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Economic Cooperation

Advancing Free Trade
for Asia-Pacific Prosperity

Analysis of the Impacts of Slow Steaming for Distant Economies

APEC Transportation Working Group

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Produced by
Starcrest Consulting Group, LLC,
PO Box 434, Poulsbo, WA 98370 USA

For
Asia-Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

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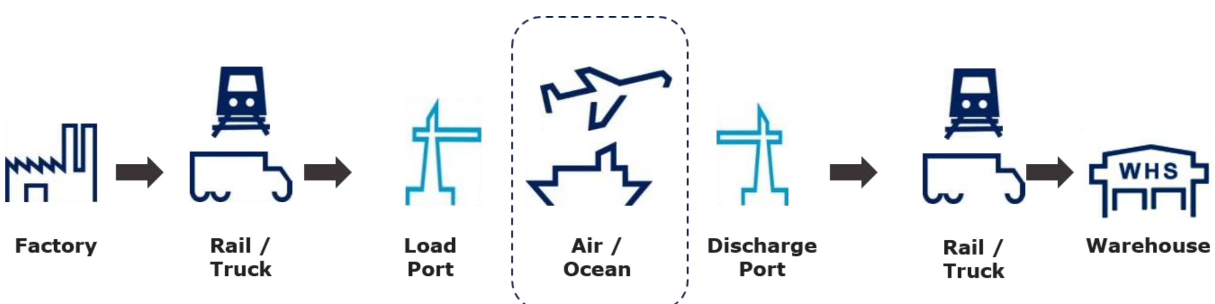
EXECUTIVE SUMMARY

At the request of the Asia-Pacific Economic Cooperation (APEC), this report examines the economic and environmental impacts of slow steaming, also referred to as vessel speed reduction (VSR), for distant economies. The objective of this study is to explain the various parameters that need to be considered when evaluating slow steaming and what the environmental and economic impacts are across a varied vessel types, fleet, distance, and cargo.

In order to further reduce greenhouse gas (GHG) emissions from ships, the International Maritime Organization (IMO) is considering short, mid, and long-term measures. One of the short term measures identified in the Initial IMO Strategy on reduction of greenhouse gas emissions from ships resolution (MEPC.304(72)) is to "consider and analyse the use of speed optimization and speed reduction as a measure, taking into account safety issues, distance travelled, distortion of the market or to trade, and that such measure does not impact on shipping's capability to serve remote geographic areas."

Global logistics networks are dictated by the needs of the shippers (cargo owners) who primarily value three metrics in designing their supply chains: cost, time and reliability. Shippers contract with suppliers to manufacture goods and transport them from the point of manufacture (origin) to the point of consumption (destination) through an end-to-end logistics network, which is commonly known as a supply chain. Within the supply chain, cargo will be handled by many different points of contact and moved by different modes of transportation, including rail, truck, ship, and airplane. As illustrated in Figure ES.1, beginning at the factory, cargo will be transported to a warehouse, container terminal or container freight station, also known as CFS, then moved to a load port (ocean or air) for long haul transport to a destination port (ocean or air), before being moved again by truck or rail to a destination warehouse or distribution center. Eventually this cargo will be moved to the final point of sale. International cargo has two main modes of long-distance transport: air and ocean; this analysis is concerned with the segment of the supply chain served by these modes of transportation.

Figure ES.1: End to End Supply Chain



Slow Steaming as a Measure to Reduce CO_2

As an emission reduction strategy, slow steaming targets propulsion-related energy and emissions by reducing a ship's speed over any distance. The potential emissions benefit for slow steaming is derived by evaluating a ship's performance over a set distance at a baseline speed versus how the ship operates over the same distance at a slower speed. From a global perspective, slow steaming to reduce carbon dioxide (CO_2) is a balance between reducing emissions, increasing transit times, and balancing that with cargo customer's tolerance for longer transit times. If the balance is lost, and the customer's tolerance is exceeded, then modal shifts to higher intensity transportation modes could negate any benefits if not dramatically increase GHG emissions.

Though slower than air freight, ocean transport, particularly container shipping, is by far the most efficient form of cargo transportation; on average, air freight is 47 times more carbon intensive than a container ship, as illustrated in Figure ES.2 below.

Figure ES.2: Comparison of CO_2 per Transport Mode[1]

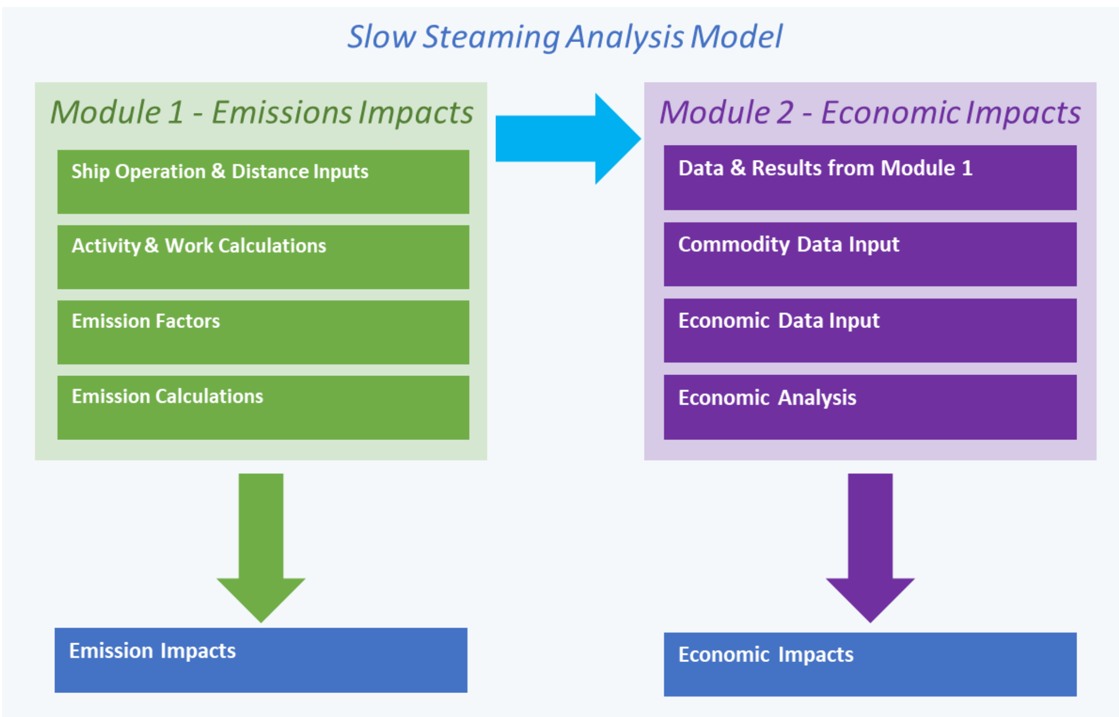
Cargoes that are time sensitive due to the nature of their industries, such as perishable, high value, or fast-moving consumer goods (FMCG) are highly affected by changes in transport time and will seek the option that meets the required cargo delivery dates, potentially resulting in shifts to higher carbon intensive transport modes, such as air freight. For lower value cargoes that cannot absorb the additional cost of air freight, trade patterns will likely change, resulting in changes to trading partners or types of products traded.

Analysis Approach

For this study, noting that each APEC member economy has its own specific trading partners, commodities, ship characteristics, and routes and that slow steaming potential benefits and impacts are specific to those combinations, the approach taken was to create a Slow Steaming Analysis (SSA) Model. The SSA Model consists of two modules: Module 1 – GHG Impacts (Module 1) and Module 2 – Economic Impacts (Module 2). The two modules allow users to input various distances, speeds, ship sizes for two class (container and bulk ships), and ship physical and operational characteristics to estimate across distances and fleets the potential impacts from slow steaming. The impacts from Module 1, for each ship type, size, and distance combination are: additional sailing time, additional ship population requirements, and percent change in carbon dioxide equivalent (CO_2e). Data and results are then transferred by the use to Module 2 where user input on variables used to determine the economic impact in Module 2 are: cargo time delay, gross domestic product (GDP) impact, interest cost, depreciation cost, and insurance cost.

The model was developed using Microsoft Excel so it could be easily used by a wide range of users. An illustration of the SSA Model and its two modules is presented in the figure below.

Figure ES.3: SSA Model Illustration



Each member economy can run its own specific combinations of the variables in each module to evaluate how the specified fleet scenario performs over a range of reduced speeds to determine what the GHG emission and economic impacts are.

Economic Impact for Distant Economies

This analysis is meant to provide APEC economies with information on the impacts that a speed reduction measure could have for distant economies, addressing the issue from a shipper's/trade point of view. This economic impact analysis is based on total annual trade in 2017 (full year volume) between the long-distance economies' pairs (export and import economies), in both total volume in kilos and value in US Dollars, for dry bulk and containerized cargoes.

Depending on the commodity, slow steaming will have a different impact. For non-perishable products, the delay due to slow steaming may be minimal. For perishable products, such as fresh cherries, the impact due to the delay caused by slow steaming may be considerable and may result in a shift to air freight. The economic impact of the products under analysis, as a percentage of economies' GDP, vary from 0.004%, in the case of Chinese memories, electronic integrated circuits to the United States, to 3.3965% in the case of Peruvian copper ore to China.

GHG Emissions Impact Analysis

From a global perspective, slow steaming as an emission reduction strategy is ultimately a balance between reducing emissions, increasing transit times, and balancing these with cargo customer's tolerance for longer transit times. If the balance is lost, and the customer's tolerance is exceeded, then modal shifts to significantly higher carbon intensity transportation modes, such as air freight, could occur or in the extreme worse case, the potential loss in trade for highly time sensitive cargos. The result of a modal shift to air freight would both significantly reduce the GHG emission benefits from slow steaming and could even result in GHG emission increases.

As with all emission reduction strategies, each strategy has its strengths, limitations, and their effectiveness is typically not the same across ship types and operational modes. The primary strength of slow steaming from an emission reduction strategy perspective is that all ships can implement the measure with no modifications to the ship. The primary limitation of slow steaming is that speed over ground does not indicate what the ship is actually turning with regard to speed through the water. The other significant challenge with slow steaming is that the potential benefits can vary significantly depending on the baseline speed, between various ship types, across ship sizes even within the same type, and across different distances due to the addition of ships to maintain acceptable arrival frequencies. Ship types that have relatively high operational speeds, like container ships, will have a higher potential to reduce emissions than those ship types that operate at relatively slow speeds, like bulk ships.

As expected, the potential benefits are dependent on physical and operating characteristics of each ship type, size category, and distance combination. The potential emission changes from slow steaming can range from either emission reductions to emission increases, so the strategy needs to be evaluated considering specifics about each scenario. As illustrated from the container and dry bulk scenarios highlighted in this study, there is not a single speed that results in consistently the highest reductions across all container or dry bulk ship size and distance combinations.

Conclusions

This study is not recommending a specific baseline speed or slow steaming speed.

