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Republic of Korea–United States Green Shipping Corridor Prefeasibility Study: Cargo Flows

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Buildings and Transportation Science Division

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1. INTRODUCTION

1.1 OBJECTIVE AND SCOPE

This prefeasibility study, as a part of the decarbonization efforts through the Mission Innovation Zero-Emission Shipping Mission [1], was conducted to provide a high-level assessment of the opportunities and challenges in planning and implementing green shipping corridors between major commercial seaports in the United States of America (USA) and the Republic of Korea (ROK). For each country, three major ports were included in the scope of this study: Seattle, Tacoma, and Everett (all in Washington State) for the USA and Busan, Ulsan, and Masan for the ROK.

This prefeasibility study report focuses on describing operation characteristics of major vessel and cargo flows between the two countries. Vessel shipments directly affect energy use and demand. Therefore, it is critically important to understand which major vessel types and cargo types are operated or transported within the selected scope and to identify potential target segments for green shipping. Furthermore, this prefeasibility study also discusses limitations and additional assessments that need to be further analyzed in the next stage of the feasibility study. The summary findings and observations discussed in this report are not intended to be used to determine the final target corridors, but to guide later, deeper assessments of their potential impacts and challenges.

In the following section, the data sources used in this study are discussed. Section 0 shows the overall vessel trades between the USA and ROK, considering all ports in the two countries. Then, a more detailed analysis by vessel type and cargo flow is presented in Sections 3–6 based on only the three-to-three ports between the two countries. Finally, Section 7 summarizes the findings with suggested target segmentations for the vessel types and discusses other limitations to be considered during the later feasibility stage.

1.2 DATA SOURCES

This prefeasibility study used the US Army Corps of Engineers (USACE)’s foreign cargo and vessel entrances/clearances data as the main source for vessel and cargo flows. In addition, various other data sources, such as the Freight Analysis Framework 5 (FAF5), US Coast Guard (USCG), and MarineTraffic, were used to provide supplemental vessel operation characteristic information. The following subsections briefly describe the data sources and how they were used in this study.

US Army Corps of Engineers

USACE provides a wealth of critical data that encompasses various aspects of water resource management [2], infrastructure development, and environmental preservation within the United States. In this study, two tables from the USACE data were used to analyze major vessel and cargo characteristics for waterborne shipments between the USA and ROK. The two tables are “Foreign Cargo” and “Vessel Entrances and Clearances.” The “Foreign Cargo” table provides tonnage of cargo shipments by commodity type, US port, foreign country, and foreign port. The “Vessel Entrances and Clearances” table provides information about vessels that entered into or cleared out from US ports, including entry and exit dates, vessels’ flags of registry, vessels’ last or next ports of call, drafts, and net and gross registered tonnages.

Freight Analysis Framework 5

The FAF5 [3], produced by the Bureau of Transportation Statistics with support from the Federal Highway Administration, serves as the most comprehensive public data source for understanding and assessing freight movements and transportation patterns within the United States. The FAF5 amalgamates data from diverse sources to construct a comprehensive depiction of freight movement across various modes of transportation, including truck, rail, water, air, and pipeline. By offering insights into freight flows, origins, destinations, and commodities, the FAF5 data aids policymakers, transportation planners, and industry stakeholders in making informed decisions regarding infrastructure investments, logistics optimization, and supply chain management.

Although the FAF5 data provides overall pictures of US nationwide freight movements for all transportation modes including water shipments, the geographical level of the FAF5 data limited their use to port-level analysis of shipping information for this study. Specifically, US entry and exit locations of import and export flows in the FAF5 data are provided by metropolitan areas (or sometimes entire states). Furthermore, the FAF5 data group import/export countries into eight foreign regions, and all the countries in Eastern Asia are grouped into one foreign region. Therefore, the FAF5 data were used in this study mainly to verify and evaluate the overall trend of shipment tonnage and value and to estimate projected growth of shipments in the future. (Refer to Figure 2-3 in Section 0.)

USCG Automatic Identification System

The USCG's Automatic Identification System (AIS) data constitute a pivotal component of maritime information [4], offering insight into vessel movements within the United States' waters and its territorial waters. Leveraging the advanced AIS technology, this data source provides a comprehensive view of vessel positions, routes, and navigational activities, aiding in the enhancement of maritime safety, security, and situational awareness. This study used USCG AIS historical data from 2020 to 2022 along the USA–ROK shipping corridor. The information was used mainly to verify individual vessels' shipping routes and trajectories by matching their IMO numbers with the list reported in the USACE data.

Washington State Department of Ecology vessel bunkering data

These vessel bunkering data, managed by Washington State Department of Ecology [5], are collected to maintain operation and safety related to bunkering activities and the associated potential risk of oil spills. In this study, these bunkering data were used to analyze the distribution of bunkering types by ports and vessel types with support from Northwest Seaport Alliance. Note that the bunkering data may not directly reflect fuel consumption because not all the vessels that entered the port area bunkered their fuels. Therefore, this study focused on the bunkering fuel type distribution rather than directly using the quantity reported in these data.

MarineTraffic

MarineTraffic is a maritime information platform that offers real-time and historical data related to vessel movements and maritime activities worldwide [6]. Using AIS technology, this platform provides information including live positions, routes, and details of ships across the globe. For this study, the detailed vessel information, such as vessel travel history, gross tonnage, fuel oil tank size, operators, etc., was used to gain valuable insights into vessel operation characteristics that could be relevant to consideration of green shipping.

Other data sources

The following data sources were identified during this prefeasibility study but have not been directly used. They are listed here because they may be useful in conducting more detailed analysis during the next stage of the feasibility study.

- USA Census Trade Online [7]
- US Department of Transportation Maritime Administration Data [8]
- MarineCadastre by the Bureau of Ocean Energy Management and the National Oceanic and Atmospheric Administration [9]
- Global Shipping Routes [10]
- US Department of Transportation SeaVision [11]
- Other proprietary sources with AIS and bill of lading data

2. OVERALL VESSEL TRADES BETWEEN USA AND ROK

Figure 2-1 shows the top 10 import and export countries to and from the USA during 2017–2021 by total shipment tonnage based on the USACE foreign cargo data. As shown in Figure 2-1, South Korea (ROK) ranked fifth in import countries to the USA and fourth in export countries from the USA. For both import and export countries, China, which neighbors the ROK, was the top trading partner with the USA.

Figure 2-2 shows the historical trend of vessel shipment tonnage between the USA and ROK. Overall, from 2017 to 2021, both the import and export shipment tonnages increased continuously, except in 2020, which was affected significantly by the pandemic. Based on this history, the total tonnage of export shipments (from the USA to the ROK) was about 30%–60% higher than the import tonnage (from the ROK to the USA).

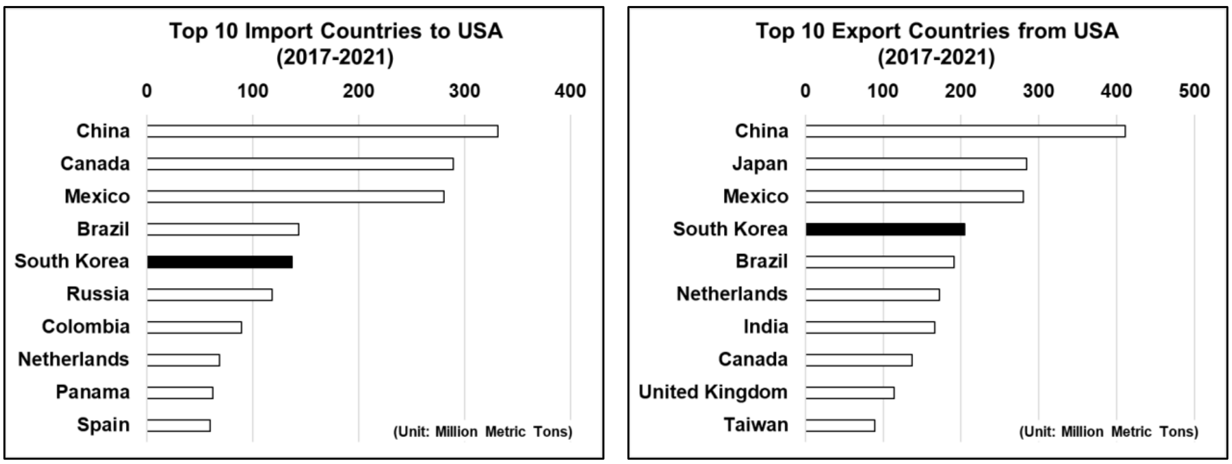

Figure 2-1. Top 10 import and export countries to and from the USA (2017–2021).

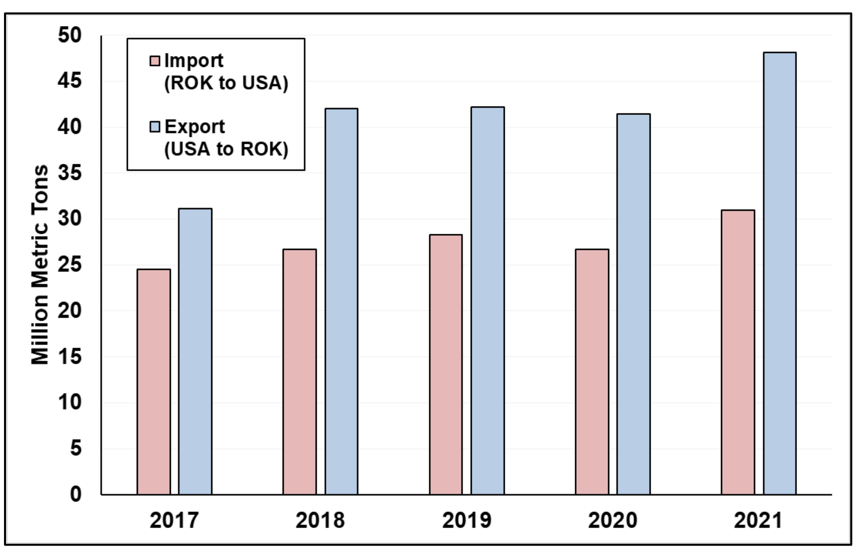

Figure 2-2. Historical trend of vessel shipment tonnage between the USA and ROK.

Whereas Figure 2-1 and Figure 2-2 show the overall trends based on the USACE's historical cargo flow data, Figure 2-3 represents the projected growth of vessel shipments between the two countries by applying forecasted growth factors from the FAF5 data to the historically reported tonnage from the USACE. Note that the applied growth factors from the FAF5 are based on more aggregated geographical levels (i.e., Seattle, Washington, metropolitan area for the US port area and Eastern Asia for the foreign trade partner). Based on this projection, the overall vessel cargo tonnage between the USA and the ROK is expected to increase by 67%–90% from 2021 to 2050.

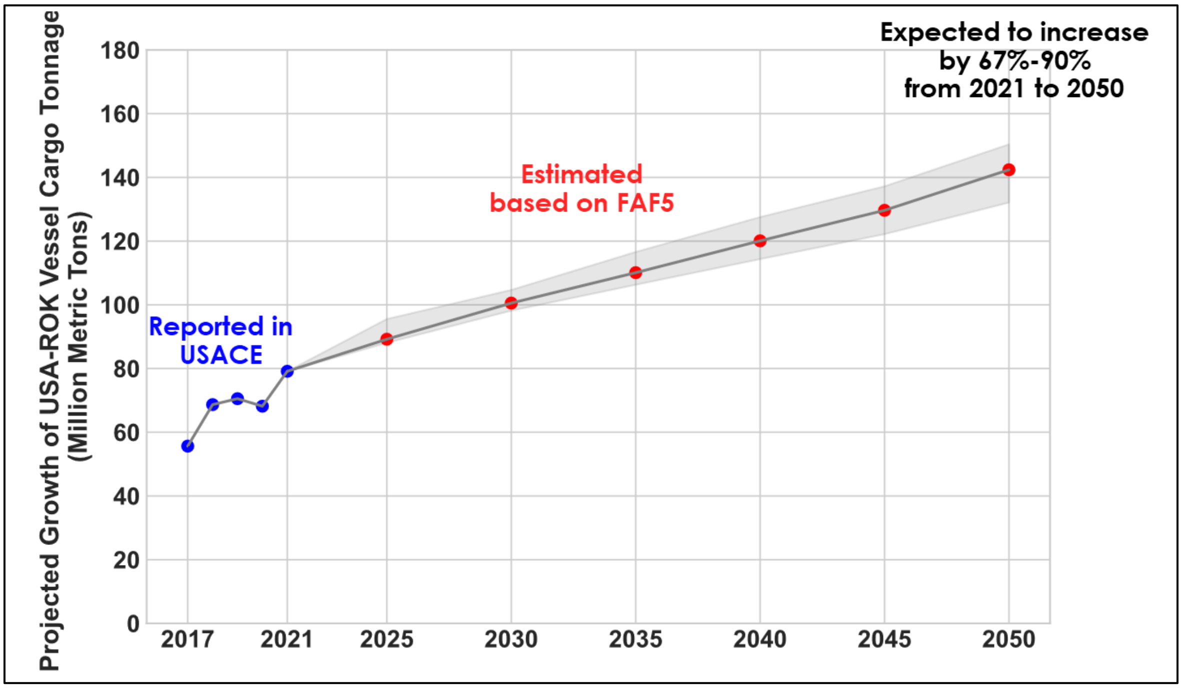

Figure 2-3. Projected growth of vessel shipments between the USA and ROK.

