kong and Kaohsiung dropped compared to those in scenario 2.1. In addition, in scenario 2.2, the conditions of Section 5 are continued, and the Port of Osaka has an advantage. Therefore, the optimal mode was the order of SEA, Osaka SEA&AIR, and AIR (from Hong Kong and

Kaohsiung). Comparing the share with Section 5, we found that both the share from Hong Kong and Kaohsiung increased slightly, and the share also increased in Scenario 2.1 in Section 6.2.1 compared to Scenario 1, indicating that truck transportation time and cost have some influence on SEA&AIR transportation. This means there is an advantage in using Kobe Airport over Kansai International Airport for SEA&AIR transportation via Japan.

Kobe Airport, assumed in Scenario 2, is approximately 5 km from the Port of Kobe and is connected by a straight road. As the cargo handling time at the port is 48 hours and 8 hours at the airport is considered inefficient, Scenario 3 is developed considering these factors.

Table 6. Comparison of scenario 2.2 and Section 5 for SEA&AIR transportation

| | Time Value (JPY/ton/hour) | Share (%) |
|---|---|---|
| Hong Kong to NY in Chapter 5 | 2,031~2,080 | 0.40 |
| Hong Kong to NY in Scenario 2.2 | 2,025~2,096 | 0.59 |
| Shenzhen to NY in Chapter 5 | — | — |
| Shenzhen to NY in Scenario 2.2 | — | — |
| Kaohsiung to NY in Chapter 5 | 1,816~2,134 | 2.73 |
| Kaohsiung to NY in Scenario 2.2 | 1,811~2,152 | 2.93 |

**6.3 Scenario 3**

The cargo handling time mainly consists of three processes: (1) arrival at the port–delivery, (2) delivery–declaration, and (3) declaration–permission, through which cargo can be transported outside the storage area. In scenario 3, cargo handling time is reduced by the promotion of DX and hot delivery service (HDS) (details to be explained later), and assuming that the Port of Kobe and the Kobe Airport area are designated as bonded areas, and cargo is transported from the port to the airline using forklifts instead of trucks; the analysis assumes that the cargo handling time is halved, that is, 24 hours at the port and 4 hours at the airport. The loading and unloading times at the port of Osaka were unchanged, and the conditions established in scenario 2.1 were retained.