From a global perspective, slow steaming as an emission reduction strategy is ultimately a balance between reducing emissions, increasing transit times, and balancing these with cargo customer's tolerance for longer transit times. If the balance is lost, and the customer's tolerance is exceeded, then modal shifts to significantly higher carbon intensity transportation modes, such as air freight, could occur or in the extreme worse case, the potential loss in trade for highly time sensitive cargos.

Slow steaming also raises significant questions for economies that are fully dependent on shipborne commerce for critical cargos that are vital to the life and welfare of their citizens. With regard to the potential magnitude of emission and economic related impacts from slow steaming, each APEC economy will need to evaluate its own specific scenarios.

In general, from an economic perspective, for containerized and dry bulk cargos, the economic impact of slow steaming on the cargo and the shipper is small, given that the supply chains will tend to adjust to the new, longer voyage times; however, the impact on perishable goods is higher than on other dry goods. Slow steaming, however, may adversely impact APEC economies that export perishable products and FMCS to distant economies.

From an emission reduction strategy perspective, as illustrated from the container and dry bulk scenarios evaluated in the study, there is not a single speed that results in consistently the highest reductions across all container or dry bulk ship size and distance combinations. The development of baseline speeds will be critical in determining the potential magnitude of emissions reductions from a slow steaming strategy.

Slow steaming is most effective for ship designed to transit the ocean at high-speeds, like container ships, vehicle carriers, etc. That being said, the magnitude of potential reductions is not the same even in the same ship type class across various distances and ship sizes. Both container ship and dry bulk scenarios showed eroding emission reduction benefits with longer transit distances. Additional ships will most likely be needed to ensure that services maintain the cargo owner's acceptable arrival tolerances, however, there comes a point when the speeds may be too slow and thus option of transporting goods by ship untenable. The result is either a modal shift to a higher carbon intensive form of transportation with a net result of higher GHG emissions or loss of trade.

A global slow steaming strategy that is not well thought out could adversely impact other stakeholder strategies targeting improvement in efficiencies such as strengthening the IMO Ship Energy Efficiency Management Plan, 'just in time arrival', and other efficiency improvements. In addition, slow steaming may render IMO Tier III ships to operate in conditions where their Tier III technologies are inoperable due to temperature loss in exhaust gases at low loads.

1.0 INTRODUCTION

In April 2018, the International Marine Organization (IMO) Marine Environment Protection Committee (MEPC) approved a program of follow-up actions to implement the Initial IMO Strategy on reduction of greenhouse gas (GHG) emissions from ships resolution (MEPC.304(72)). IMO also considered how to further progress the reduction of GHG emissions from ships by considering short, mid, and long-term measures. One of the short-term measures identified in the Initial IMO Strategy is to "consider and analyse the use of speed optimization and speed reduction as a measure, taking into account safety issues, distance travelled, distortion of the market or to trade, and that such measure does not impact on shipping's capability to serve remote geographic areas." Concrete proposals on candidate short-term measures were considered at MEPC 74 (May 2019). At the request of the Asia-Pacific Economic Cooperation (APEC), this report (APEC study) examines the economic and environmental impacts of slow steaming, also referred to as vessel speed reduction (VSR), for distant economies.

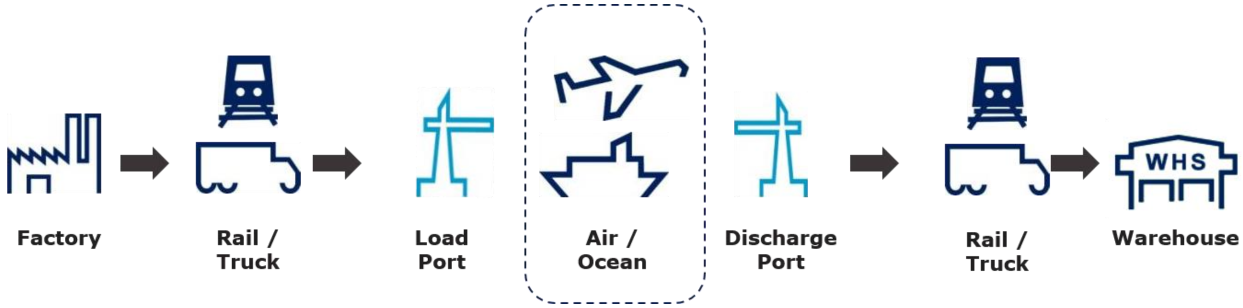
The objective of this study is to explain the various parameters that need to be considered when evaluating slow steaming and what the environmental and economic impacts are across varies vessel types, fleet, distance, and cargo. For the purpose of this study, slow steaming and vessel speed reduction are terms used interchangeably and the meaning is literally to reduce speed. The terms have not been clearly defined at the international level and it is not the intent of this study to define them. This study is not recommending a specific baseline speed or slow steaming speed.

1.1 Global Logistics Context

Global logistics networks are dictated by the needs of the shippers (cargo owners) who primarily value three metrics in designing their supply chains: cost, time and reliability. These metrics are further influenced by a number of factors including market demand, port and inland infrastructure, availability of skilled labor, vessel and network capacity, transit times, government and regulatory issues, and environment and energy efficiency.

Shippers contract with suppliers to manufacture goods and transport them from the point of manufacture (origin) to the point of consumption (destination) through an end-to-end logistics network, which is commonly known as a supply chain. Within the supply chain, cargo will be handled by many different points of contact and moved by different modes of transportation, including rail, truck, ship, and airplane. As illustrated in Figure 1 below, beginning at the factory, cargo will be transported to a warehouse, container terminal or container freight station (CFS), then moved to a load port (ocean or air) for long haul transport to a destination port (ocean or air), before being moved again by truck or rail to a destination warehouse or distribution center. Eventually this cargo will be moved to the final point of sale. International cargo has two main modes of long-distance transport: air and ocean; this analysis is concerned with the segment of the supply chain served by these modes of transportation.

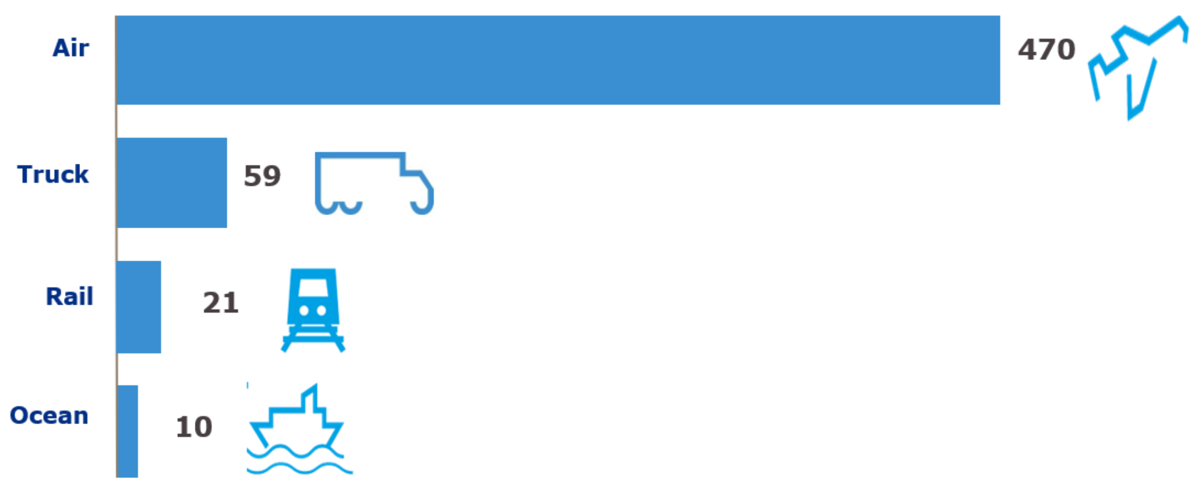
Figure 1: End to End Supply Chain



Though slower than air freight, ocean transport, particularly container shipping, is by far the most efficient form of cargo transportation; on average, air freight is 47 times more carbon intensive than a container ship, as illustrated in Figure 2 below. Cargoes that are time sensitive due to the nature of their industries, such as perishable, high value, or fast-moving consumer goods (FMCG) are highly affected by changes in transport time and will seek the option that meets the required cargo delivery dates, potentially resulting in shifts to higher carbon intensive transport modes, such as air freight. For lower value cargoes that cannot absorb the additional cost of air freight, trade patterns could potentially change, resulting in changes to trading partners or types of products traded.

One unintended consequence of slow steaming may be increased emissions as a result of modal shifts, primarily to air freight, to meet supply chain delivery dates. Not only would this outcome be in direct conflict with the intent of a potential slow steaming strategy, it could potentially increase GHG emissions above what would have been emitted in a business-as-usual scenario for ship speeds.

Figure 2: Comparison of CO_2 per Transport Mode (g/ton-km)[2]



While it is true that many shippers, particularly those in consumer-facing sectors, have environmental goals to reduce GHGs from their transportation operations, it is also true that these same shippers have performance and financial goals tied to their three main supply chain metrics (cost, time and reliability). To date, most shippers have focused their efforts to reduce their GHG emissions on logistics efficiency improvements (increased utilization, modal shifts, network optimization and supplier management), rather than investing in expensive and emerging technologies. In this way, shippers are able not only to reduce their carbon footprints and meet their environmental goals but are able to improve efficiency and decrease costs in support of their performance and financial goals. In an 'all else being equal' scenario (where cost, time and reliability are the same but the environmental impacts are different), many shippers will then select the transport option with the lowest carbon footprint. However, in today's hyper-competitive economic environment, shippers will nearly exclusively choose the transport option that gives them a market advantage.

1.2 Economic Impact of Slow Steaming on Shippers

Most of the existing literature focuses on the economic impact from the ship operator's point of view; that is, the reduction in shipping cost due to the reduction of speed, and, as well, the environmental impact of doing so. Several earlier papers considered slow steaming as strategy during periods of weak demand, low freight rates, and/or high fuel costs, and as a way generally to reduce vessel operating costs. The research focused on the impact on the shipper's total landed cost and the economic impact on economies.

Transport costs are one of the key elements of trade costs. The reviewed literature indicates that transport costs represent approximately 10% of total landed costs,[3] and fuel is almost 50%[4] of vessel operating costs. Some literature indicates that the impact of slow steaming, as a reduction of trade volume, would be minimal, although agricultural products could be impacted, due to possible product substitution from shorter-distance suppliers.

Longer transit times due to vessel speed reduction can increase a shipper's logistics costs. One of the main components to be adjusted on a shipper's supply chain is inventory. Longer transit times require more inventory in the pipeline; that, in turn, creates additional capital expense, inventory cost, storage fees, and the possible adjustment of a shipper's supply chain. Surveys referenced in the literature indicate that shippers value the reliability of ocean transport more than longer transit times resulting from slow steaming.

Some of the higher costs included in longer transit times include depreciation in the value of products, inventory holding costs, insurance cost, and interest/financing. Other technical literature also considers shippers' cash flow, lost sales, and production breakdown as additional potential impacts of slow steaming, as well as the impact on product shelf-life (food, pharmaceuticals, chemicals, fashion, ephemeral products, electronics, etc.). To counter some of these higher costs, transport in refrigerated containers can extend product storage life, if best practice techniques are adopted.