3. VESSEL SHIPMENT CHARACTERISTICS WITHIN THE SELECTED SCOPE

This section discusses major vessel and cargo types for waterborne shipments operated in 2017–2021. Note that all the figures and tables presented in this section and later sections are based on vessel shipments within the scope (i.e., shipments between the three ports [Seattle, Tacoma, and Everett] in the USA and the three ports [Busan, Ulsan, and Masan] in the ROK).

3.1 VESSEL TYPES

Imports (from the ROK to the USA) by vessel type

Figure 3-1 depicts the number of vessel trips by vessel type from the three origin ports in the ROK to the three destination ports in the USA. Overall, as shown in Figure 3-1, container ships were the dominant type of vessel in terms of the number of vessel trips (71%). Bulk carriers, which are generally designed to transport large quantities of bulk commodities such as coal or grains, account for about 14% of vessel trips. The two most contributing shipment flows were container ships from Busan to Seattle and Tacoma, accounting for more than 70% of total vessel trips. Bulk carrier shipments were also mostly from Busan to Seattle and Tacoma, but the number of vessel trips from Busan to Tacoma was higher than the number of vessel trips from Busan to Seattle. Shipments by roll-on/roll-off (RO-RO) carriers, which are generally used for transporting vehicles and have special ramps designed for loading and unloading vehicles, were mostly imported to Tacoma.

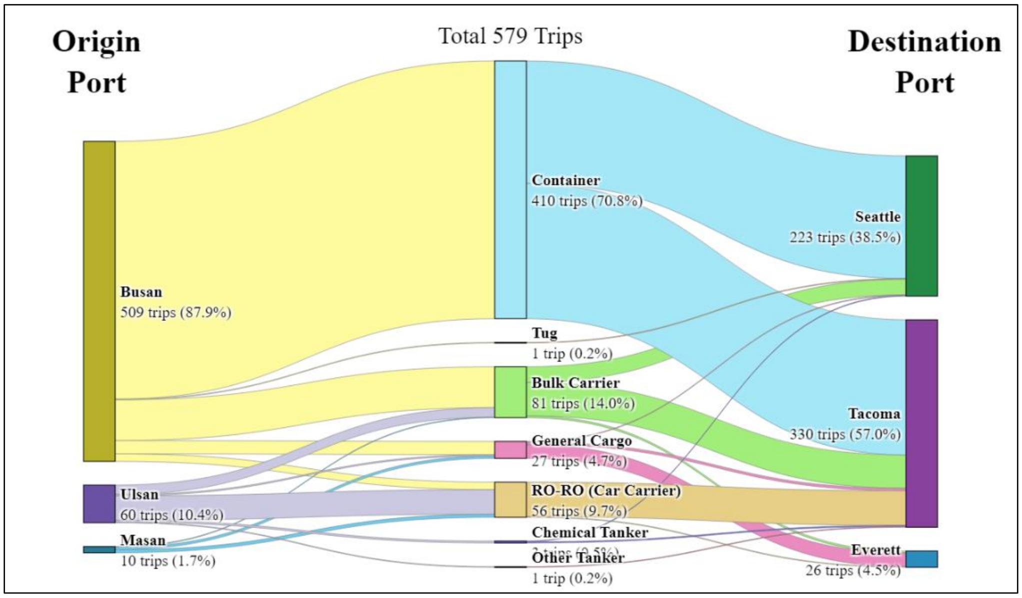

Figure 3-1. Vessel trips by port and vessel type for import shipments from the ROK to the USA (2017–2021).

Exports (from the USA to the ROK) by vessel type

Similar to Figure 3-1 for import flows, Figure 3-2 shows the major corridors and vessel types by the numbers of vessel trips from the three origin ports in the USA to the three destination ports in the ROK. Overall, the export flows were much more dominated by container ships, which accounted for about 89% of vessel trips. RO-RO carriers contributed about 5% to the number of vessel trips, and each of the other vessel types (bulk carrier, chemical tanker, general cargo, etc.) contributed less than 3% of vessel trips.

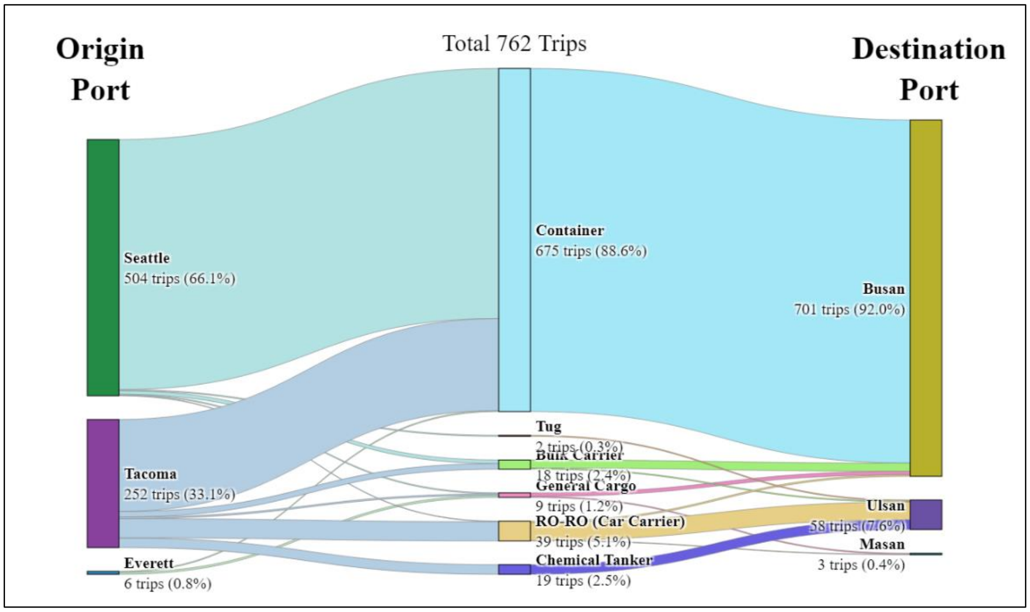

Figure 3-2. Vessel trips by port and vessel type for export shipments from the USA to the ROK (2017–2021).

In terms of the corridors, the most contributing shipment flow was container ships from Seattle to Busan, followed by container ships from Tacoma to Busan. For shipments by RO-RO carriers, Tacoma to Ulsan had the highest number of RO-RO carrier shipments. Only six export vessel trips (mostly by general cargo vessels) from Everett were reported during 2017–2021.

In Section 0, the target segmentation analysis focuses on the three major vessel types (i.e., container, RO-RO carrier, and bulk carriers).

3.2 CARGO TYPES

Imports (from the ROK to the USA) by cargo type

Figure 3-3 shows the distribution of the import tonnage by cargo type from the three origin ports in the ROK to the three destination ports in the USA. In this figure, the cargo types are based on the two-digit codes defined in the USACE foreign cargo data. The rest of cargo types, other than the top five import cargo types, were grouped into *all others* in this summary.

Only focusing on the cargo distribution (in the middle of Figure 3-3), all manufactured equipment, machinery, and products, which include parts for vehicle manufacturing, accounted for more than half of the total cargo import tonnage from the ROK to the USA. The second most contributing cargo type was other chemicals and related products, which accounted for about 11% of total import cargo tonnage in 2017–2021.

In terms of the major corridors by the tonnage of imports from the ROK to the USA, the most contributing shipment flows were all manufactured equipment, machinery and products from Busan to Seattle and Tacoma. In addition, the port of Seattle contributed more than Tacoma and Everett for most of the cargo types. Of the ROK exporting ports, the Busan port contributed more than 97% of the import shipment cargo tonnage to the three ports in the USA.

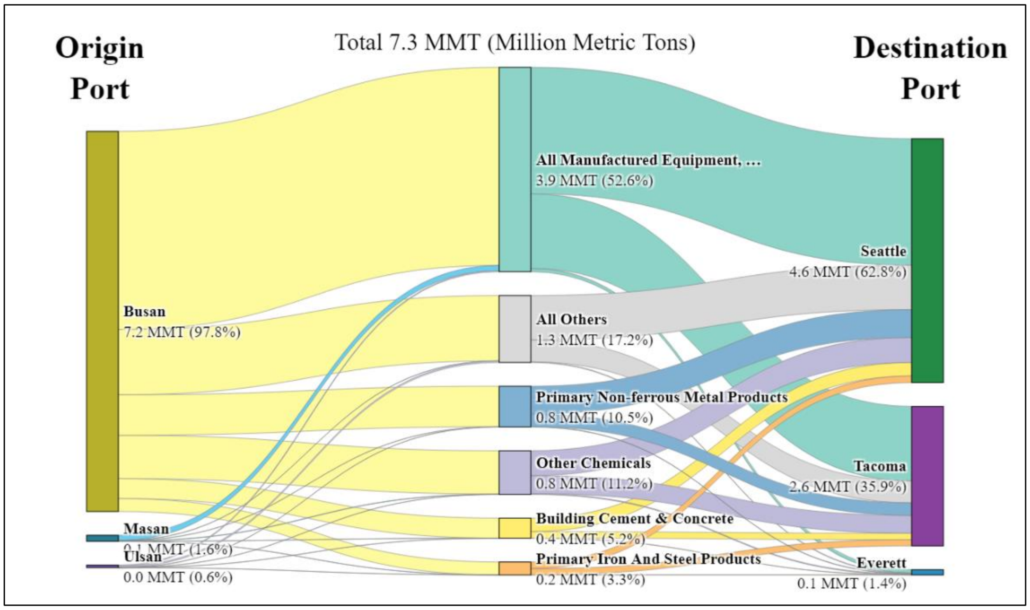

Figure 3-3. Tonnage of vessel imports (from the ROK to the USA) by port and cargo type (2017–2021).

Exports (from the USA to the ROK) by cargo type

Figure 3-4 shows the major corridors and cargo types by export tonnage from the three origin ports in the USA to the three destination ports in the ROK. Similar to Figure 3-3 for import flows, the cargo types are based on the two-digit codes defined in the USACE foreign cargo data, and the rest of the cargo types, other than the top five export cargo types, were grouped into *all others* in this summary.

As shown in Figure 3-4, the most contributing cargo flow was animal feed, grain mill products, flour, and processed grains from Seattle to Busan by export tonnage from 2017 to 2021. The second most contributing commodity type was corn, accounting for about 13% of the total export cargo tonnage. For shipments of corn, the Tacoma-to-Busan corridor had higher tonnage than the Seattle-to-Busan corridor, whereas the Seattle-to-Busan corridor had higher tonnage for most of the other cargo types. In the ROK, over 95% of cargo shipment export tonnage went to the Busan port.

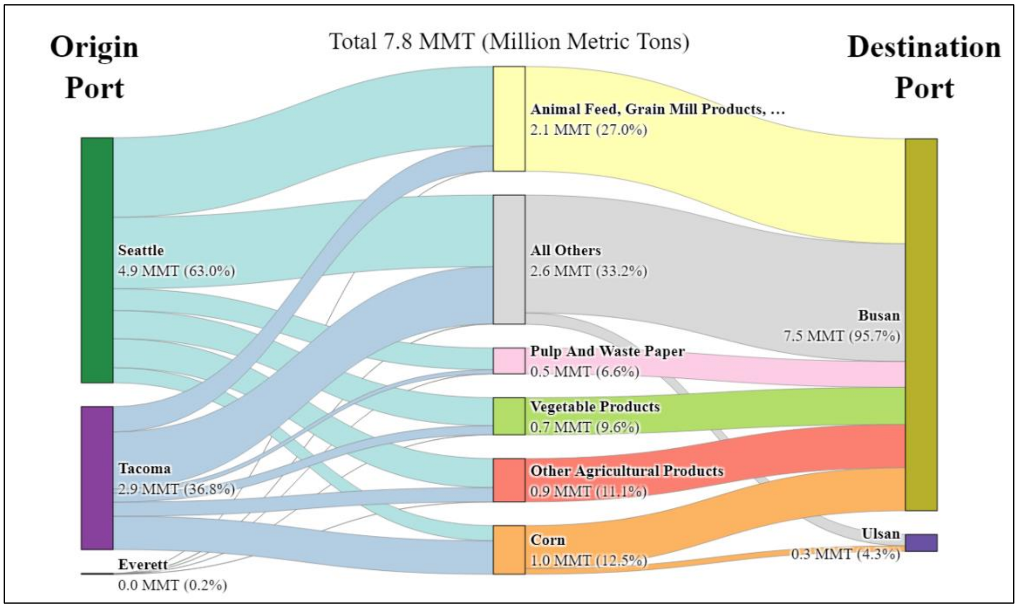

Figure 3-4. Tonnage of vessel exports (from the USA to the ROK) by port and cargo type (2017–2021).