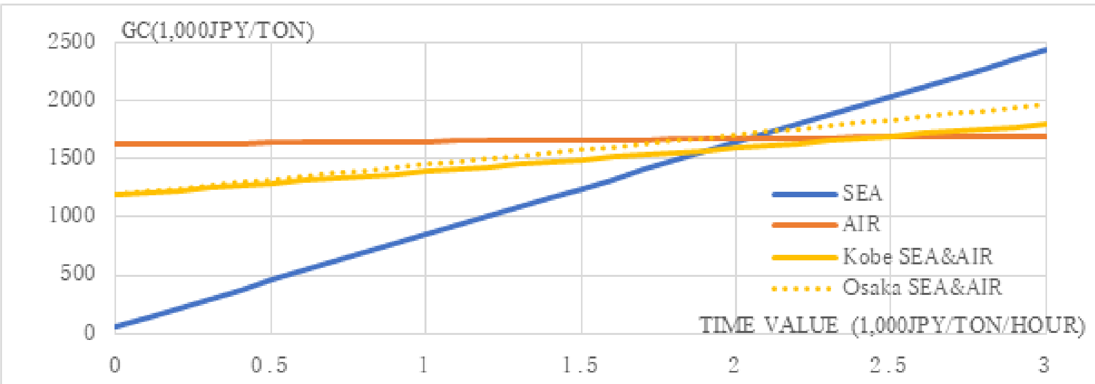


Figure 9. Hong Kong to NY generalized cost model for Scenario 3

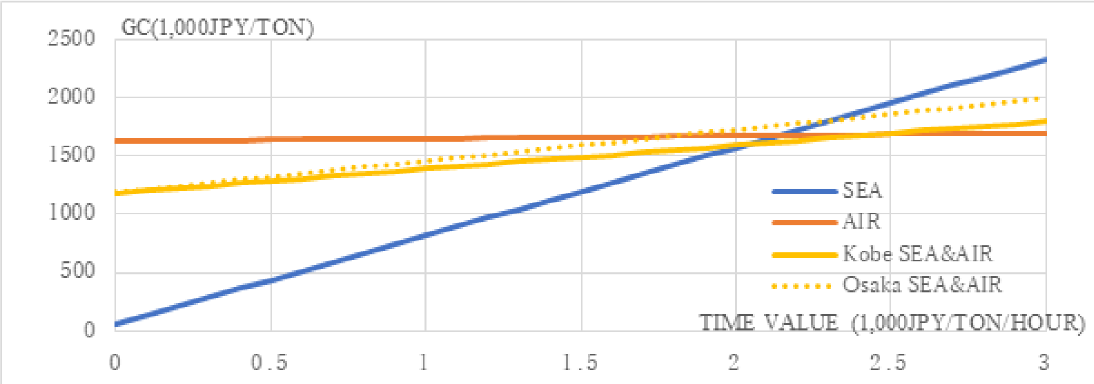

Figure 10. Shenzhen to NY generalized cost model for scenario 3

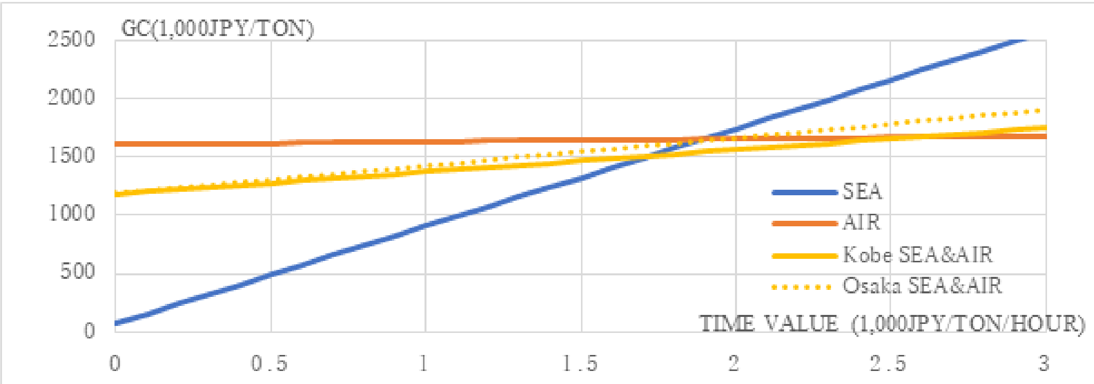

Figure 11. Kaohsiung to NY generalized cost model for scenario 3

Table 7. Comparison of scenarios 3 and 2.1 for SEA&AIR transportation

| | Time Value (JPY/ton/hour) | Share (%) |
|---|---|---|
| Hong Kong to NY in Scenario 2.1 | 2,016~2,121 | 0.87 |
| Hong Kong to NY in Scenario 3 | 1,920~2,455 | 4.20 |
| Shenzhen to NY in Scenario 2.1 | — | — |
| Shenzhen to NY in Scenario 3 | 2,035~2,448 | 3.16 |
| Kaohsiung to NY in Scenario 2.1 | 1,799~2,192 | 3.35 |
| Kaohsiung to NY in Scenario 3 | 1,721~2,563 | 6.78 |

Figures 9–11 show that Shenzhen also has the potential for SEA&AIR transportation via Kobe. The time value of the section with the lowest generalized cost for Kobe SEA&AIR transportation was 1,920–2,455 (JPY/ton/hour) for the route from Hong Kong to NY, with a share of 4.20%. The generalized cost for the Shenzhen to NY route is the lowest, in the range of 2,035–2,448 (JPY/ton/hour), and its share is 3.16%. The Kaohsiung to NY route has the lowest generalized cost in the range of 1,721–2,563 (JPY/ton/hour), and its share is 6.78%. The time value range comparison for Hong Kong and Kaohsiung to NY in Table 7 shows that SEA&AIR transportation is taking a share of air transportation.

## 7. DISCUSSION

Based on the results of the previous analysis, the following conditions are necessary to realize SEA&AIR transportation, as proposed in Section 5.1: (1) the time value range of sea transportation from the origin to the destination must be wide, that is, the share of sea transportation must be somewhat large, and (2) the farther the destination is, the wider the time value range becomes, with air transportation reducing the share of sea transportation.