High value and perishable commodities, as well as those in the FMCG sector, are more sensitive to the increase in transport time and these are more susceptible to consider other modes of transportation. The Internet of Things (IoT) is becoming a tool for monitoring perishable products in the supply chain during the complete voyage.

1.3 Logistics and Supply Chain Costs

The reviewed literature on supply chain and logistics cost considers inventory costs to be determined by the value of the inventory, the interest rate, and the inventory and service levels. The inventory cost includes the inventory holding cost and pipeline costs.

Marginal value of time in a supply chain falls within a range of 0.4 – 0.8% of product unit cost per week.[5] This means that changes in lead-time have a very small impact on inventory costs.

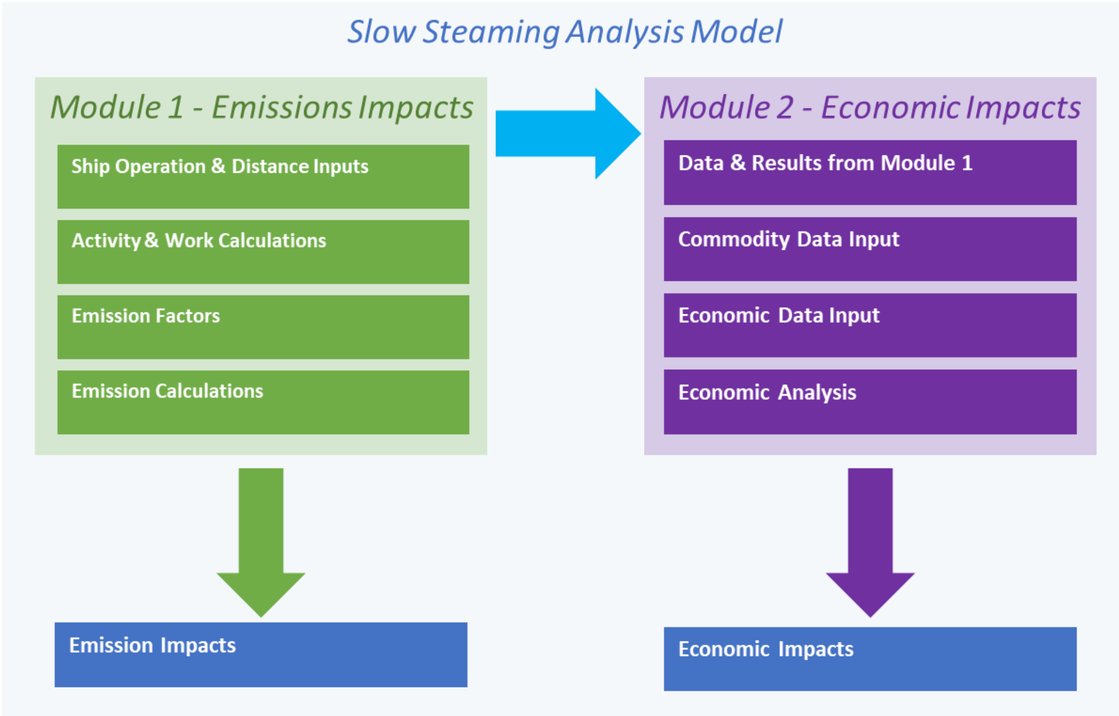
Product characteristics are a determinant of selection of transport mode, and total transport costs also influence the modal choice. The selection of transport mode becomes a trade-off between in-transit time and freight charges. Even though it is not always possible, perishable, high-value products may select air transport over sea transport because the value of the product can absorb the cost of typically higher air freight.[6] Time sensitive products, such as FMCG, are also more likely to select air transport over sea transport in order to meet their supply chain delivery deadlines

1.4 Slow Steaming Analysis Model

For this study, noting that each APEC member economy has its own specific trading partners, commodities, ship characteristics, and routes and that slow steaming potential benefits and impacts are specific to those combinations, the approach taken was to create a Slow Steaming Analysis (SSA) Model. The SSA Model consists of two modules: Module 1 – GHG Impacts (Module 1) and Module 2 – Economic Impacts (Module 2). The two modules allow users to input various distances, speeds, ship sizes for two class (container and bulk ships), and ship physical and operational characteristics to estimate across distances and fleets the potential impacts from slow steaming. The impacts from Module 1, for each ship type, size, and distance combination are: additional sailing time, additional ship population requirements, and percent change in carbon dioxide equivalent (CO_2e). Data and results are then transferred by the use to Module 2 where user input on variables used to determine the economic impact in Module 2 are: cargo time delay, gross domestic product (GDP) impact, interest cost, depreciation cost, and insurance cost.

The model was developed using Microsoft Excel so it could be easily used by a wide range of users. An illustration of the SSA Model and its two modules is presented in the figure below.

Figure 3: SSA Model Illustration



Each member economy can run its own specific combinations of the variables in each module to evaluate how the specified fleet scenario performs over a range of reduced speeds to determine what the GHG emission and economic impacts are. Module 1 is further discussed in Section 4 and Appendix B. Module 2 is further discussed in Section 3.

2.0 APEC ECONOMIC AND TRADE HIGHLIGHTS

Due to its length, a portion of this section is included in Appendix A. Appendix A summarizes the high-level macroeconomic profile of individual APEC economies, as well as the trade patterns among them. The analysis was used as a guide to identify and select the subject trade flows, the representative distances and the product categories moving on the selected trades for container and dry bulk vessels.

2.1 Distances

In general terms, all APEC economies trade a large amount of their exports with nearby economies; the data show for Asia, Far East Asia and North America, more than 50% of their trade (exports) is shipped to a nearby economy or region.

However, more than 50% of the Oceania and South America exports have Asia and Far East Asia, a long-distance trade, as their main destinations. The information developed in this section has been used to identify a total of nine (9) representative Intra-APEC long distance trade partners, based on the percentage of their trade with other long distance economies.

In percentage terms, economies with the largest share of long-distance trade exports are listed in the following table. The table lists the exporting economies, regional destination block, Intra-APEC trade share with that region, the main economy of destination in the block, and the share of Intra-APEC exports to that destination economy.

Table 1: Largest Long-Distance Export Trade, by Value USD$, Year 2017

Origin Economy – Exporter	Destination Block	Destination Block Share	Main Destination Economy	Economy Share
Australia	Asia	68%	China	59%
Peru	Asia	61%	China	58%
Chile	Asia	49%	China	46%
Russia	North America	36%	United States	26%
Indonesia	North America	22%	United States	20%
Japan	North America	22%	United States	19%
China	North America	30%	United States	17%
Viet Nam	North America	51%	United States	17%
USA	Asia	27%	China	15%

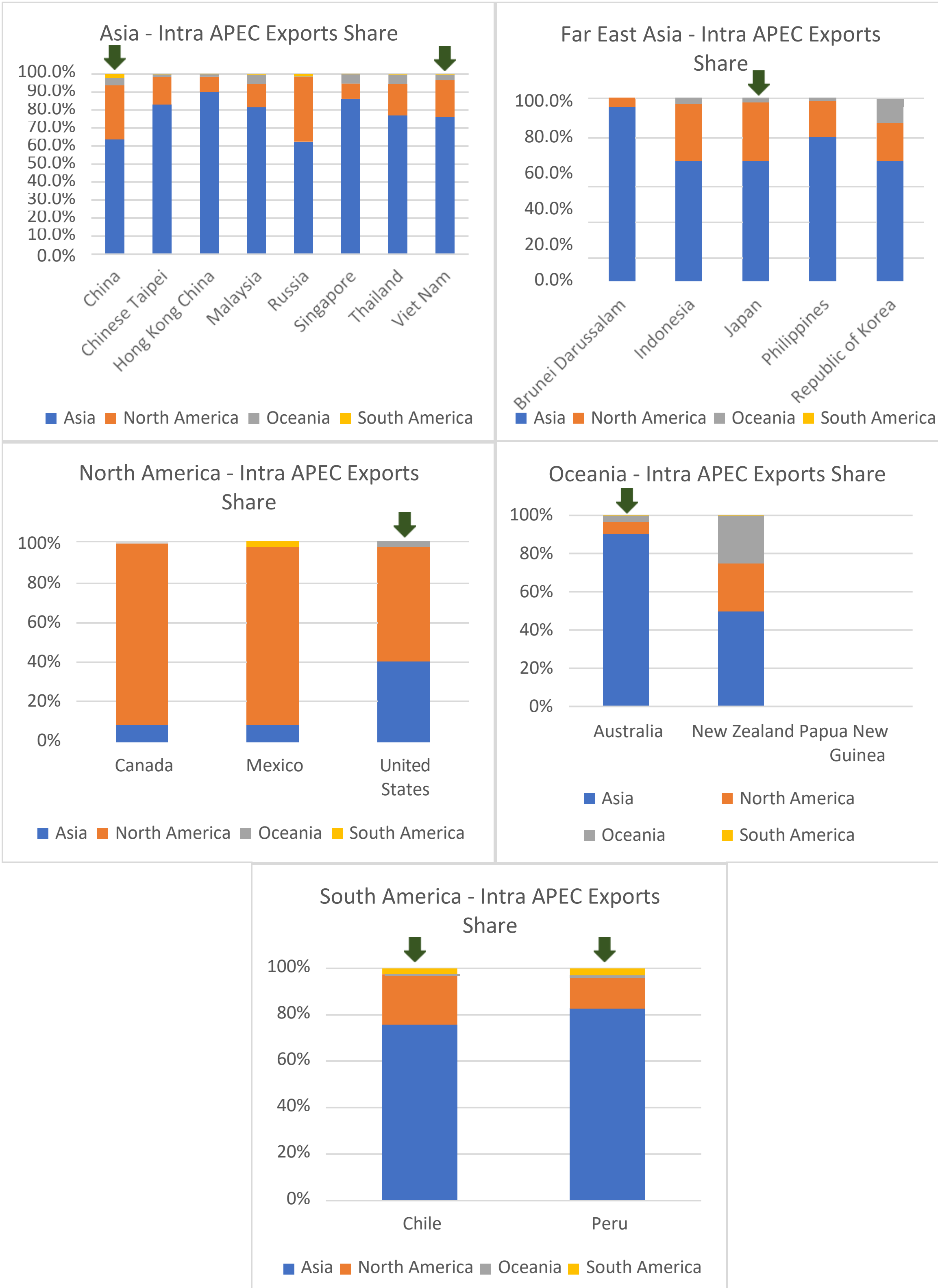
Source: developed by the consultant from UN, The World Bank, and data from APEC economies

To measure the potential economic impact of slow steaming, the nine trade flows listed in Table 1 were selected using the following three criteria:

a) Intra-APEC trade flow only
b) Origin economy within one of the APEC blocks (3 from Asia, 2 South America, 2 Far East Asia, 1 North America, and 1 Oceania),
c) Export share of the origin economy represents a relevant percentage of total Intra-APEC export share to the destination regional block and economy.