4. VESSEL OPERATION CHARACTERISTICS BY US PORT

This section discusses other vessel operation characteristics, such as vessel age, gross tonnage, fuel oil tank, bunkering fuel types, and vessel and cargo type distribution, for each port in the USA. This more detailed information can be useful for considering the feasibility of each port's implementation of alternative fuels for green shipping. Note that the summaries provided in this section include both directions (i.e., inbound and outbound) of vessel flows between the two countries, and vessels without operation characteristic information were excluded in the analysis.

4.1 SEATTLE

Vessel types by ROK port

Figure 4-1 shows the distribution of vessel types for each of the three ROK ports for vessel trips from and to the port of Seattle. For both import and export vessel trips, the container ship was the dominant vessel type, accounting for over 98% of the export vessel trips from Seattle to Busan. The second most contributing vessel type was bulk carriers; less than 30 bulk carrier vessel trips from all the three ROK ports to the Seattle port were reported during 2017–2021.

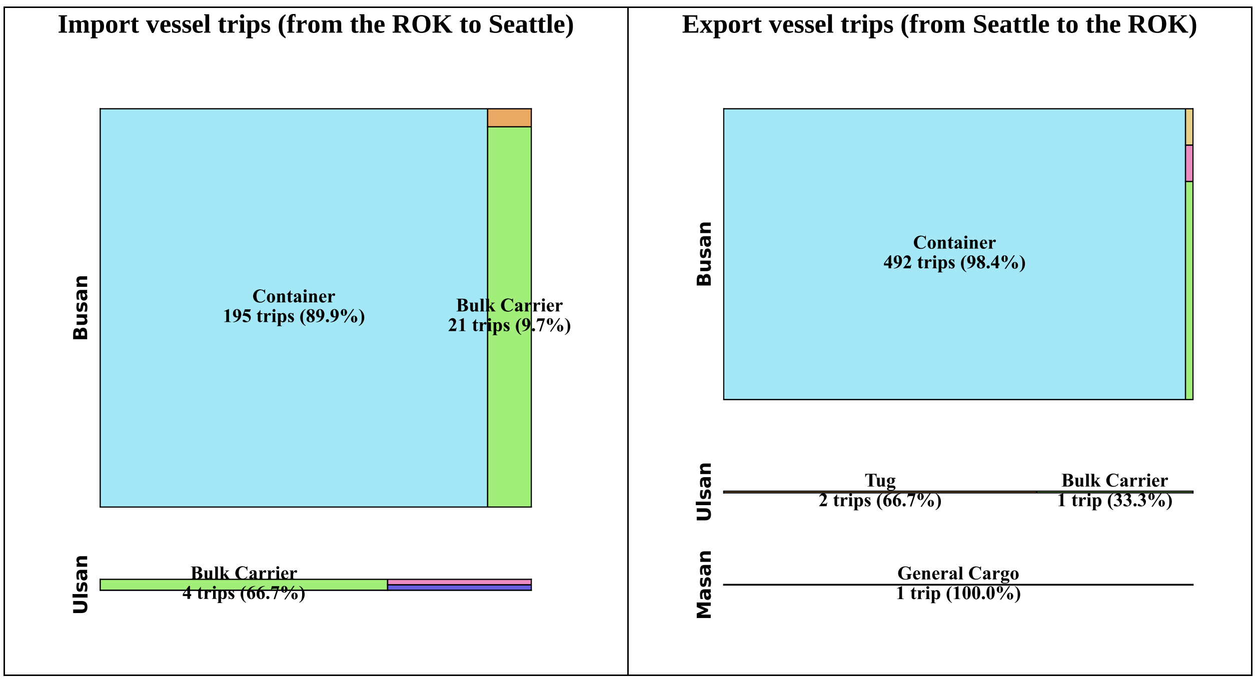

Figure 4-1. Distributions of vessel types for ROK ports for shipments from and to Seattle (2017–2021).

Cargo types by ROK port

Whereas Figure 4-1 shows the distribution of vessel types, Figure 4-2 represents the distribution of cargo types by import and export cargo tonnage from and to the port of Seattle for each ROK port. As shown in Figure 4-2, the trading partners with the Seattle port were heavily concentrated on the port of Busan. In addition, the major cargos for imports and exports were quite different in types. The major cargos for imports (mostly Busan to Seattle) were all manufactured equipment, machinery, and products (51.9%) followed by primary metal products (11.4%) and other chemicals (10.2%); the major cargos for exports (mostly Seattle to Busan) were animal feed, grain mill products, flour, and processed grains (32.8%) followed by other agricultural products (12.0%) and vegetable products (11.6%).

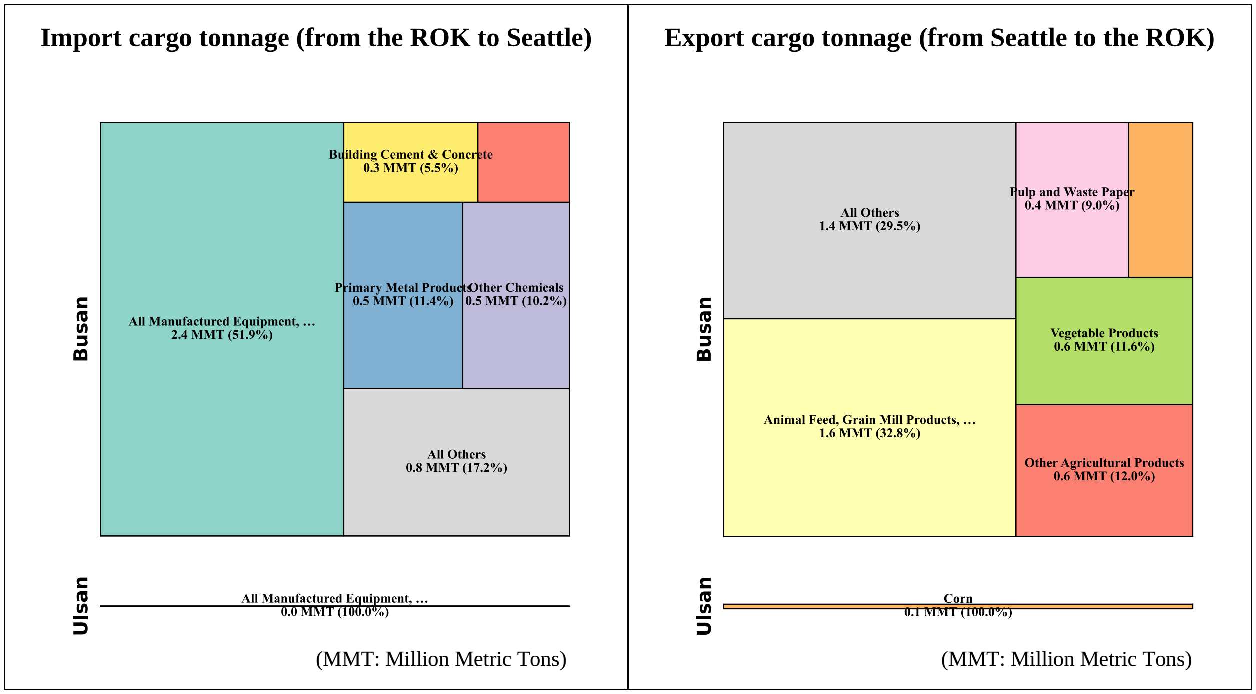

Figure 4-2. Distribution of cargo types for ROK ports for shipments from and to Seattle (2017–2021).

Vessel operation age distribution

The age of a vessel (the number of years operated from the year built) could also be an important factor for the potential starter of green shipping because it might be more cost-effective to consider replacing or retrofitting older vessels than newer vessels. Figure 4-3 displays the distribution of vessel ages in 5-year intervals for all the unique vessels operated between the Seattle port and the three ROK ports. As shown in Figure 4-3, more than 60% of vessels were 10 years old or younger, whereas about 6% of vessels were over 15 years old.

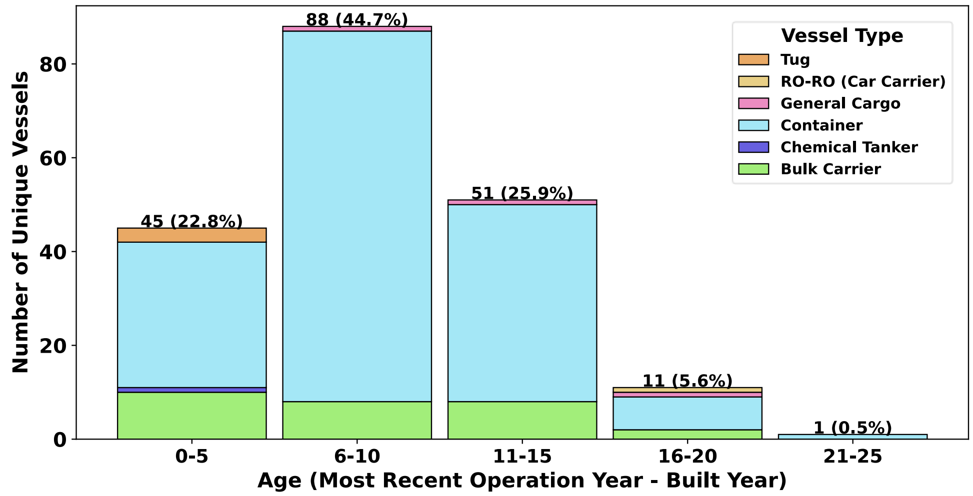

Figure 4-3. Vessel age distribution for unique vessels operated between Seattle and the ROK ports (2017–2021).

Gross registered tonnage distribution

Gross registered tonnage, which is a vessel's overall internal volume (including cargo, storage, fuel, passengers, and crew) expressed in register tons, could be an important factor to determine the specs of a vessel's engine power and fuel capacity when considering switching to alternative fuels. Figure 4-4 displays the distribution of gross registered tonnage for all the unique vessels operated between the Seattle port and the three ROK ports in 2017–2021. As shown in Figure 4-4, over 60% of vessels had less than 100 thousand register tons.

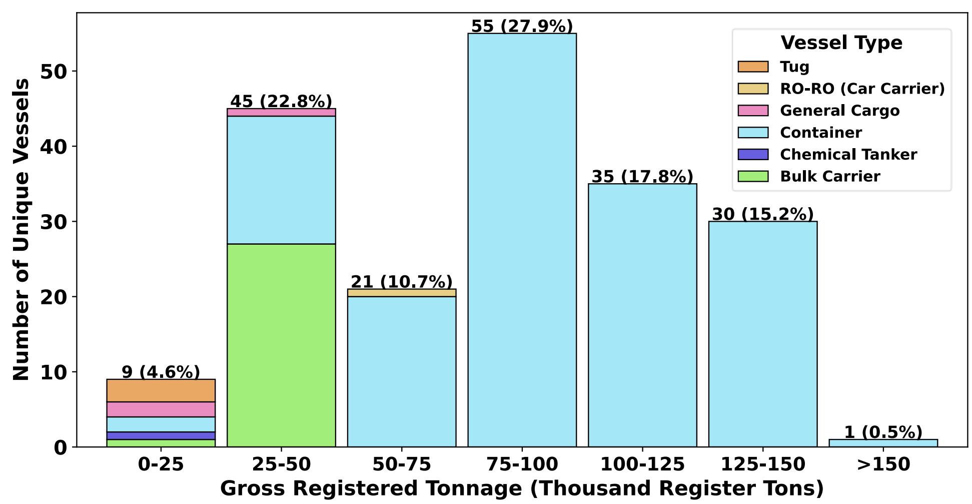

Figure 4-4. Gross tonnage distribution for unique vessels between Seattle and the ROK ports (2017–2021).

Fuel oil tank size distribution

The current fuel oil tank size could also be an important factor to estimate the required fuel tank size for alternative fuels, assuming the vessels' operating routes do not change substantially. Figure 4-5 shows the distribution of fuel oil tank size, in thousand cubic meters, for all unique vessels with fuel oil tank size information that operated between the Seattle port and the three ROK ports in 2017–2021.