SEA&AIR transportation is a mode of transportation that reduces the share of air transportation. In addition to (1) and (2), Kobe SEA&AIR transportation from Shenzhen to NY has been realized, suggesting that SEA&AIR transportation via Japan is possible if the gap is less than approximately 100,000 JPY/ton by reducing the order of vessel calls and cargo handling time. The results of this analysis also proved that shortening the sea transportation time, average waiting time, and cargo handling time are significant factors in achieving efficient transportation not only for SEA&AIR transportation but also for intermodal transportation. Moreover, the results of this analysis proved that shortening the sea transportation time, average waiting time, and cargo handling time are the significant factors in achieving efficient SEA&AIR transportation. SEA&AIR transportation not only offers shippers the best mode of transportation but also provides high-quality intermodal transportation solutions to environmental and energy issues from the perspective of reducing unnecessary air transportation in the current global situation.

To realize SEA&AIR transportation in Japan in the future, it is necessary to reduce overall transportation costs and cargo handling time. The sea transportation time, air transportation time, land transportation time, cargo handling time, and costs for each are often estimated, so there is scope for improvement in all areas. One of the most promising future developments is the widespread use of HDS. In international sea and air transportation, cargo handling time, customs clearance time, traffic congestion, and other time losses occur. To solve this problem, the promotion and diffusion of HDS is effective. According to the Transport Policy Council (2007), HDS refers to a same-day service after arrival at the port with immediate customs clearance and delivery, and the service is limited to only a few shipping companies and routes, mainly between Japan and China. Specifically, when shippers who select a route between the loading and unloading points where HDS is applicable wish to reduce the loading and unloading time and pick up the cargo earlier, they can have the containers loaded at the loading point in a position that is easier for them to load and unload first. The fee for this service is approximately 20,000 JPY/teu. There is a high need for this service in the apparel and food industries, where a timely supply of cargo to the market is required. It is estimated that HDS can reduce the time from arrival at Japanese ports to accepting cargo, reducing the lead time by an average of less than two days. This also reduces the arrival time in the Kansai back region, which is an advantage when dealing with high-time-value goods. It would be possible to accelerate sea transportation from East Asia by adopting HDS when conducting SEA&AIR transportation.

Cooperation with the Japanese government is essential for realizing SEA&AIR transportation, and various policy supports will help develop SEA&AIR transportation.

## 8. CONCLUDING REMARKS AND POLICY IMPLICATIONS

In this study, the feasibility of SEA&AIR transportation via Japan was examined by finding new routes and estimating the feasibility of each route using a generalized cost model. In this regard, some routes used actual values for cost and transport time. Still, some routes were calculated using distance ratios where the values were unknown, and not all graphs in the generalized cost model were definite. SEA&AIR transportation incurs additional cargo handling costs when handling port and air transportation and incurs more costs than other forms of transportation. In this study, the extra cargo handling cost for SEA&AIR transportation was assumed to be 30,000 JPY/ton. As specific values for ton-based cargo handling costs have not been published, a sensitivity analysis for all values is an issue for the future. The cargo time value of Akakura et al. (2021) was unavoidably adopted, as it only affects the generalized cost model in terms of share and does not affect the feasibility of SEA&AIR Transportation via Japan, which is the goal of this analysis. This is an issue for the future.

The following policy implications were obtained from the results. First, the most promising route for possible SEA&AIR transportation is from Kaohsiung to NY via Japan, which can be promoted. However, as mentioned before, no cargo operator in Japan currently provides SEA&AIR transportation, which suggests that some obstacles that need to be clearly stated in this research can exist. For example, a type of business practice would be one. In any case, future SEA&AIR transportation via Japan will require reduced transportation time, cargo handling time and costs, and the promotion of HDS, as mentioned in the previous section. This will help manage the burden on shippers and storage conditions, further improve convenience, and enhance not only SEA&AIR transportation but also the international transport competitiveness of the hinterlands. In addition, to solve the problems associated with cargo handling and transportation infrastructure, SEA&AIR transportation must be promoted not only by port operators and air transportation companies, as in Incheon, Korea, where SEA&AIR transportation is currently being implemented, but also by the Japanese government.

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