The following graphs show all APEC exporting economies and their Intra-APEC regional destination block share. The arrows on each graph represent those economies trading a considerable percentage of their international trade with long-distance economies. In that sense, the following trades were selected: a) China, that trades with the American continent 32% of its total exports; b) Viet Nam, sharing 20.7% of its total exports with the American Continent; c) Japan, exporting 22.2% of its total trade to the American Continent; d) The United States (USA), exporting 42.8% of its trade to Asian economies; e) Australia, exporting 90.1% of its international trade to Asian economies; f) Chile, exporting 75.6% of its international trade to Asia; and g) Peru, exporting to Asia 82.7% of its international trade. A complete explanation of the outcomes in Figure 4 is included in Appendix A.

Figure 4: Intra-APEC Economies Export Destinations Share by Regional Block, Year 2017



2.2 Intra-APEC Vessel Traffic Flows

Once the nine long-distance Intra-APEC trade flows were identified, it was determined which ones would be part of the economic analysis based on recent actual trade flows and the main commodities traded between them, for both containerized and dry bulk vessels.

In the case of container vessels, the selection of trade flows also depended on current liner shipping services between selected ports and economies. As a result of these considerations, three dry bulk trade routes and six containerized cargo trades were selected, shown in the following tables.

Table 2: Container Vessels: Selected Trade Flows and Cargoes, December 2017

Origin Economy	Port of Origin	Destination Economy	Port of Destination	Product	Category	FOB Value	Weight	Value Kg
Australia	Melbourne	China	Shanghai	Fresh or chilled boneless bovine meat	Perishable	$8,716	1 254	$6.95
Chile	San Antonio	China	Shanghai	Cherries	Perishable	$26,414	11 760	$2.25
Japan	Tokyo	USA	Los Angeles	Machines for Man. Semiconductor Devices/elec	High value	$695,456	18 000	$38.64
China	Shanghai	USA	Los Angeles	Memories, Electronic integrated circuits	Consumer goods	$117,724	8 187	$14.38
Viet Nam	Ho Chi Minh City	USA	Los Angeles	Furniture nesoi[7] and parts	Consumer goods	$144,127	8 791	$16.39
USA	Los Angeles	China	Shanghai	Waste and Scrap paper	Low value	$560	18 662	$0.03

Source: Datamyne

In the case of dry bulk carriers working in tramp service, the economic and environmental impact analyses assume only one-way traffic flow, meaning from the exporting economy to the destination economy; this is the laden leg of the trip. The impact of a new charter or a redeployment of the vessel once ballast at the destination was not evaluated. In the case of containerized cargo, economic analysis was performed considering service rotation in order to analyze distance and economic impact of slow steaming in accordance with the service route including intermediate port calls.

Table 3: Dry Bulk Vessels: Selected Trade Flows and Cargoes, March 2017

Origin Economy	Port of Origin	Destination Economy	Port of Destination	Product	Parcel size - tons	Rate	Measure	Price USD$/ton
Australia	Dampier	China	Qingdao	Iron ore	170 000	$5.38	USD$/ton	$92.91
Peru	Matarani	China	Shanghai	Copper ore	41 748	$6,000.00	USD$/day	$5,798.15
USA	Tacoma	China	North China	Soybean	60 000	$22.52	USD$/ton	$669.94

Source: prepared by the consultant from Shanghai Shipping Exchange, Market Index, Infomine, The World Bank

2.3 Vessel Characteristics

The characteristics for dry bulk and container vessel used in this analysis are summarized below.

2.3.1 Dry Bulk Cargo Vessels

Three trade flows were selected for dry bulk vessels; one from Oceania, one from South America and one from North America, all of them to Asia as a final, long-distance destination. Below is the description of each trade route and the corresponding vessel characteristics. These data represent existing services and typical dry bulk ship characteristics on each route.

Table 4: Dry Bulk Vessels Characteristics

Port of Origin	Port of Destination	Vessel Size	Name of Ship	IMO	DWT	LOA	Beam	Draft	Speed Max	Speed Avg
Dampier	Qingdao	Capesize	Cotswold	9729180	179 611	292	45	9	12	11
Matarani	Shanghai	Handymax	West Treasure	9691620	61 292	200	32	6	14	13
Tacoma	North China	Panamax	Bulk Holland	9746700	81 712	229	32	9	13	12

Source: *www.Marinetraffic.com*

2.3.2 Container Vessels

In the case of container shipping, there are three ocean carrier shipping alliances controlling nearly 80% of global trade and almost 90% of vessel carrying capacity. These alliances are:

- 2M Alliance: Maersk, MSC, Hyundai Merchant Marine and Hamburg Sud
- Ocean Alliance: CMA CGM, Cosco, OOCL, APL and Evergreen
- The Alliance: ONE, Hapag Lloyd, Hyundai Merchant Marine and Yang Ming[8]

The three alliances deploy almost the same number of services in the transpacific, each with similar characteristics regarding vessel size, number of vessels, weekly frequency and rotation. There are mainly two trading patterns, from Asia to North America and from Asia to Latin America. A search into the main shipping alliance members' web pages was conducted and it was found that CMA CGM, as well as Ocean Alliance members, offers a complete description of their services including a graphical representation of the trade lane, service characteristics, ports of call, number of vessels deployed, duration of the complete voyage (service rotation), and detailed characteristics of each vessel, and therefore it was decided to use them as reference. Below is a description of the various services selected for the economic impact analysis. The information is taken from shipping lines' webpages in April 2019, including vessel names and characteristics, port rotation, service duration, and average speed.

1) Melbourne, Australia to Shanghai, China:[9]

Table 5, Table 6 and Figure 5 present characteristics of the China Australia Service 3 (CA3), a joint service where ONE, APL, Evergreen, Hapag Lloyd and Yang Ming Lines deploy and share six vessels in total. As presented in the following trade, transporting goods in CA3 service, from Melbourne, Australia to Shanghai, China is not a direct route. The vessel calls to the ports of Sydney, Brisbane, Yokohama, Osaka, Busan and Qingdao, prior to arrival at the cargo final destination which implies a total of 6,660 nautical miles (nm).

Table 5: China Australia Service 3 (CA3) Characteristics

Service Name	Economies Served	Ports of Call	Port Rotation	Service Duration	Frequency	Number of Vessels
China Australia Service 3 (CA3)	Japan; Republic of Korea; China and Australia	9	Yokohama (0), Osaka (1), Busan (3), Qingdao (5), Shanghai (8), Ningbo (10), Melbourne (23), Sydney (26), Brisbane (29), Yokohama (41)	42 days	Weekly	6

Source: *www.apl.com/products-services/line-services/flyer/CA3APL*

Figure 5: CA3 Service Rotation

Source: *www.apl.com/products-services/line-services/flyer/CA3APL*

Table 6: Vessel Characteristics for Melbourne, Australia to Shanghai, China

Vessel Name	Operator	Type	Geared	Nominal Capacity	Reefer Plugs	Dwt	Built	Flag	Design Speed
BROOKLYN BRIDGE	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	4 432	300	52 055	2010	PANAMA	24
CMA CGM EIFFEL	APL CO PTE LTD	CC	N	4 404	400	58 334	2002	MALTA	25
ITAL LIBERA	EVERGREEN MARINE CORPORATION LTD	CC	N	5 090	454	67 986	2006	ITALY	22
ITAL LIRICA	EVERGREEN MARINE CORPORATION LTD	CC	N	5 090	550	68 138	2007	ITALY	23
SC MARA	HAPAG LLOYD	CC	N	5 060	454	68 164	2006	MARSHALL ISLANDS	26
YM SEATTLE	YANG MING LINES	CC	N	4 253	400	50 500	2007	CYPRUS	25

Source: *www.apl.com/products-services/line-services/flyer/CA3APL*

2) San Antonio, Chile to Shanghai, China:[10]

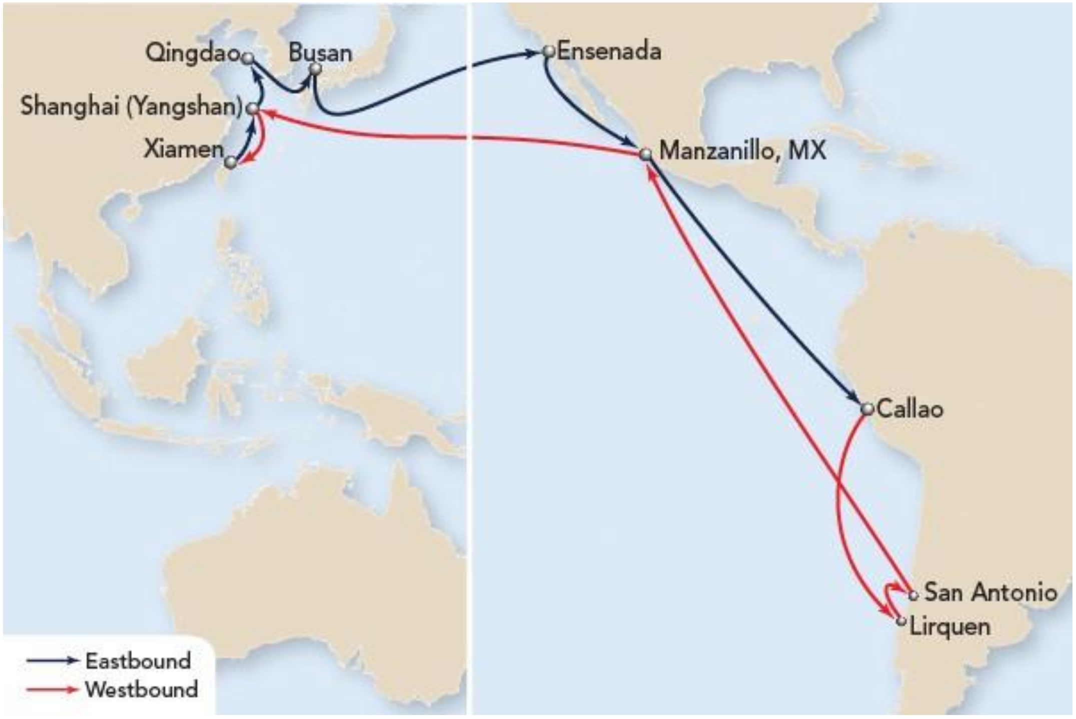
The Falcon Express (FCX) was selected for the economic impact analysis in this trade route, where 11 vessels are deployed by Cosco Line. Shipping cherries in the Falcon Express service means that the vessel will call first to the port of Manzanillo, Mexico before reaching the final destination for the cargo with a total distance of 10,531 nm.