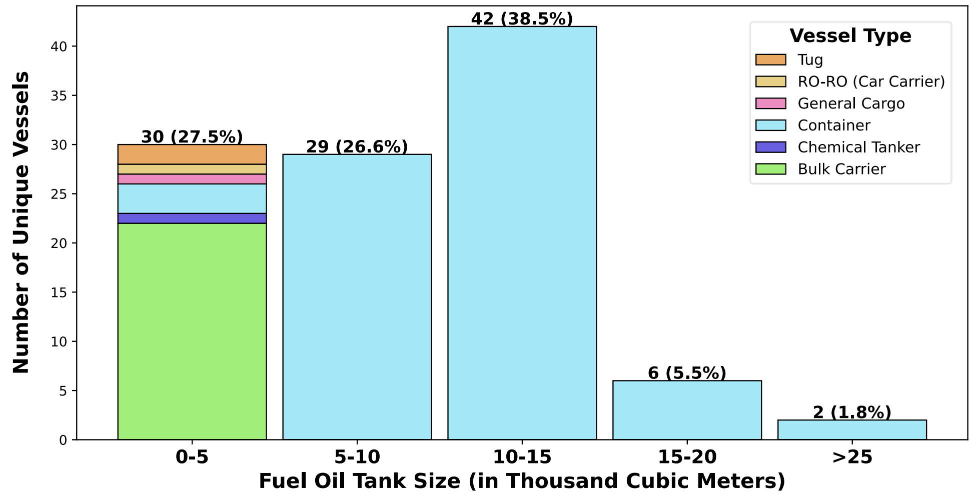

Figure 4-5. Fuel oil tank distribution for unique vessels between Seattle and the ROK ports (2017–2021).

As shown in Figure 4-5, about 39% of the vessels had fuel oil tank sizes of 10–15 thousand cubic meters, and more than half of the vessels had fuel oil tank sizes of less than 10 thousand cubic meters. Note that not all vessels had fuel oil tank size information, and these vessels were excluded from the summary.

4.2 TACOMA

Vessel types by ROK port

Figure 4-6 shows the distribution of vessel types for each of the three ROK ports from and to the port of Tacoma. For both import and export vessel trips between Tacoma and Busan, the container ship was the dominant vessel type, accounting for about 80%–90% of the vessel trips within this corridor.

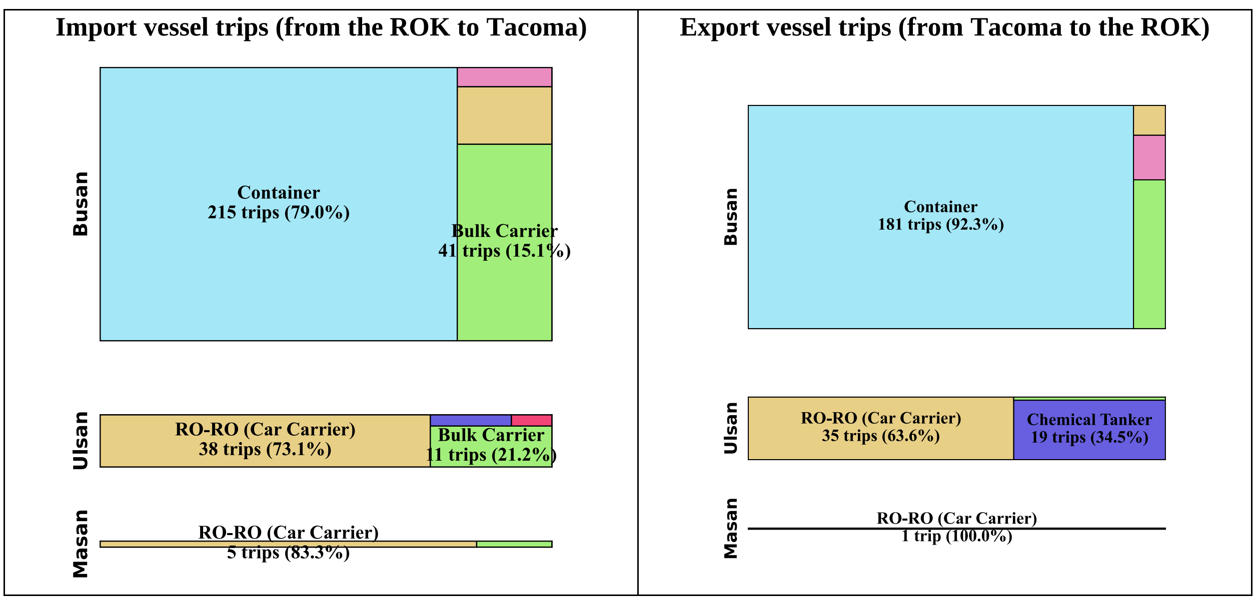

Figure 4-6. Distribution of vessel types for ROK ports for shipments from and to Tacoma (2017–2021).

For vessel trips between Tacoma and Ulsan, the RO-RO carriers accounted for over 60% of trips, whereas no container ships were reported for this corridor in 2017–2021. Only five vessel trips were reported for import shipments from Masan to Tacoma during the same period.

Cargo types by ROK port

Similar to Figure 4-2, Figure 4-7 represents the distribution of cargo types by import and export cargo tonnage between the port of Tacoma and each of the three ROK ports. As shown in Figure 4-7, the trading partners with the Tacoma port were heavily concentrated on the port of Busan. For the imports from Busan to Tacoma, the major cargos showed a quite similar pattern as the Busan-to-Seattle corridor: all manufactured equipment, machinery, and products (52.2%) was the largest contributor, followed by other chemicals (13.4%) and primary metal products (9.4%). For the exports from Tacoma to Busan, corn was the most contributing commodity type, accounting for 23.7% of the total export tonnage.

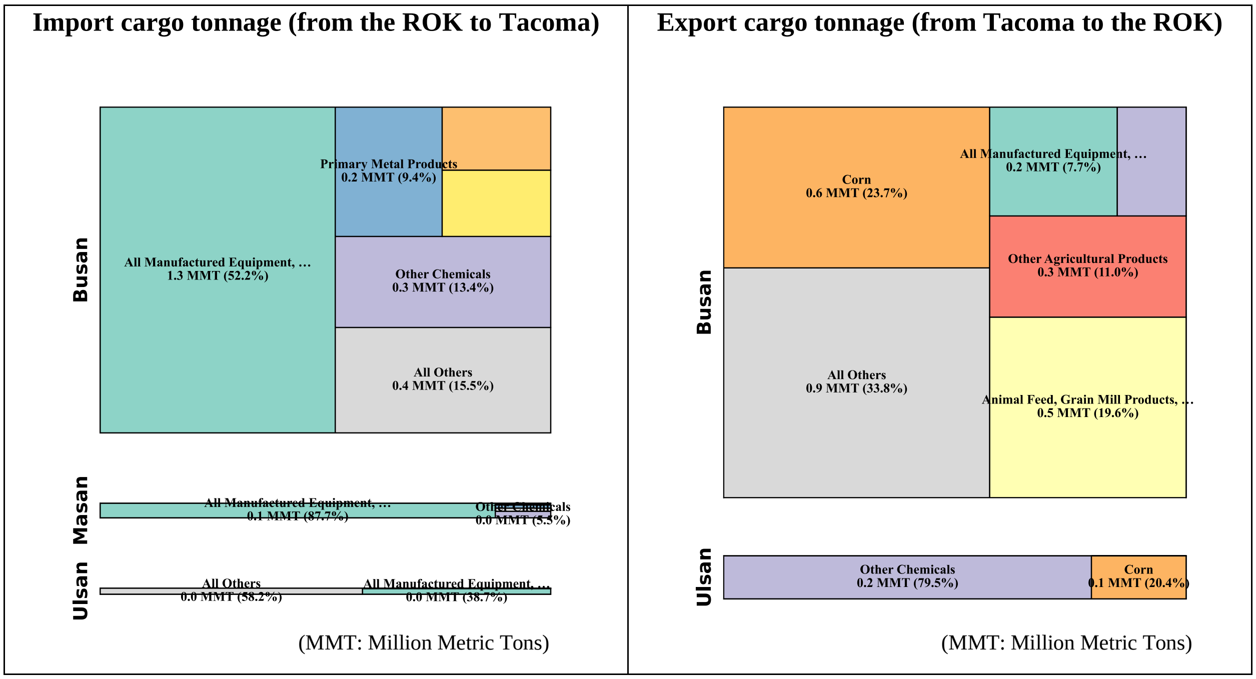

Figure 4-7. Distribution of cargo types for ROK ports for shipments from and to Tacoma (2017–2021).

Vessel operation age distribution

Similar to Figure 4-3, Figure 4-8 shows the distribution of vessel ages in 5-year intervals for all the unique vessels operated between the Tacoma port and the three ROK ports. As shown in Figure 4-8, more than half of vessels were 10 years old or younger, whereas about 16% of vessels were over 15 years old. Note that seven vessels (2.9%) operated during 2017–2021 were older than 25 years.

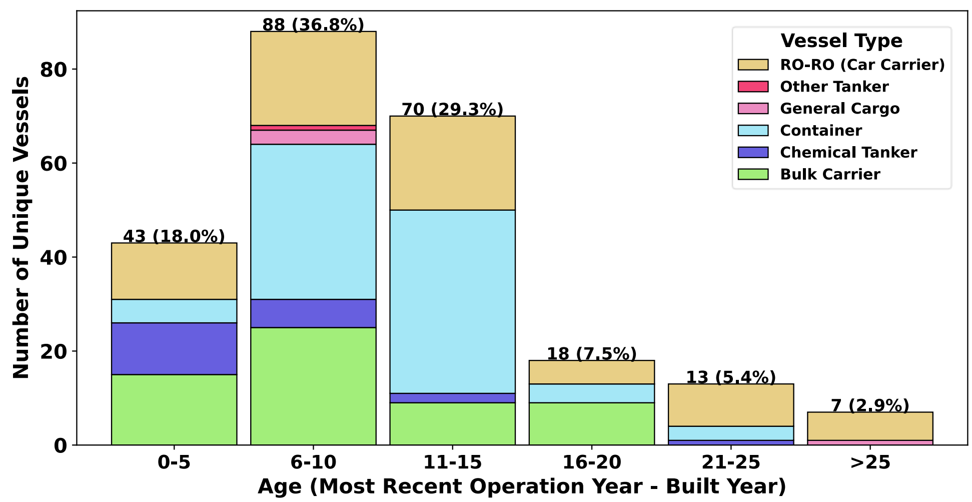

Figure 4-8. Vessel age distribution for unique vessels operated between Tacoma and the ROK ports (2017–2021).

Gross registered tonnage distribution

Similar to Figure 4-4, Figure 4-9 shows the distribution of gross registered tonnage for all the unique vessels operated between the Tacoma port and the three ROK ports in 2017–2021. As shown in Figure 4-9, over 96% of vessels had less than 100 thousand register tons.

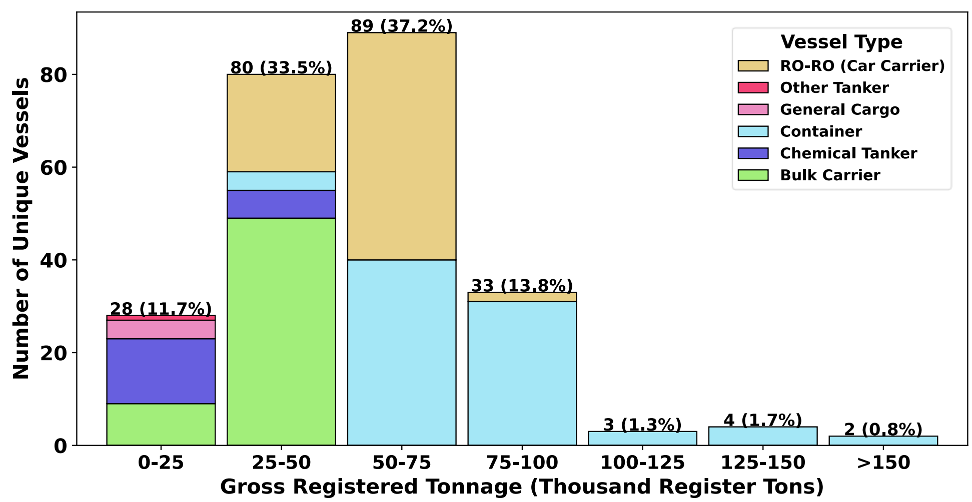

Figure 4-9. Gross tonnage distribution for unique vessels operated between Tacoma and the ROK ports (2017–2021).

Fuel oil tank size distribution

Similar to Figure 4-5, Figure 4-10 shows the distribution of fuel oil tank sizes, in thousand cubic meters, for all unique vessels with fuel oil tank size information that operated between the Tacoma port and the three ROK ports in 2017–2021. As shown in Figure 4-10, about 90% of vessels had fuel oil tank sizes of less than 10 thousand cubic meters whereas three vessels (2%) had fuel oil tank sizes of over 25 thousand cubic meters. Note that not all vessels had fuel oil tank size information, and these vessels were excluded from the summary.