Table 7: Falcon Express (FCX) Characteristics

Service Name	Economies Served	Ports of Call	Port Rotation	Service Duration	Frequency	Number of Vessels
Falcon Express (FCX)	China; Republic of Korea; Mexico; Peru and Chile	11	Xiamen (0), Shanghai (1), Qingdao (4), Busan (7), Ensenada (21), Manzanillo (27), Callao (34), Lirquen (39), San Antonio (41), Manzanillo (52), Shanghai (72), Xiamen (76)	77 days	Weekly	11

Source: *www.apl.com/products-services/line-services/flyer/ACSA2*

Figure 6: Falcon Express (FCX) Service Rotation



Source: *www.apl.com/products-services/line-services/flyer/ACSA2*

Table 8: Vessel Characteristics for San Antonio, Chile to Shanghai, China

Vessel Name	Operator	Type	Geared	Nominal Capacity	Reefer Plugs	Dwt	Built	Flag	Design Speed
COSCO HELLAS	COSCO SHIPPING LINES CO LTD	CC	N	9 469	1034	107 277	2006	GREECE	25
COSCO KOREA	COSCO SHIPPING LINES CO LTD	CC	N	8 501	700	102 336	2010	HONG KONG, CHINA	26
COSCO MALAYSIA	COSCO SHIPPING LINES CO LTD	CC	N	8 501	700	102 796	2010	HONG KONG, CHINA	26
CSCL LONG BEACH	COSCO SHIPPING LINES CO LTD	CC	N	9 572	700	111 737	2007	HONG KONG, CHINA	25
E.R. TEXAS	COSCO SHIPPING LINES CO LTD	CC	N	8 533	700	100 800	2006	LIBERIA	25
KURE	COSCO SHIPPING LINES CO LTD	CC	N	7 403	703	90 456	1996	LIBERIA	25
LLOYD DON PASCUALE	COSCO SHIPPING LINES CO LTD	CC	N	8 533	700	100 800	2007	LIBERIA	25
XIN OU ZHOU	COSCO SHIPPING LINES CO LTD	CC	N	8 488	700	101 530	2007	CHINA	25
XIN PU DONG	COSCO SHIPPING LINES CO LTD	CC	N	5 668	610	68 303	2003	CHINA	26
XIN QIN HUANG DAO	COSCO SHIPPING LINES CO LTD	CC	N	5 688	610	69 308	2004	CHINA	26
XIN YA ZHOU	COSCO SHIPPING LINES CO LTD	CC	N	8 533	700	102 396	2007	CHINA	24

Source: *www.apl.com/products-services/line-services/flyer/ACSA2*

3) Tokyo, Japan to Los Angeles, United States:[11]

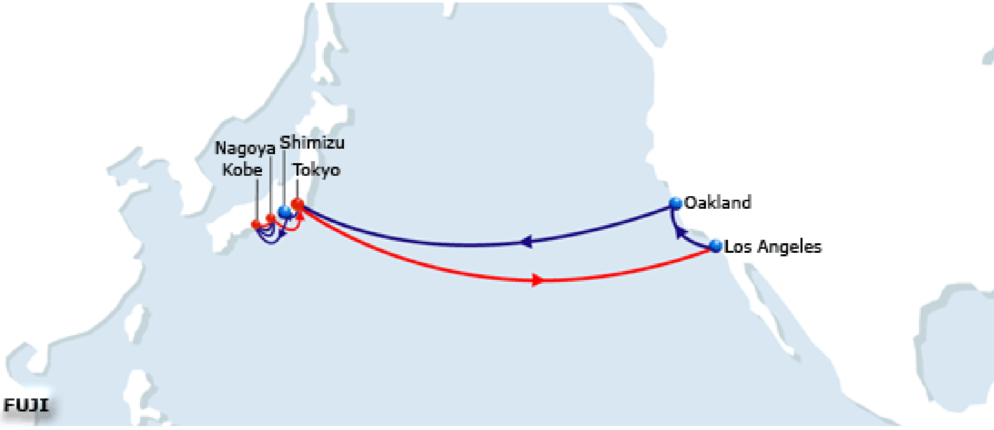
To analyze the economic impact on this trade route, the Fuji Service was selected for which ONE has deployed 15 vessels to provide a weekly service. In the case of this service, the vessel sails directly from the port of Tokyo to the port of Los Angeles, a 4,854 nm distance.

Table 9: Fuji Service Characteristics

Service Name	Economies Served	Ports of Call	Port Rotation	Service Duration	Frequency	Number of Vessels
Fuji Service	Japan and West Coast of United States	9	Kobe (0), Nagoya (1), Tokyo (2), Los Angeles (15), Oakland (21), Tokyo (33), Shimizu (34), Kobe (35), Nagoya (36), Kobe (38)	39 days	Weekly	15

Source: *www.cma-cgm.com/products-services/line-services/flyer/FUJI*

Figure 7: Fuji Service Rotation



Source: *www.cma-cgm.com/products-services/line-services/flyer/FUJI*

Table 10: Vessel Characteristics for Tokyo, Japan to Los Angeles, United States

Vessel Name	Operator	Type	Geared	Nominal Capacity	Reefer Plugs	Dwt	Built	Flag	Design Speed
HAMBURG BRIDGE	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	8 212	800	98 849	2009	PANAMA	25
HARBOUR BRIDGE	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	8 212	800	99 214	2007	PANAMA	25
HENRY HUDSON BRIDGE	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	8 212	800	99 214	2008	PANAMA	25
HUMBER BRIDGE	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	8 212	800	99 214	2006	PANAMA	25
NYK OCEANUS	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	8 628	784	99 563	2007	PANAMA	21
NYK ORION	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	8 628	784	99 563	2008	PANAMA	21
NYK ORPHEUS	NYK NIPPON YUSEN KABUSHIKI KAISHA	CC	N	8 628	784	99 563	2008	JAPAN	25
NYK VEGA	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	9 012	800	103 300	2006	PANAMA	21
NYK VESTA	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	9 012	800	103 300	2007	PANAMA	21
NYK VIRGO	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	9 012	800	103 300	2007	SINGAPORE	21
ONE HAMMERSMITH	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	8 212	800	98 849	2009	PANAMA	25
ONE HANNOVER	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	8 212	800	99 214	2006	PANAMA	25
ONE OLYMPUS	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N	8 628	784	99 563	2008	SINGAPORE	21
ONE TBN 1	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N		1 000				
ONE TBN 2	OCEAN NETWORK EXPRESS PTE. LTD.	CC	N		1 000				

Source: *www.cma-cgm.com/products-services/line-services/flyer/FUJI*

4) Shanghai, China to the United States:[12]

The Hangzhou Bay Bridge Service, provided by Evergreen, was selected to develop the economic impact analysis of slow steaming in this trade route. This service calls to the port of Ningbo before arriving at the port of Los Angeles with a total distance for the trip being 5,781 nm.

Table 11: Hangzhou Bay Bridge Service Characteristics

Service Name	Economies Served	Ports of Call	Port Rotation	Service Duration	Frequency	Number of Vessels
Hangzhou Bay Bridge	Japan; China and West Coast of United States	6	Qingdao (0), Shanghai (1), Ningbo (3), Los Angeles (18), Oakland (23), Tokyo (37), Qingdao (41)	42 days	Weekly	6

Source: *www.cma-cgm.com/products-services/line-services/flyer/HBB*

Figure 8: Hangzhou Bay Bridge Service Rotation

Source: *www.cma-cgm.com/products-services/line-services/flyer/HBB*

Table 12: Vessel Characteristics for Shanghai, China to the United States

Vessel Name	Operator	Type	Geared	Nominal Capacity	Reefer Plugs	Dwt	Built	Flag	Design Speed
EVER LENIENT	EVERGREEN MARINE CORPORATION LTD	CC	N	8 452	942	95 516	2014	UNITED KINGDOM	25
EVER LIBRA	EVERGREEN MARINE CORPORATION LTD	CC	N	8 452	942	104 471	2012	CHINESE TAIPEI	25
EVER LOGIC	EVERGREEN MARINE CORPORATION LTD	CC	N	8 452	942	105 000	2013	CHINESE TAIPEI	25
EVER LOVELY	EVERGREEN MARINE CORPORATION LTD	CC	N	8 508	948	104 357	2015	SINGAPORE	25
EVER LUCENT	EVERGREEN MARINE CORPORATION LTD	CC	N	8 508	942	104 100	2014	SINGAPORE	25
NAVARINO	EVERGREEN MARINE CORPORATION LTD	CC	N	8 533	700	102 303	2010	HONG KONG, CHINA	24

Source: *www.cma-cgm.com/products-services/line-services/flyer/HBB*

5) Vung Tau, Viet Nam to Long Beach, United States:[13]

The South China Sea Service, deploying six OOCL vessels was selected to conduct the economic impact analysis of slow steaming on furniture's from Viet Nam to the United States. The South China Sea Service calls to the ports of Hong Kong, China; Yantian, and Kaohsiung before reaching the port of Long Beach for a total of 9,257 nm.

Table 13: South China Sea Service Characteristics

Service Name	Economies Served	Ports of Call	Port Rotation	Service Duration	Frequency	Number of Vessels
South China Sea	Viet Nam; China; Hong Kong, China; Chinese Taipei and United States	6	Vung Tao (0), Honk Kong (3), Yantian (3), Kaohsiung (5), Long Beach (19), Kaohsiung (38) and Vung Tau (41)	42 days	Weekly	6

Source: *www.cma-cgm.com/products-services/line-services/flyer/SCS*

Figure 9: South China Sea Service Rotation

Source: *www.cma-cgm.com/products-services/line-services/flyer/SCS*

Table 14: Vessel Characteristics for Vung Tau, Viet Nam to Long Beach, United States

Vessel Name	Operator	Type	Geared	Nominal Capacity	Reefer Plugs	Dwt	Built	Flag	Design Speed
OOCL BEIJING	ORIENT OVERSEAS CONTAINER LINE.	CC	N	8 888	700	101 589	2011	HONG KONG, CHINA	25
OOCL GENOA	ORIENT OVERSEAS CONTAINER LINE.	CC	N	8 825	700	101 589	2015	HONG KONG, CHINA	26
OOCL HO CHI MINH CITY	ORIENT OVERSEAS CONTAINER LINE.	CC	N	8 888	700	101 047	2015	HONG KONG, CHINA	23
OOCL MEMPHIS	ORIENT OVERSEAS CONTAINER LINE.	CC	N	8 888	700	101 544	2013	HONG KONG, CHINA	24
OOCL MIAMI	ORIENT OVERSEAS CONTAINER LINE.	CC	N	8 825	700	101 589	2013	HONG KONG, CHINA	26
OOCL T.	ORIENT OVERSEAS CONTAINER LINE.	CC	N	8 825	700	101 589	2015	HONG KONG, CHINA	26

Source: *www.cma-cgm.com/products-services/line-services/flyer/SCS*

6) Los Angeles, United States to Shanghai, China:[14]

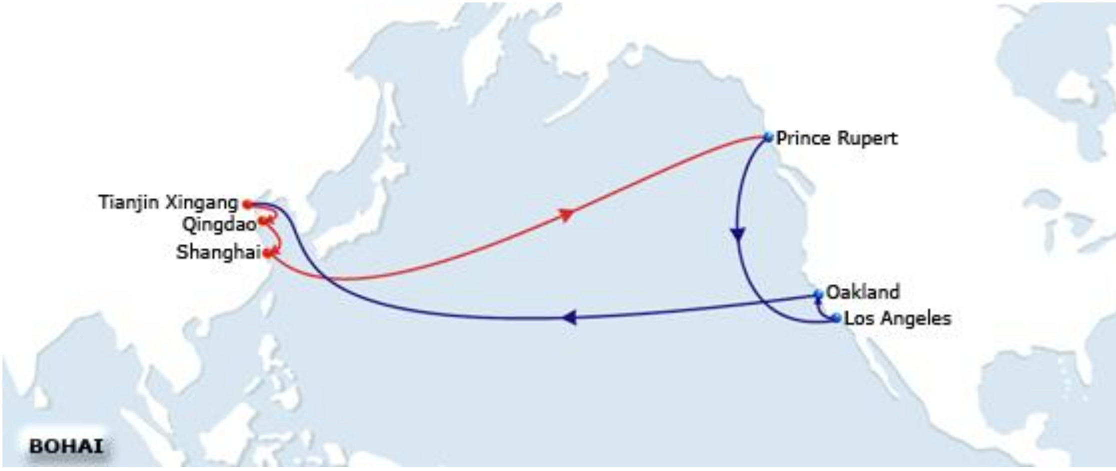
The selection for the economic impact analysis of slow steaming on this trade route is the Bohai Service, deploying seven Cosco vessels. Tables 15 and 16 present the characteristics of this trade route. The Bohai Service calls three ports (Oakland, Tianjin, and Qingdao) before arriving to the port of Shanghai for a total distance of 6,668 nm.