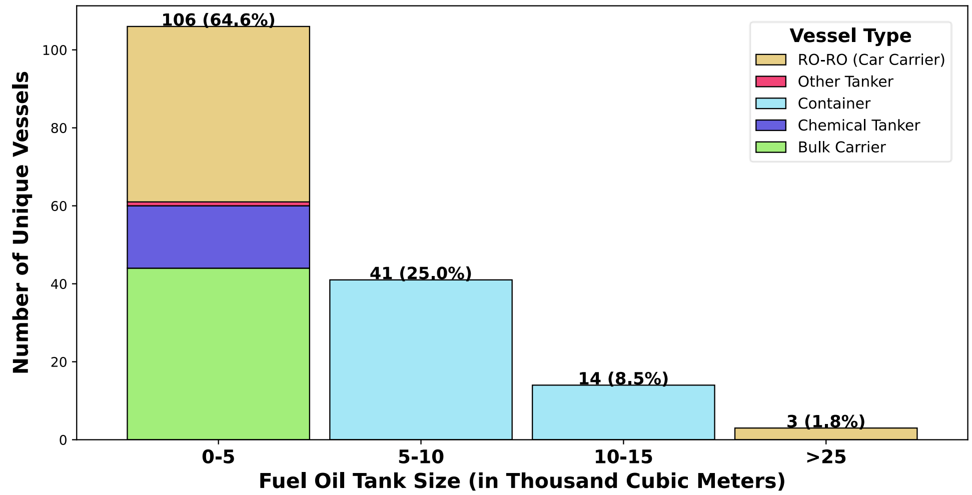

Figure 4-10. Fuel oil tank distribution for unique vessels between Tacoma and the ROK ports (2017–2021).

4.3 EVERETT

Vessel types by ROK port

Figure 4-11 shows the distribution of vessel types for each of the three ROK ports from and to the port of Everett. As shown in Figure 4-11, only six export vessel trips were observed from Everett to Busan and Masan during 2017–2021. For both import and export vessel trips between Everett and the three ROK ports, general cargo vessels were the most frequently operated vessel type, whereas the container ship was the dominant vessel type for Seattle and Tacoma.

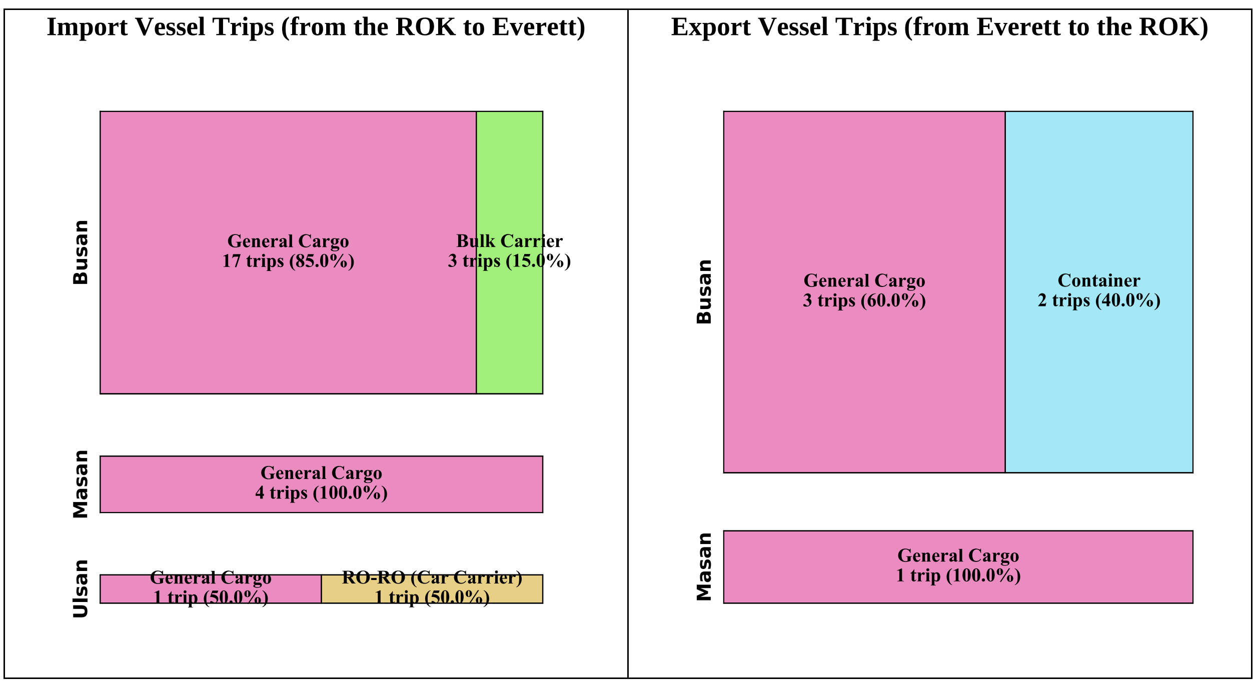

Figure 4-11. Distribution of vessel types for ROK ports for shipments from and to Everett (2017–2021).

Cargo types by ROK port

Similar to Figure 4-2 and Figure 4-7, Figure 4-12 shows the distribution of cargo types by import and export cargo tonnage between the port of Everett and each of the three ROK ports. As shown in Figure 4-12, the trading partners with the Everett port were heavily concentrated on the port of Busan. For the imports from Busan to Everett, the top two major cargo types were the same as the Busan-to-Seattle corridor: all manufactured equipment, machinery, and products (61.8%) followed by other chemicals (15.4%). For the exports from Everett to Busan, other chemicals were the most contributing commodity type, accounting for 23.8% of the total export tonnage.

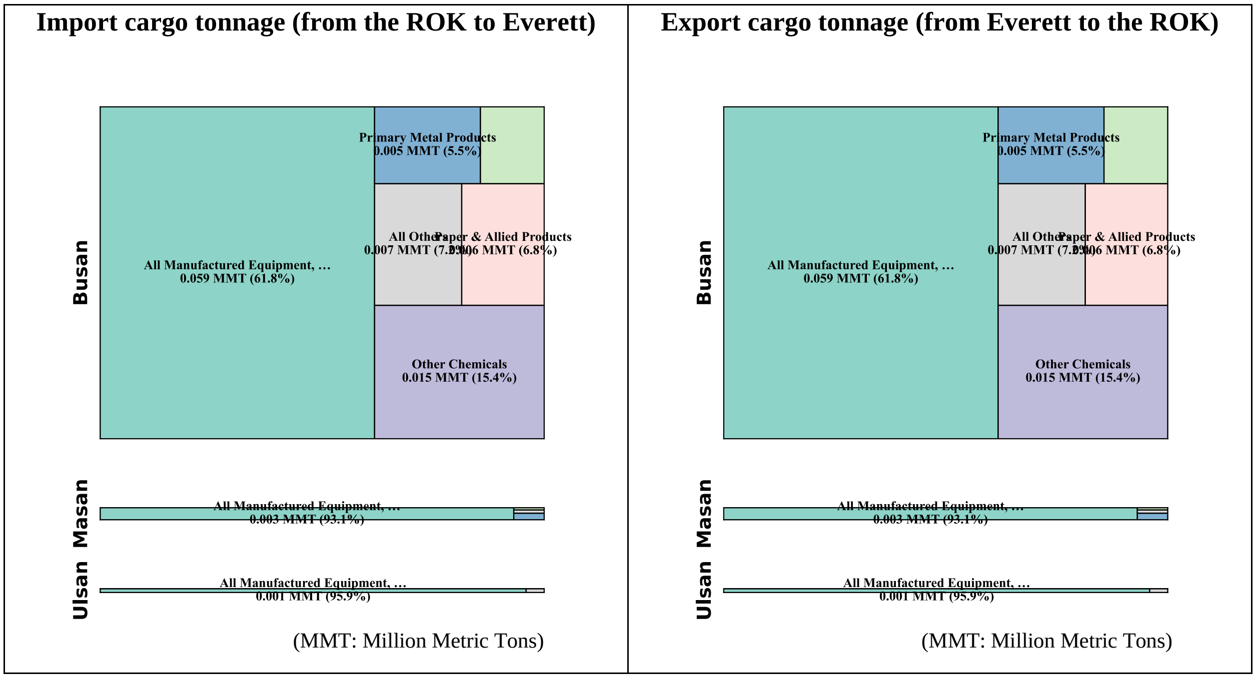

Figure 4-12. Distribution of cargo types for ROK ports for shipments from and to Everett (2017–2021).

Vessel operation age distribution

Similar to Figure 4-3 and Figure 4-8, Figure 4-13 shows the distribution of vessel ages in 5-year intervals for all the unique vessels operated between the Everett port and the three ROK ports. As shown in Figure 4-13, 11 vessels (36%) were 10 years old or younger, whereas 6 vessels (about 19%) were over 15 years old. Note that this distribution is based on only 31 unique vessels.

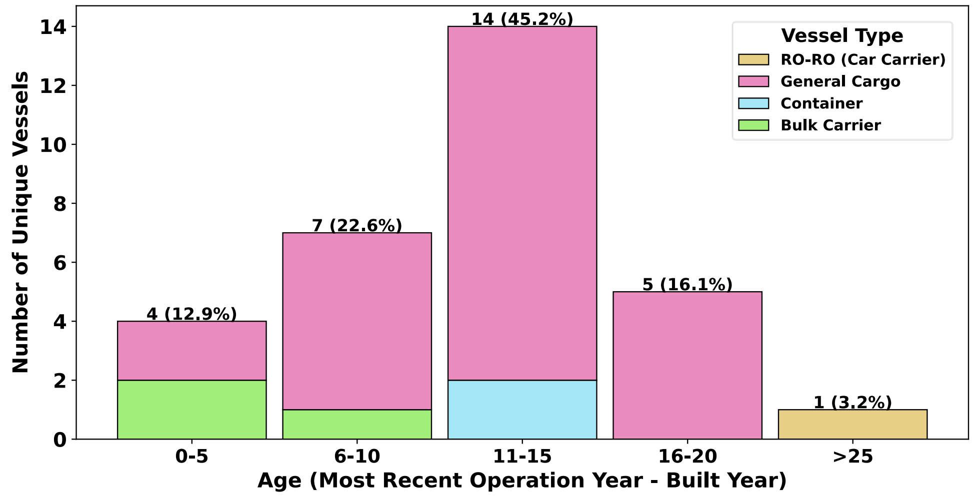

Figure 4-13. Vessel age distribution for unique vessels operated between Everett and the ROK ports (2017–2021).

Gross registered tonnage distribution

Similar to Figure 4-4 and Figure 4-9, Figure 4-14 shows the distribution of gross registered tonnage for all the unique vessels operated between the Everett port and the three ROK ports in 2017–2021. As shown in Figure 4-14, over 90% of these vessels had less than 50 thousand register tons. Note that this distribution is based on only 31 unique vessels.

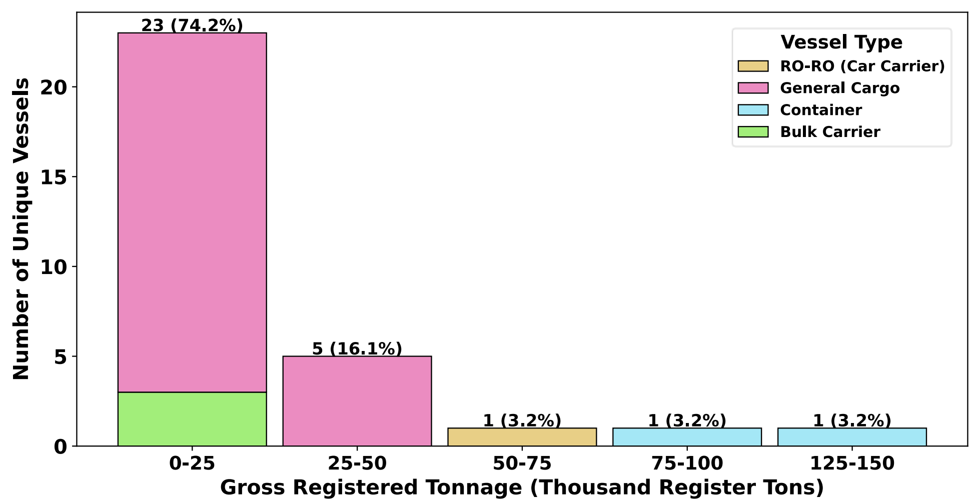

Figure 4-14. Gross tonnage distribution for unique vessels operated between Everett and the ROK ports (2017–2021).

Fuel oil tank size distribution

Similar to Figure 4-5 and Figure 4-10, Figure 4-15 shows the distribution of fuel oil tank sizes, in thousand cubic meters, for all the unique vessels with fuel oil tank size information that operated between the Everett port and the three ROK ports. For the vessels operated between Everett and the three ROK ports in 2017–2021, only eight unique vessels had fuel oil tank size information, and six of them had fuel oil tank sizes under 5 thousand cubic meters.