Table 15: Bohai Service Characteristics

Service Name	Economies Served	Ports of Call	Port Rotation	Service Duration	Frequency	Number of Vessels
Bohai	China; United States and Canada	6	Tianjin (0), Qingdao (1), Shanghai (4), Prince Rupert (16), Los Angeles (23), Oakland (29), Tianjin (47)	49 days	Weekly	7

Source: *www.cma-cgm.com/products-services/line-services/flyer/BOHAI*

Figure 10: Bohai Sea Service Rotation



Source: *www.cma-cgm.com/products-services/line-services/flyer/BOHAI*

Table 16: Vessel Characteristics for Los Angeles, United States to Shanghai, China

Vessel Name	Operator	Type	Geared	Nominal Capacity	Reefer Plugs	Dwt	Built	Flag	Design Speed
COS TBN 2	COSCO SHIPPING LINES CO LTD	CC	N		1 000				
COSCO GLORY	COSCO SHIPPING LINES CO LTD	CC	N	13 114	800	140 637	2011	HONG KONG, CHINA	25
COSCO SPAIN	COSCO SHIPPING LINES CO LTD	CC	N	13 386	1 008	156 572	2013	HONG KONG, CHINA	24
CSCL BOHAI SEA	COSCO SHIPPING LINES CO LTD	CC	N	10 036	700	121 824	2014	HONG KONG, CHINA	24
CSCL EAST CHINA SEA	COSCO SHIPPING LINES CO LTD	CC	N	10 036	700	121 185	2014	HONG KONG, CHINA	24
CSCL SPRING	COSCO SHIPPING LINES CO LTD	CC	N	10 036	700	121 849	2014	HONG KONG, CHINA	24
CSCL WINTER	COSCO SHIPPING LINES CO LTD	CC	N	10 036	700	121 805	2014	HONG KONG, CHINA	24

Source: *www.cma-cgm.com/products-services/line-services/flyer/BOHAI*

3.0 ECONOMIC IMPACT FOR DISTANT ECONOMIES

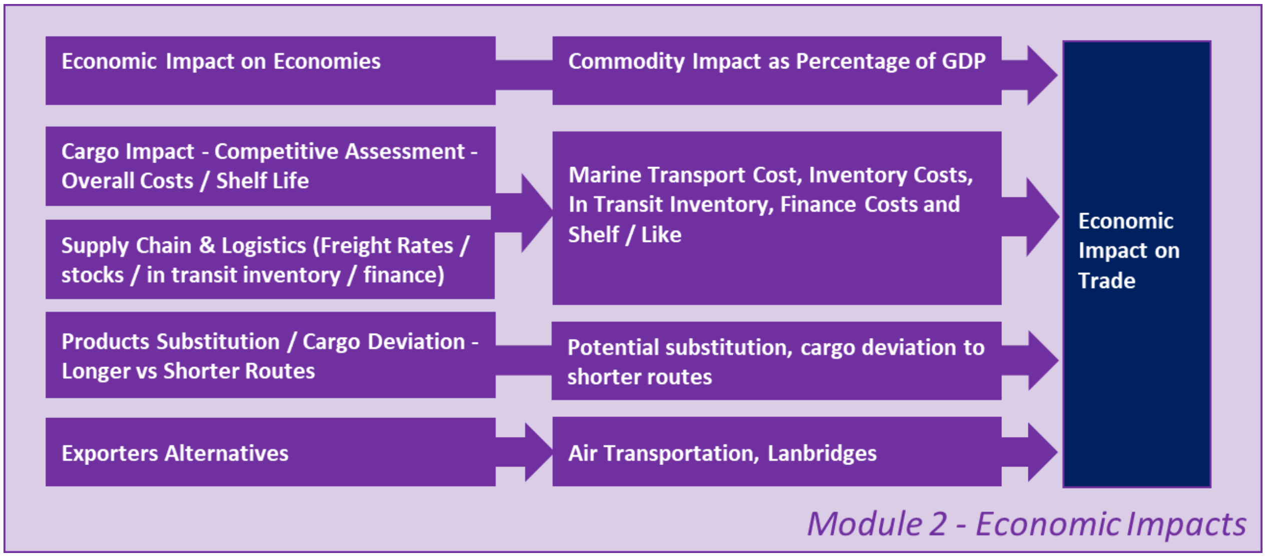
3.1 Introduction

The objective of this part of the economic portion of the study is to provide APEC economies with information on the economic impacts that a mandatory reduction on vessel´s speed could have for distant economies, addressing the problem from a shipper's/trade point of view. Therefore, the economic impact analysis focuses mainly on the cargo effects and the implications for shippers who initiate the exports of goods to distant economies.

The approach in developing this impact analysis considers slow steaming as a norm across the shipping industry and does not consider the higher cost of cleaner fuel that will be come into force 1 January 2020. The limit for sulfur in fuel oil used on board ships operating outside designated emissions control areas will be reduced to 0.5%.[15] The economic impact approach assumes that the proposed IMO slow steaming strategy, if implemented, will apply to the entire global maritime shipping community. This study concentrates on identifying and estimating the impact of the vessel speed reduction from the export port of origin to the arrival at the final import port of destination. The environmental emission analysis section (Section 4.0) elaborates on the slow steaming assumptions. The two models (environmental and economic) were developed based on these assumptions with a range of 10 different speed reduction scenarios.

For the purpose of this analysis, the shipper is the exporter, the one who sells products in the international market to a client abroad (consignee). For each vessel type and cargo category, quantitative and qualitative analysis was conducted to determine the economic impact. The structure of the SSA Model, Module 2 – Economic Impacts is illustrated in Figure 11 on the next page.

Figure 11: SSA Model, Module 2 – Economic Impacts Illustration



This economic impact analysis is based on total annual trade (full year volume) between the long-distance economies' pairs (export and import economies), in both total volume in kilos and value in US Dollars for the year 2017. As total supply chain logistics will have to adapt to the delivery time delay after slow steaming, and in all cases the total number of days is less than 22 days, at 10 knots for container vessels, the assumption is that the total volume of yearly trade will not increase simply because of slow steaming.[16]

Intra-APEC long distance trade has a limited number of alternatives. Due to geography, options to transport cargo are either by sea, by air or a combination of both. There are not rail or road connections or corridors; for example, from Chile to China, or from Chile to Canada, Mexico or the United States. Sea transportation is the preferred and most economical mode of transportation for large cargo volumes; exporters and importers have accommodated their supply chain to the ocean transportation transit time.

There is no evidence of modal shift when slow steaming was employed in 2008 and thereafter. A reduction of speed in the dry bulk cargo segment will not impact the current supply chain of the products under analysis, since the range speed differential is only 2 knots, from 12 knots (GSA) to 10 knots (GSA-10) and there is no product deterioration.

In the case of containerized cargo, the economic impact assessment was based on two ranges of vessel speed scenarios; a speed High Baseline Speed Scenario that ranges from 20.0 knots to 10.0 knots and a 2012 Global Average Speed Scenario that ranges from 16.3 knots to 10 knots for container ships, based on their size. Further information on the scenarios is provided in Section 4.4.

Data supporting this economic analysis and model come from different sources: service line information, including vessels' characteristics and transit times, as well as port rotation, from current services' web pages; cargo volume from the United Nations Comtrade web page; bulk cargo parcel size, and rates from Shanghai Shipping Exchange; price per ton for dry bulk cargo from the Market Index web page, InfoMine web page, and the YCharts web page. In the case of containers, Free on Board (FOB) value and weight is sourced from Descartes Datamyne; GDP data from The World Bank web page.

As explained previously, the slow steaming economic model captures only ocean transit or time differentials caused by slow steaming; no impact on the vessel or ship owner, or on inland transportation or warehousing is considered. The analysis is based on actual maritime distances for liners and bulk carriers, average vessel speed and a range of slow steaming speed options to calculate the impact of delay on annual cargo trade. Shippers' costs include interest or financial cargo cost, cargo depreciation cost, and insurance costs. Current values for different commodities are sourced from the UN Comtrade database. Inland costs are not impacted due to slow steaming although shippers might increase the level of inventory to maintain the reliability of their supply chains.

The economic analysis does not capture price volatility throughout the year. In order to capture the impact on fresh perishable goods due to obsolescence, the depreciation rate is set at 30%. This depreciation percentage is completely variable and can be set by the model user. The dry bulk depreciation rate has been set at 5%, which can also be changed by the model user.

If shippers choose to increase inventories to accommodate slow steaming and longer supply chains, it is assumed that this inventory is used solely as an adjustment for the longer delivery time and does not represent any increase in demand for the commodity in question.

Variables used to measure the economic impact of slow steaming are:

- **Time delay**: number of hours or days that slow steaming will delay the cargo arrival at the destination port compared with current vessel speed.
- **GDP impact**: the product exports are measured as an impact on total economy Gross Domestic Product (GDP). In order to measure the relative importance of the product category under analysis, the study also compares the impact in its sector category of GDP. The World Bank website has been used as the source of information for total economy GDP and GDP sectors: a) agriculture, forestry and fishing, b) industry (including construction), c) manufacturing, and d) services.
- **Interest cost**: the financial cost of capital invested in inventory over time. This measures the impact of each hour or day of delay in the cost of the product due to cost of money or interest rate (here assumed to be 5%).

- **Depreciation cost**: the cost allocation of a product, or reduction of the product value, over its useful life (for this economic analysis, it is assumed as 10% for containerized cargo that is non-perishable, 30% for perishable cargo, and 5% for dry bulk cargo).
- **Insurance cost**: a cost paid by the shippers to protect their goods while in transit (the percentage used in the economic analysis is 2%).

SSA Model, Module 2 – Economic Impacts, allows the user to input the following variables: time delay will change by modifying vessel speed; GDP impact may be updated when data are available; commodity may be changed, as well as the information related to it; interest, depreciation and insurance costs are adapted for each case to reflect, for example, the impact of perishable goods with a higher depreciation rate and the bulk cargo with a lower rate. This is an input that can be changed by the economic model user as needed.