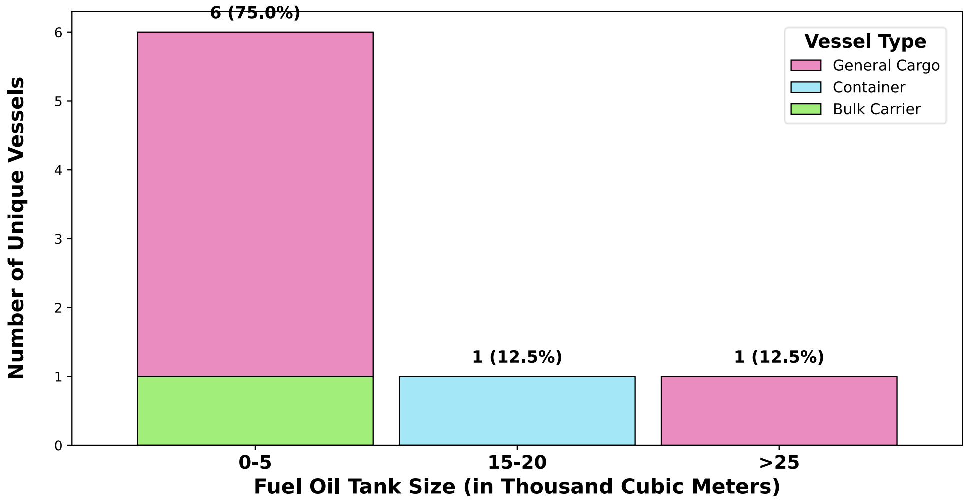

Figure 4-15. Fuel oil tank distribution for unique vessels operated between Everett and the ROK ports (2017–2021).

5. TARGET SEGMENTATION BY VESSEL TYPES

To determine the target segmentation for each vessel type, the fuel consumption was estimated using each vessel's engine power and miles traveled. Then, which corridor contributed most among all the three-to-three port corridor combinations was investigated. Finally, the contribution by only the top five operators was further analyzed.

To estimate the overall fuel consumption, a simple method was used. The engine power (kWh) and the average fuel consumptions (kg/kWh) were multiplied based on the fuel type, assuming all the vessels within the scope were operated with heavy fuel oil (HFO) or marine gas oil (MGO). Table 5-1 shows the average fuel consumptions (originally reported in kg/kWh) for fuel types from various sources. Note that there were vessels without engine power information, and they were estimated by vessel size (i.e., twenty-foot-equivalent unit for containers and gross registered tonnage for other vessels).

Although the selected corridors were dominated by container ships, and therefore their contribution to the fuel consumption was certainly the largest, the other two vessel types also can be expected to target green shipping segments because they might be favorable to switching to green alternative fuels, as they were shown to have used relatively cleaner fuels based on the bunkering fuel type distribution. (Refer to Section 6.1.)

Table 5-1. Energy density and average fuel consumption for fuel types

Fuel Type	Kilograms per Kilowatt-hour	Example for 50 MWh Engine	
		Metric Tons per Day	Metric Tons per Nautical Mile[a]
HFO [13]	0.18	216	0.41
MGO [13]	0.18	216	0.41
Liquified Natural Gas [13]	0.13	156	0.30
Methanol [14]	0.18	216	0.41
Biodiesel [15]	0.22	264	0.50
Hydrogen [16]	0.06	72	0.14

[a] Assuming the average sailing speed of 22 knots, based on Mohseni et al. [12]

5.1 CONTAINER SHIPS

To identify the corridors that could have greater impacts by switching to alternative fuels, the number of vessel trips and the estimated fuel consumption for each corridor between the two countries were investigated. Figure 5-1 shows those corridor-level numbers of vessel trips and estimated fuel consumptions for container ships in 2017–2021.

As shown in Figure 5-1, the Seattle-Busan corridor (both directions) was the top corridor by both the number of vessel trips and the estimated fuel consumption, accounting for over 63% of all the corridors within the scope of this study. The second busiest corridor was Tacoma-Busan, which accounted for about 37% of the number of vessel trips and the estimated fuel consumption. Note that no container ships traveled into or out of the ports of Ulsan and Masan during 2017–2021.

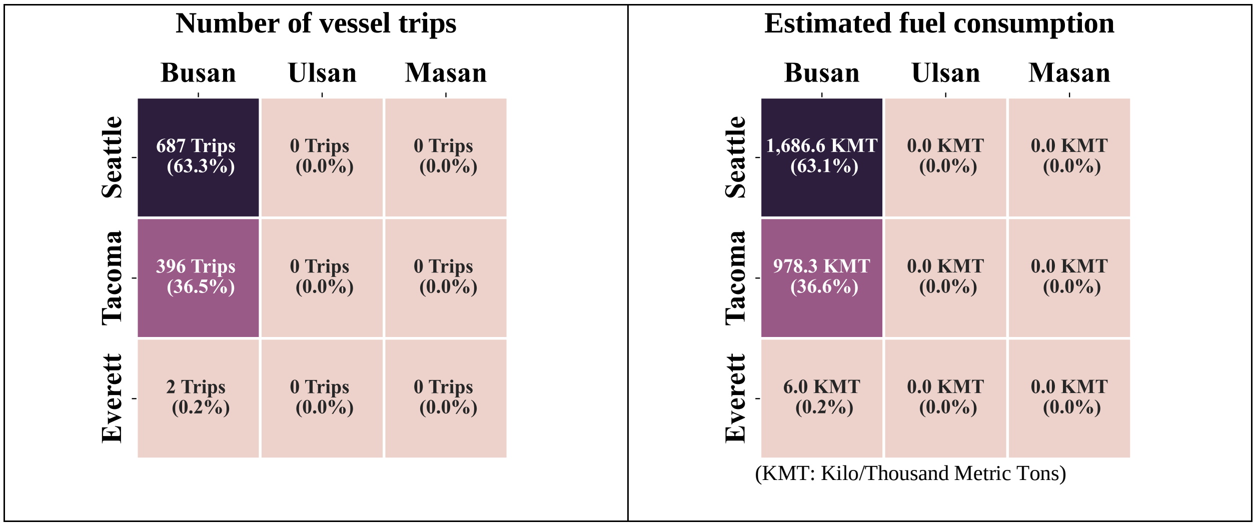

Figure 5-1. Container vessel trips and estimated fuel consumption by corridor in 2017–2021.

Figure 5-2 shows the process of target segmentation for the container ships within the scope. From left to right, the first vertical bar chart shows the distribution of container ships among all the corridors; the container ships accounted 96% of the overall estimated fuel consumption. Among the container ships, the top corridor, Seattle-Busan (as discussed in Figure 5-1), accounted for about 63% of the container ships, as shown in the middle of Figure 5-2.

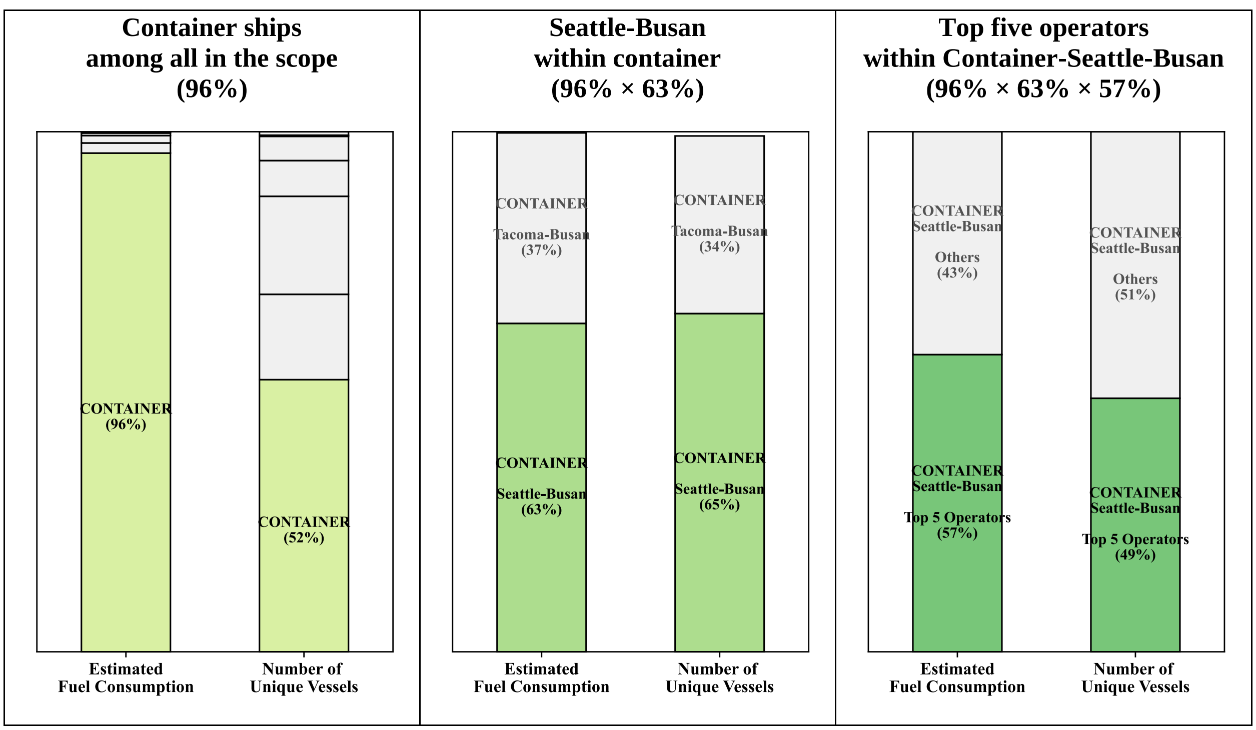

Figure 5-2. Target segmentation for container vessels within the scope.

The contribution of top five operators was further investigated to evaluate whether the top five operators heavily contribute to the overall fuel consumption. As shown in the rightmost vertical bar chart in Figure 5-2, the top five operators accounted for more than half of the container shipments between Seattle and Busan in terms of the estimated fuel consumption. This suggests that the feasibility study and the initial starter of the USA-ROK green shipping corridor could be focused on selected top container ship operators within the Seattle-Busan corridor.

5.2 BULK CARRIERS

Similar to Figure 5-1, Figure 5-3 shows corridor-level numbers of vessel trips and estimated fuel consumptions for bulk carriers in 2017–2021. As shown in Figure 5-3, the Tacoma-Busan corridor (both directions) was the top corridor by both the number of vessel trips and the estimated fuel consumption, accounting for about half of all the corridors within the scope of this study. The second busiest corridor was Seattle-Busan, which accounted for 27% of the number of vessel trips and 28% of the estimated fuel consumption.

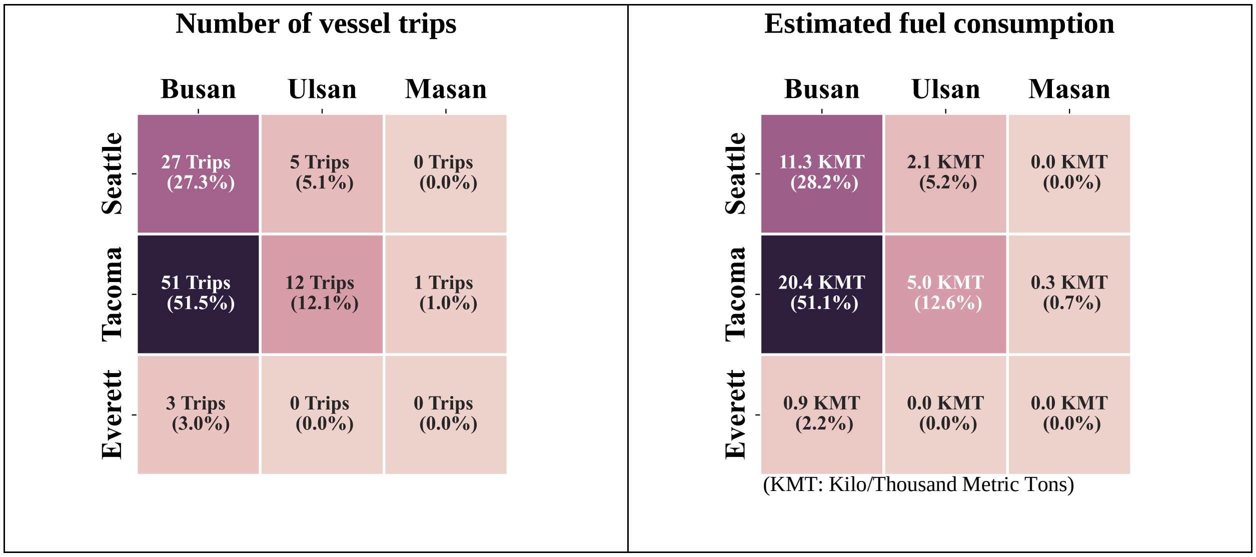

Figure 5-3. Bulk carrier vessel trips and estimated fuel consumption by corridor in 2017–2021.