For each of the selected commodities or product categories, the total amount of cargo in terms of volume (kilograms) and trade value was obtained from United Nations (UN), Department of Economic and Social Affairs. The impact of the commodity exports was compared to the export economy GDP and the commodity export value as a percentage of current GDP (2017) was also obtained.

The interest, depreciation and insurance cost estimates were developed by multiplying the rates for each of the three cost items by the total amount of products/commodities exported that year (2017) to each economy of destination, then divided by 365.25 days per year to obtain the daily cost during the transit or during any extra voyage days due to slow steaming.[17]

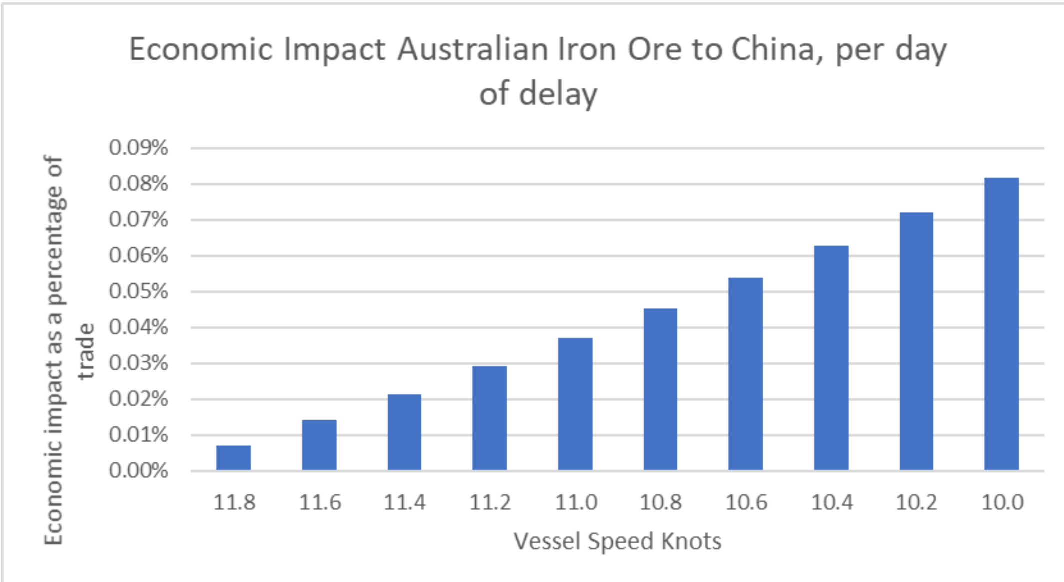
3.2 Dry Bulk Vessels

The three trade flows selected for dry bulk vessels are discussed below. The trade flows include one from Oceania (Australia), one from South America (Peru) and one from North America (The United States). All three trade flows have Asia as the final destination. Global Speed Average (GSA) ranges used for dry bulk cargos are closer to the current market situation.

A. Iron Ore from Australia to China

Australia is China's largest source of iron ore representing 60.78% of total import value in 2017. According to the UN Comtrade database, Australia's total iron ore exports to China, in the year 2017, amounted to 689.1 billion kilograms and a total value of USD$39.8 billion or 3.01% of Australia's GDP, or 12.7% of the Australian industry sector GDP. The economic impacts associated with the High Baseline Speed Scenario were evaluated from a range of 12.0 knots to 10.0 knots for bulk ships. As a result of slowing, the total voyage time will increase by 0.21 to 2.49 transit days and the interest cost, depreciation and insurance will add from 0.01% to 0.08% per extra travel day for all iron ore exports from Australia to China in 2017.

Figure 12: Economic Impact as a Percentage of Trade Value: Iron Ore, Australia to China, High Baseline Speed Scenario



The above figure indicates that the economic impact per day of delay over 2017 Australian iron ore export trade value to China ranges from 0.01% per day, when reducing speed from 12 to 11.8 knots, or 0.08% per day of total value when reducing speed from 12 to 10 knots.

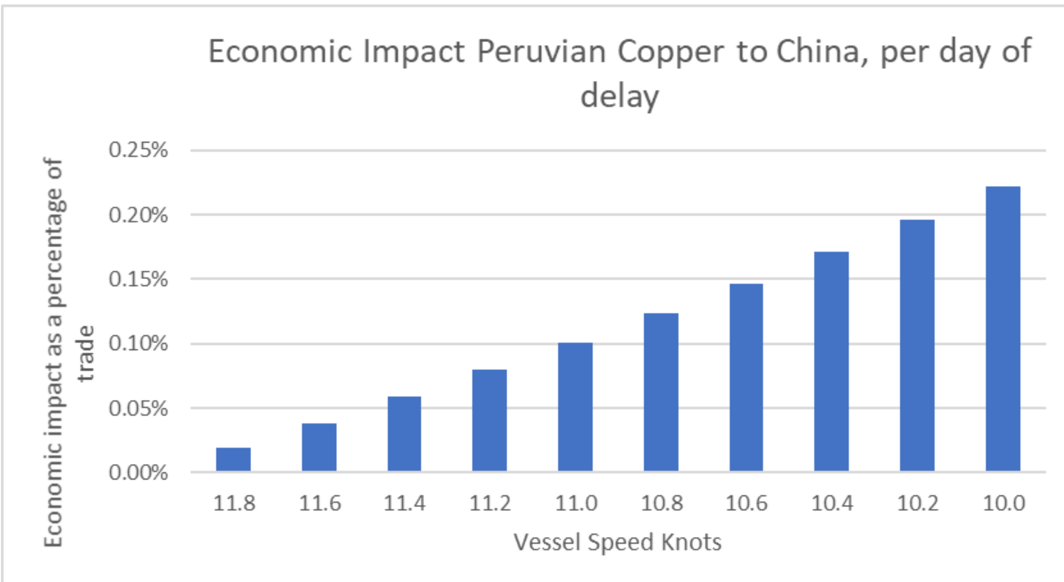
The economic impact model was also run using 2012 Global Average Speed Scenario. Total voyage time will increase by 0.20 to 2.17 transit days and the interest cost, depreciation and insurance will add from 0.01% to 0.07% per extra travel day for all iron ore exports from Australia to China in 2017.

There is no real impact on product shelf life and the likelihood of transporting from Australia by using other means of transportation is almost nonexistent. Other sources of iron ore for China are Brazil 22.70% of total imports in 2017, South Africa 4.61%, India 2.29%, Iran 1.82%. The top five trading partners represent 92.2% of total imports to China, in terms of value.

B. Copper ore from Peru to China

Peru's copper ore exports to China totaled 4.7 billion kilograms or a total of USD$7.2 billion, in the year 2017, which represented 3.39% of Peru's GDP for that year, or 10.9% of Peruvian industry sector GDP. Total delay by slow steaming, using the High Baseline Speed Scenario, from Matarani to Shanghai ranges from 0.57 to 6.76 additional transit days. A per-extra-day cost impact (interest, depreciation and insurance) ranges from 0.02% to 0.22% per extra travel day for copper exports from Peru to China in 2017.

Figure 13: Economic Impact as a Percentage of Trade Value: Copper Ore, Peru to China, High Baseline Speed Scenario



The above figure indicates that the economic impact per day of delay for 2017 Peruvian copper export trade value to China ranges from 0.02% per day, when reducing speed from 12 to 11.8 knots, or 0.22% per day of total value of yearly trade value when reducing speed from 12 to 10 knots.

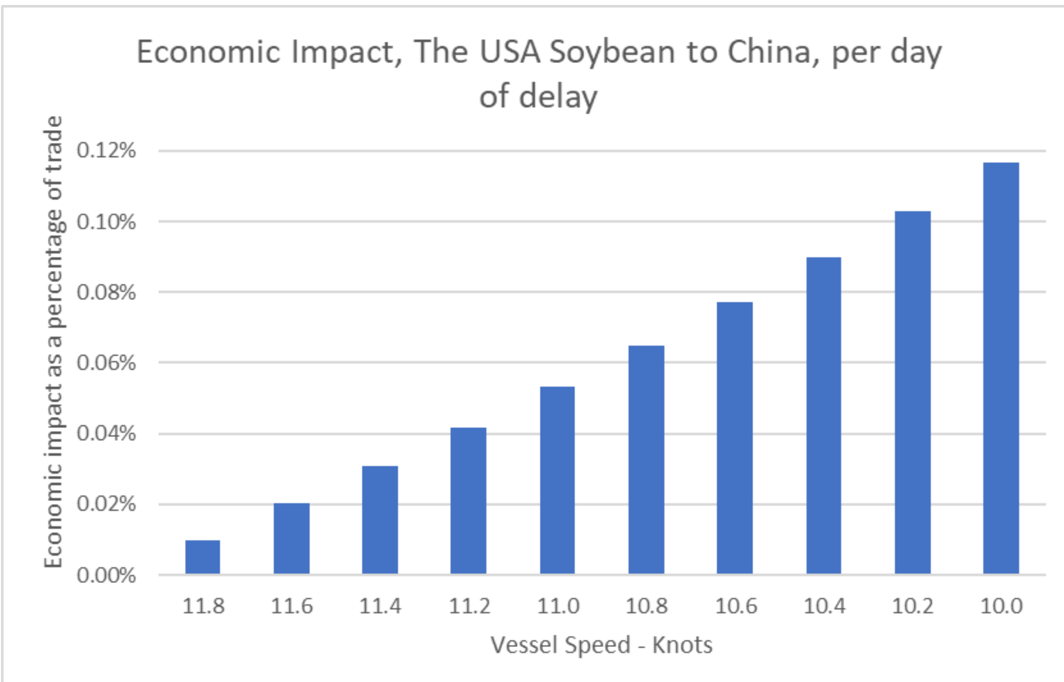
The economic impact model was also run using 2012 Global Average Speed Scenario. Total voyage time will increase by 0.53 to 6.19 transit days when comparing to the 10 incremental slow steaming speed assumptions used in the analysis. A per-extra-day cost impact (interest, depreciation and insurance) ranges from 0.02% to 0.20% per extra travel day.

There is no real impact on product shelf life; nevertheless, the option would be to rail or truck to neighboring economies, or to dispatch cargo by sea to closer destinations, which will not have the capacity to consume China's volume. Peru is the largest exporter of copper ore to China; its share in 2017 reached 29.93%, followed by Chile with 27.64%, Mongolia 6.22%, Mexico 5.33% and Australia 4.98%. The top five exporters account for 74.10% of China's total copper ore imports.

C. The United States grain to China

The United States (US) is the second largest exporter of soybeans to China, with 35.17% share. In the year 2017, a total of 35.9 billion kilograms of soybean were shipped to China, at a value of USD$14.2 billion, representing 0.063% of the United States GDP, or 6.97% of their agricultural sector GDP. Reducing the vessel speed from 12.0 to 10.0 knots using the High Baseline Speed Scenario, adds 0.30 to 3.55 transit days and in terms of interest, depreciation and insurance, this means an additional cost ranging from 0.01% to 0.12% per extra travel day for all the United States soybean exports to China that year.