Similar to Figure 5-2 for the container ships, Figure 5-4 shows the process of target segmentation for the bulk carriers within the scope. From left to right, the first vertical bar chart shows the distribution of bulk carriers among all the corridors; the bulk carriers were 1% of the overall estimated fuel consumption and 19% of the number of unique vessels. Among the bulk carriers, the top corridor was Tacoma-Busan (as discussed in Figure 5-3), which contributed about half of the bulk carriers, as shown in the middle of Figure 5-4. Finally, as shown in the rightmost vertical bar chart in Figure 5-4, the top five operators accounted for about 21% of the estimated fuel consumption for the bulk carriers between Tacoma and Busan.

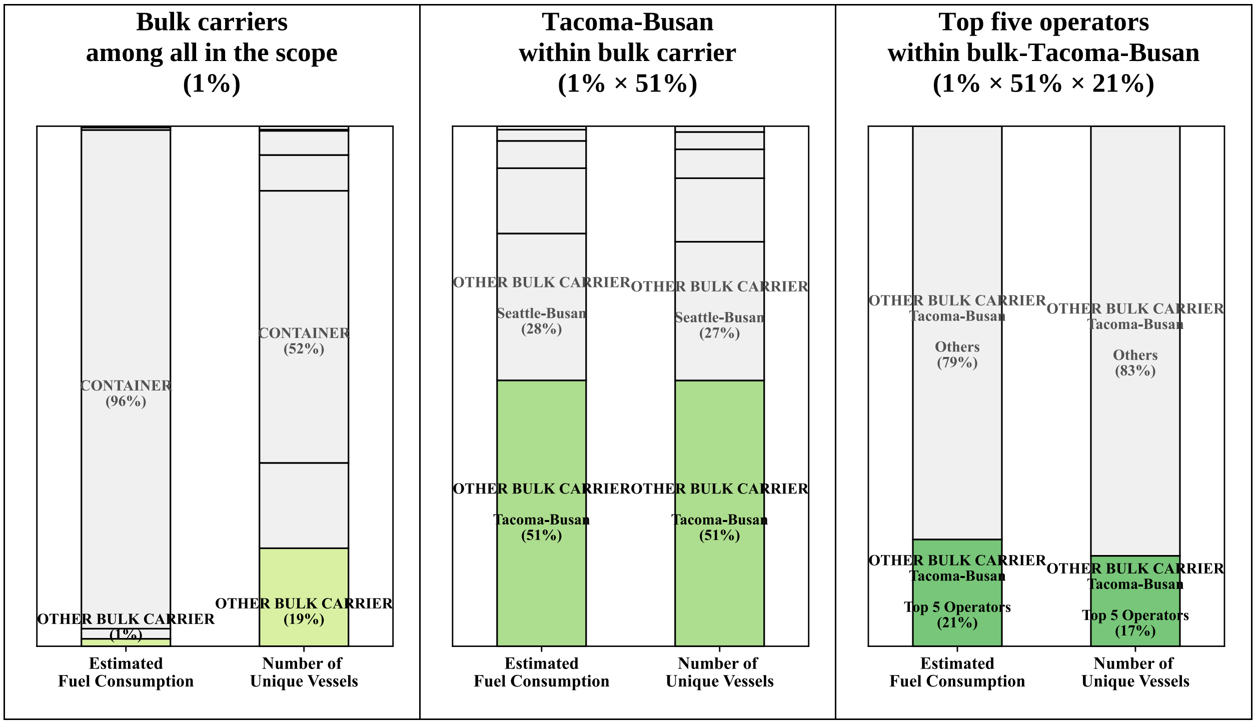

Figure 5-4. Target segmentation for bulk carrier vessels within the scope.

5.3 RO-RO CARRIERS

Similar to Figure 5-1 and Figure 5-3, Figure 5-5 shows corridor-level numbers of vessel trips and estimated fuel consumptions for RO-RO carriers in 2017–2021. As shown in Figure 5-5, the Tacoma-Ulsan corridor (both directions) was the top corridor by both the number of vessel trips and the estimated fuel consumption, accounting for over 76% of all the corridors within the scope of this study. The second busiest corridor was Tacoma-Busan, which accounted for 15% of the number of vessel trips and 14% of the estimated fuel consumption.

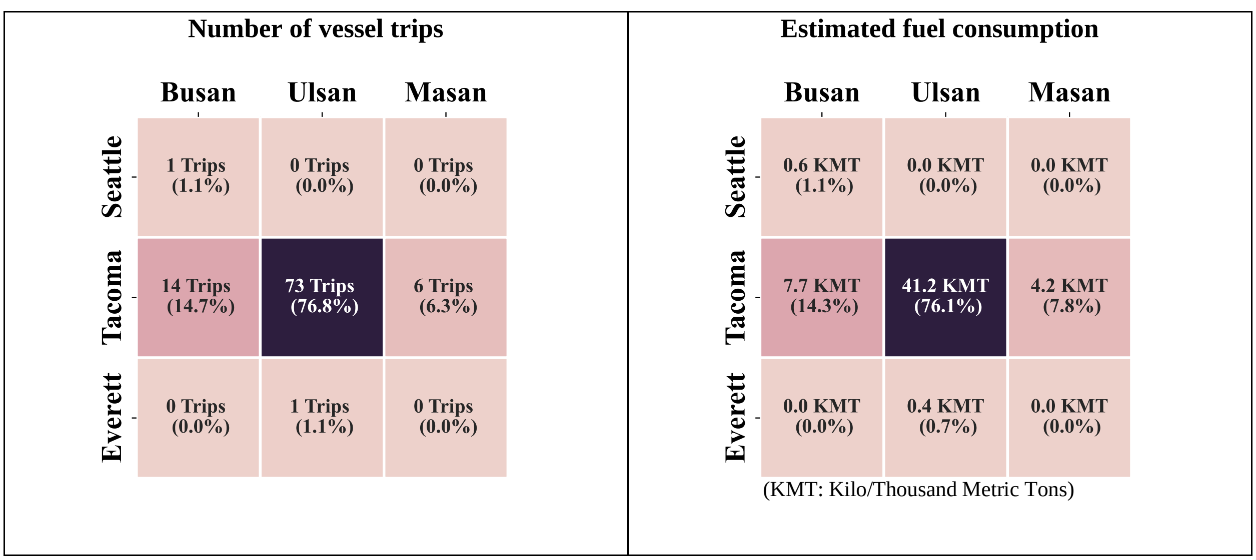

Figure 5-5. RO-RO carrier trips and estimated fuel consumption by corridor in 2017–2021.

Figure 5-6 shows the process of target segmentation for the RO-RO carriers within the scope. From left to right, the first vertical bar chart shows the distribution of RO-RO carriers among all the corridors; the RO-RO carriers accounted 2% of the estimated fuel consumption and 16% of the number of unique vessels. Among the RO-RO carriers, the top corridor was Tacoma-Ulsan (as discussed in Figure 5-5), contributing about 76% of the estimated RO-RO carrier fuel consumption, as shown in the middle of Figure 5-6. Finally, as shown in the right vertical bar chart in Figure 5-6, the top five operators accounted for about 47% of the estimated fuel consumption for the RO-RO carriers operated between Tacoma and Ulsan.

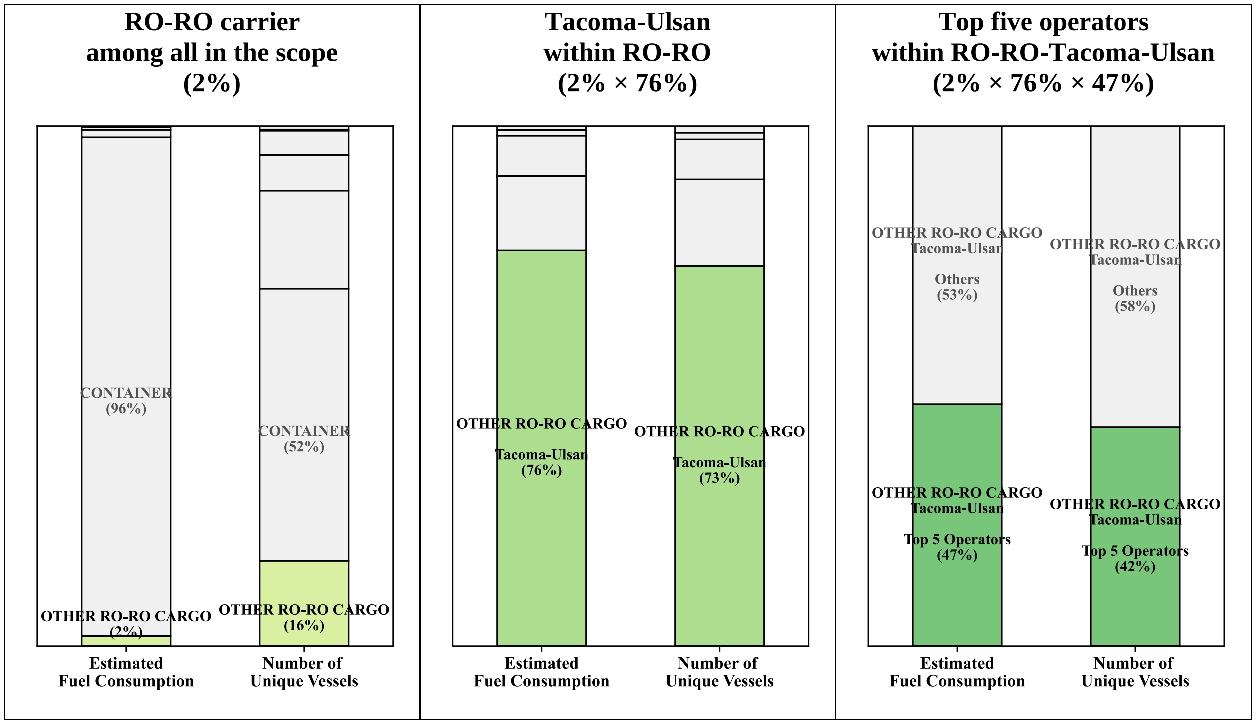

Figure 5-6. Target segmentation for RO-RO carriers within the scope.

5.4 SUMMARY

This section summarizes the target segmentation analysis for the three vessel types (i.e., containers, bulk carriers, and RO-RO carriers) in Sections 5.1–5.3. At this stage of prefeasibility, it has not yet been determined which target segments will be considered in the next phase (i.e., the feasibility study). Therefore, the analysis is summarized into two scenarios: target segmentation by vessel type for all operators and target segmentation by vessel type for only the top five operators. This is mainly to provide the impact of each segment on the fuel consumption and to guide decision-making regarding where the starter of the green shipping corridor should be focused on, which must be finalized with various other factors.

Target segmentation by vessel type for all operators

Table 5-2 summarizes the number of unique vessels and the estimated fuel consumption for all operators of each target segmentation by vessel type. The container ships between Seattle and Busan contributed the most in terms of the estimated fuel consumption, accounting for more than 60% of the overall estimated fuel consumption. For the top corridors of bulk carriers and RO-RO carriers, their overall contribution to the fuel consumption was much smaller (accounting for about 2% combined) compared with the container ships, whereas their number of unique vessels accounted for over 10% of all the unique vessels operated among all the corridors within the scope in 2017–2021.

Table 5-2. Target segmentation by vessel type for all operators

Target Segment	All Vessel Types	Container	Bulk Carrier	RO-RO (Car Carrier)
Corridor	All three-three ports	Seattle-Busan	Tacoma-Busan	Tacoma-Ulsan
Number of Unique Vessels	451 vessels (100%)	160 vessels (35%)	46 vessels (10%)	57 vessels (13%)
Estimated Fuel Consumption	2,785 KMT (100%)	1,687 KMT (61%)	20 KMT (0.7%)	41 KMT (1.5%)

(KMT: Kilo/Thousand Metric Tons)

Target segmentation by vessel type for only the top five operators

Whereas Table 5-2 covers all operators, Table 5-3 summarizes the number of unique vessels and the estimated fuel consumption for only the top five operators of each segment. This could be an important aspect to consider because the starter of the green shipping corridor could be focused on selected operators, but not all the operators, unless they are required by law or regulation to be operated with alternative fuels.

Similar to the summary of all operators in Table 5-2, the container ships' contribution to the estimated fuel consumption was much higher than those of the bulk carriers and the RO-RO carriers. In addition, the top five operators contributed about half of the estimated fuel consumption for all operators of the container ships and the RO-RO carriers. (Compare Table 5-2 and Table 5-3.)

Table 5-3. Target segmentation by vessel type for only the top five operators

Target Segment	All Vessel Types	Container	Bulk Carrier	RO-RO (Car Carrier)
Corridor	All three-three ports	Seattle-Busan	Tacoma-Busan	Tacoma-Ulsan
Number of Unique Vessels	451 vessels (100%)	78 vessels (17%)	8 vessels (1.8%)	24 vessels (5.3%)
Estimated Fuel Consumption	2,785 KMT (100%)	964 KMT (35%)	4 KMT (0.2%)	19 KMT (0.7%)

(KMT: Kilo/Thousand Metric Tons)

Although the overall shares of the bulk carriers and the RO-RO carriers were much smaller than the share of the container ships, they could be favorable to consider cleaner alternative fuels based on their current bunkering fuel type distributions. (Refer to Section 6.1.) The following list summarizes the key findings from the target segmentation analysis:

- Based on the number of vessel trips and the estimated fuel consumption, the first target segment can be the containers ships operated between Seattle and Busan.
- The top corridors were different depending on the vessel type: Seattle-Busan for container ships, Tacoma-Busan for bulk carriers, and Tacoma-Ulsan for RO-RO carriers.
- For the selected target corridors of both the container ships and the RO-RO carriers, the top five operators accounted for about half of the estimated fuel consumptions. Therefore, if these vessel types are selected as the target segments, selected top operators can be considered first because their overall impacts are expected to be greater than those of other operators.

- The contributions to the overall fuel consumption by bulk carriers and RO-RO carriers were much smaller than the contributions of the container ships. However, they could be more favorable to considering alternative cleaner fuel types. See Section 6.1.
- For bulk carriers, the top corridor was Tacoma-Busan among the selected corridors, with only eight unique vessels operated by the top five operators.

6. OTHER CONSIDERATIONS FOR GREEN SHIPPING CORRIDOR

This prefeasibility study focused on the major vessel types and the cargo types in selected corridors by overall tonnage of cargo and number of vessel trips. However, in addition to the volume of vessel trips and the estimated fuel consumption, many other operation characteristics must be considered for green shipping corridors. Although this prefeasibility study's scope is limited, a brief discussion of several factors is included as examples to be further investigated during the next stage (the feasibility study) if applicable.

6.1 CURRENT BUNKERING FUEL TYPE DISTRIBUTION

To investigate the current bunkering fuel types, this study analyzed the distribution of bunkering quantity by fuel type and vessel type based on the bunkering data reported to the Washington State Department of Ecology [5] with support from the Northwest Seaport Alliance. Note that the bunkering data summary presented in Figure 6-1 covers bunkering activities for only Seattle and Tacoma during 2019–2021. Because bunkering activities are affected by many factors (e.g., vessels' complete routes and fuel prices at other ports), the analysis focused on only the distribution of bunkering fuel types by vessel type.

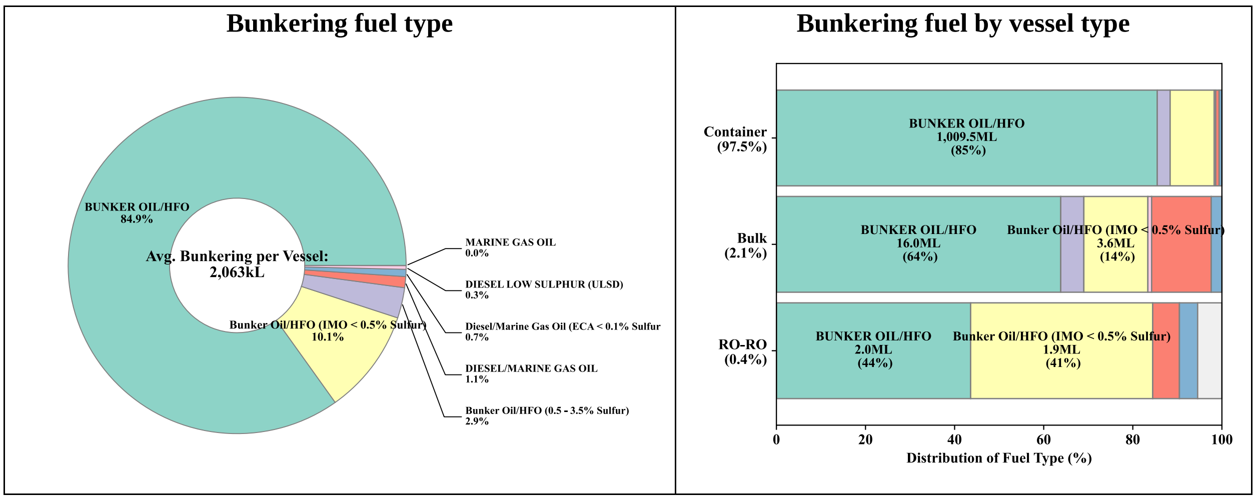

Figure 6-1. Distribution of bunkering fuel types by vessel type at Northwest Seaport Alliance ports (2019–2021).

First, the left side of Figure 6-1 shows the overall distribution of bunkering fuel types. On average, the vessels operated within the scope bunkered their fuels about 2 million liters. The most common fuel type was HFO, also known as bunker oil, which accounted for about 85% of total bunkered fuel during 2019–2021. Because container ships were the dominant vessel type operated in the selected corridors, it is not surprising that a much higher contribution (over 97%) to the bunkering by container ships was observed, as shown on the right side of Figure 6-1. However, RO-RO carriers tended to use cleaner fuels, such as lower sulfur-level diesels and marine oils that are generally more expensive than the HFO. This can be an important factor to consider because these vessels' operators (or the shippers using these vessels) might be more likely to favor switching to cleaner alternative fuels.

6.2 OTHER MAJOR PORTS ALONG THE SELECTED CORRIDORS

This prefeasibility study focused on analyzing vessel and cargo flows between the three ports in the USA and the three ports in the ROK. However, it is very unlikely that these vessels would be operated exclusively between the selected corridors. This could be a limiting factor for the vessel operators because the use of alternative fuel can affect their operations if the alternative fuel bunkering facilities are available only on the selective target ports. Therefore, it is essential to understand their full trip-chains of operation routes and identify key major ports where they transport cargo other than the selected corridors.

To quickly identify other major ports along the selected corridors, a full travel history for the top 10 vessels by number of vessel trips within the selected corridors was analyzed. Figure 6-2 highlights the top 10 major ports that were visited by these vessels from June 2022 to June 2023. Interestingly, all the top 10 major ports visited by these vessel shipments are concentrated in Eastern Asia because their industries and trades are highly interconnected. Note that two ports, Shanghai and Singapore, have been selected along with the ports in this study as ongoing study areas for implementing the green shipping corridors as part of the effort for the Zero-Emission Shipping Mission [17].

Figure 6-2. Major ports along the selected corridors. Red outer circles indicate ports that have been selected as ongoing study areas for implementing green shipping corridors as part of the Zero-Emission Shipping Mission.

6.3 POTENTIAL PATHWAYS TO EXPAND USA-ROK GREEN SHIPPING CORRIDORS

The near-term objective of this prefeasibility study is to understand operation characteristics of vessel and cargo flows along the selected corridors and their impacts to fuel consumption, emissions, and implementation of green shipping. In the long-term, these showcasing corridors need to be benchmarking places where other ports and corridors expand the practical implementation and use of alternative fuels to reduce carbon footprints.

With this long-term objective in mind, the share of shipments covered between the USA and the ROK in terms of cargo tonnage was analyzed by adding one additional port on each side of country, as shown in Figure 6-3. For instance, the selected scope (the three USA ports to the three ROK ports) covers about 5% of total cargo tonnage between the USA and the ROK, and an additional 7.4% would be covered by expanding the green shipping corridor to the Houston port in the USA and the Samil port in the ROK. Based on this analysis, about half of cargo tonnage is expected to be covered by expanding to an additional 10 ports on each side of country.

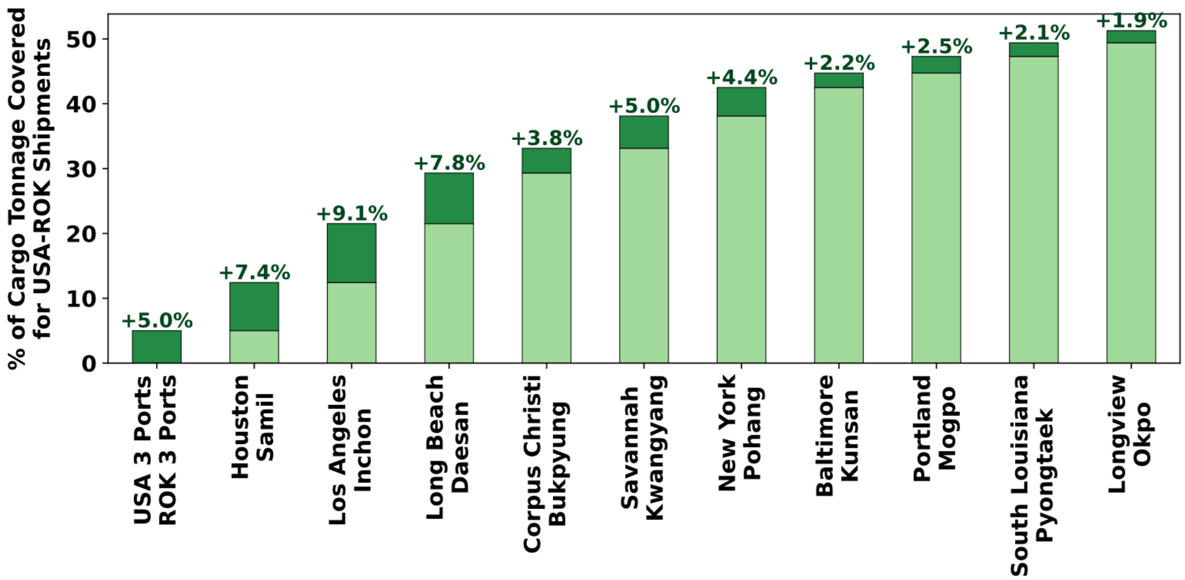

Figure 6-3. Percent of cargo tonnage covered for USA-ROK vessel shipments.

7. FINAL REMARKS

This prefeasibility study focused on a high-level overview of vessel and cargo flow characteristics between the USA and the ROK. The following list highlights key observations from this study:

- The vessel shipments between the USA and the ROK are expected to grow by 67%–90% from 2021 to 2050.
- The major cargo types are quite different depending on the trade type (imports vs. exports). The most contributing cargo shipments are all manufactured equipment, machinery, and products (53%) for imports and animal feed, grain mill products, flour, and processed grains (27%) for exports.
- The majority (over 90%) of vessel shipments within the scope is dominated by container ships.
- The top corridors for each vessel type are different: Seattle-Busan for the container ships, Tacoma-Busan for the bulk carriers, and Tacoma-Ulsan for the RO-RO carriers.
- The container ships between Seattle and Busan, the top segment among all, accounts for about 61% of the total estimated fuel consumption among all the vessels within the scope.
- The RO-RO carriers tend to use cleaner fuels, such as lower sulfur-level diesels and marine oils that are generally more expensive than the HFOs. This bunkering fuel type analysis indicates that the RO-RO carriers might be more favorable to cleaner alternative fuels.
- There are other ports along the selected corridors, and their top port locations are concentrated in Eastern Asia. This should be further analyzed in the feasibility stage.
- Assuming the green shipping corridors between the three USA ports and three ROK ports are all implemented, about half of cargo tonnage between the two countries is expected be covered by expanding to an additional 10 ports on each side of country.

The main objective of this prefeasibility study was to understand the vessels' operation characteristics along the selected corridors and identify the potential target segments that could potentially be considered for switching to alternative fuels. Because the prefeasibility study was conducted as a very high-level analysis, a more detailed assessment of the selected green corridor will be needed. The following list summarizes the limitations of this prefeasibility study that are suggested for the further analyses during the next stage (the feasibility study):

- A very simple method, applying an average fuel consumption by fuel type and engine power, was used to estimate the fuel consumption in this prefeasibility study. The fuel consumption, energy demand, and associated emissions can be more accurately estimated by integrating more detailed information (e.g., speed, temperature, wind) based on each vessel's AIS history.
- Fuel consumption/demand and bunkering activity can be quite different depending on each vessel's operation strategy. Therefore, a detailed analysis to estimate the expected fuel demand accurately at each port will be needed. This analysis will need to consider operation routes, port infrastructure, and fuel prices of the target port and neighboring ports along the routes.
- Regarding the bunkering demand of alternative fuels at the port level, the effect of seasonality on peak demand may need to be considered during the feasibility study.
- Each vessel's full vessel travel history should be thoroughly investigated to identify other ports that are involved on their routine operations.
- Because of the impact of supply chain disruption events such as the pandemic, operational characteristics could change in recent and upcoming years. Therefore, the feasibility study should capture those changes with most recent data and evaluate whether the changed operation pattern will continue.

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