Figure 14: Economic Impact as a Percentage of Trade Value: Grain, the United States to China, High Baseline Speed Scenario



The above figure indicates that the economic impact per day of delay over 2017 for the United States soybean export trade value to China ranges from 0.01% per day, when reducing speed from 12 to 11.8 knots, or 0.12% per day when reducing speed from 12 to 10 knots.

The economic impact model was also run using 2012 Global Average Speed Scenario. Total voyage time will increase from 0.28 to 3.25 transit days when comparing to the 10 incremental slow steaming speed assumptions used in the analysis. A per-extra-day cost impact (interest, depreciation and insurance) ranges from 0.01% to 0.11% per extra travel day.

The impact on soybean shelf life as a result of slow steaming is minimal. Sea transport is the only means to dispatch such cargo. Brazil is the largest exporter of soybeans to China with 52.77% share, Argentina 6.77%, Uruguay 2.6% and Canada 2.23%; the top five exporters are responsible for 99.54% of all soya imported by China.

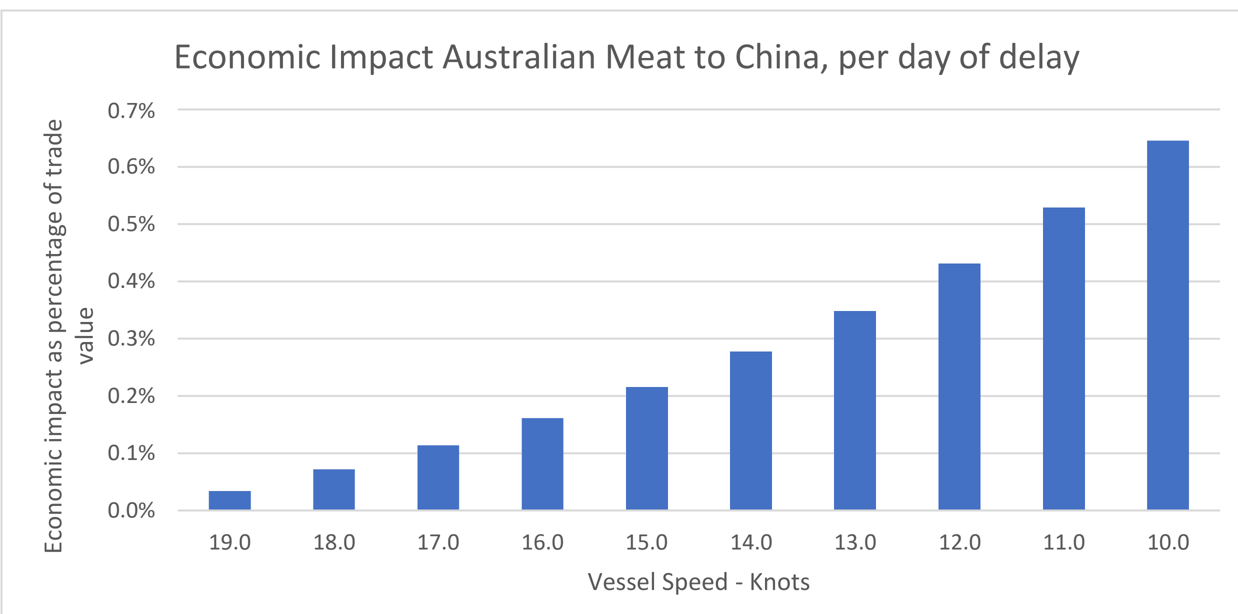
3.3 Container Vessels

The six trade flows selected for containerized cargo vessels include Australia to China, Chile to China, Japan to the United States, Shanghai to the United States, Viet Nam to the United States, and the United States to China. As mentioned before, super slow steaming for container vessels is defined in previous pages as 15 knots. Nevertheless, the Global Speed Average (GSA) range presented in the model goes to the extreme low case of 10 knots.

A. Australian meat to China

According to UN Comtrade data, there were only three “meat of bovine animals; fresh or chilled” exporters to China in 2017. Australia is the largest exporter with 89.65% share. Australia total exports to China in 2017 amounted to 6.0 million kilograms or USD$59.9 million worth of products. Meat, as a percentage of Australia GDP, represents 0.0045%, or 0.17% of its agriculture sector GDP. Reducing the vessel speed from 20.0 to 10.0 knots using the High Baseline Speed Scenario, will add 0.68 to 10.41 additional transit days on the CA3 service, and that will represent an additional cost ranging from 0.03% to 0.48% per extra travel day of delay for all Australian meat exported to China in 2017. At 15.0 knots, the time differential will be 4.00 days and 0.19% of additional cost per day.

Figure 15: Economic Impact as a Percentage of Trade Value: Meat, Australia to China, High Baseline Speed Scenario



The above figure indicates that the economic impact per day of delay over 2017 for Australian meat of bovine export trade value to China ranges from 0.03% per day, when reducing speed from 20 to 19 knots, or 0.65% per day of total value when reducing speed from 20 to 10 knots.

Evaluating the 2012 Global Average Speed Scenario the results are: slow steaming from 16.3 to 10.0 knots, will add 0.71 to 10.73 additional transit days on the CA3 service, and that will represent an additional cost ranging from 0.03% to 0.50% per extra travel day of delay for all Australian meat exported to China in 2017. At 15.0 knots, the time differential will be 1.48 days and 0.07% of additional cost per day.

Evaluating the High Baseline Speed Scenario, the total increase in the voyage transit time ranges from 0.68 to 10.41 days and the economic impact per day of delay ranges from 0.03% to 0.48%, which, when multiplied by the numbers of days, is an impact of 0.02% to 5.04% of total fresh or chilled boneless bovine meet exports for the year 2017. Under Average Speed IMO 2014 Scenario, the impact is lower speed reduction from 16.3 knots to 10.0 knots, will increase transit time from 0.7 to 10.63 days and the economic impact per day of delay ranges from 0.03% to 0.50%, which multiplied by the numbers of days is an impact of 0.02% to 5.35% of total fresh or chilled boneless bovine meet exports for the year 2017.

The impact on fresh or chilled boneless bovine meat as a result of slow steaming is minimal due to the reefer technology now available, and most of the products are transported frozen in containers. Shippers' only alternative to export their products from Australia is by air. Other sourcing options of products are the United States with a 6.88% share and New Zealand with a 3.46% share of China's total imports.

B. Chilean cherries to China

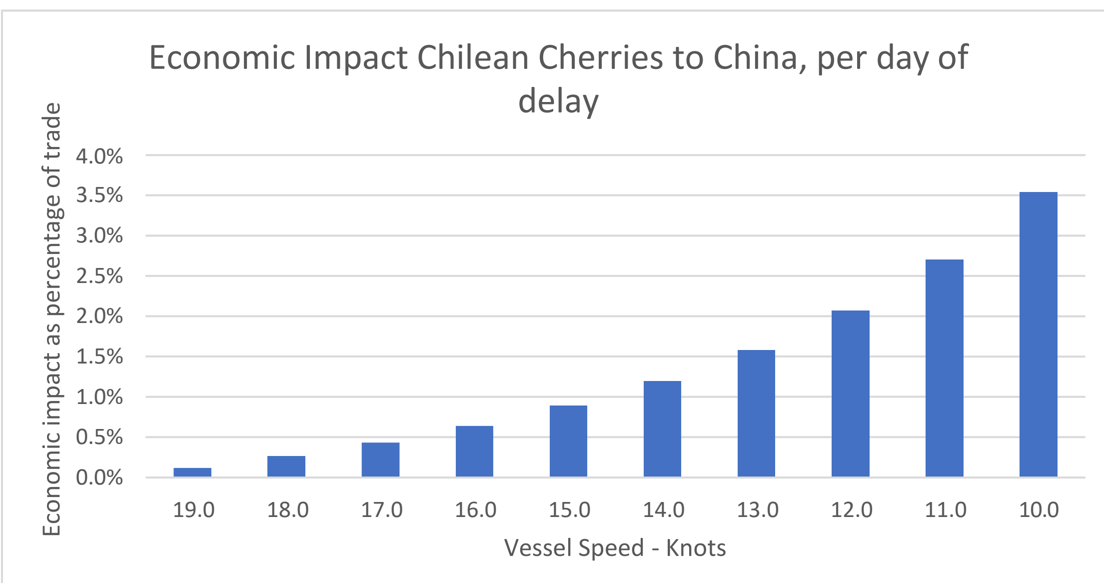
Chile is by far, the largest exporter of fresh apricots, cherries, peaches, plums and sloes (HS 0809) with a 69.57% share of China's imports. In the year 2017, total exports amounted to 94.1 million kilograms, with a total value of USD$474.6 million. Exports of fresh apricots, cherries, peaches, plums and sloes represents 0.1927% of Chilean GDP, or 4.9% of its agricultural sector GDP. Reducing the vessel speed from 20.0 to 10.0 knots using the High Baseline Speed Scenario, will add 1.15 to 21.94 additional transit days from San Antonio, Chile, to Shanghai, China in the CFCX Service. This delay will represent an additional cost ranging from 0.12% to 3.54% per extra travel day of delay on this trade (2017). Using an average vessel speed of 15.0 knots, the additional time is 7.31 days and an additional cost of 0.89%.

China is the main destination for Chilean cherries, according to ASOEX (Chilean Fruit Exports Association), with an 85% share of total exports. Cherries shipped by air arrive to their destination in two to three days, while it takes 20 to 25 days via ocean.[18] The study team communicated with the association of cherry growers in Chile and the State of Oregon. The State of Oregon commented that a majority of their cherries move by air freight to Asia; the ASOEX reported that air freight is often the only option for transporting cherries to distant economies at the start of the harvest season when events, such as the Chinese New Year, increase the demand for cherries but the maritime transit time is too long. ASOEX also reported that shipping the entire first harvest by ship could result in missing the market demand. In 2017, 7% of Chile's cherry exports were shipped by air freight.

Even though cherry exporters from the United States and Chile are using air transportation to ship cargo to the China market, the likelihood of a radical modal shift of sea transportation to air transportation in the case of Chilean exporters is not likely to occur. As any other fresh perishable product, temperature is an essential factor on product shelf-life. Container reefer technology is essential for sensitive perishable products traveling long distances by sea. As a reference, transporting 2017 Chilean cherries export volume to China would require 913 dedicated Boeing 777F airplanes, using only the airplane payload.

In an article published January 10, 2019, by Jing Zang, Chilean cherries are transported to China in combined sea and air shipments, confirming that transport alternatives are being used by shippers. The article says that Shanghai Oheng Import and Export Company is buying cherries from Garces Fruit, in Chile, and the transit time using this system (sea-air) takes from 14 to 17 days to reach final destination. Cherries are shipped by sea from Chile to California, and then by air. This sea-air transport has been used for over a decade from Chile to Hong Kong, China. It is recognized that sea transportation is time consuming, but cost effective, while air is fast, but high priced. This article recognized that ocean shipments from Chile to Hong Kong, China take 22 days.

Figure 16: Economic Impact as a Percentage of Trade Value: Cherries, Chile to China, on an All-Water Route, High Baseline Speed Scenario



The above figure indicates that the economic impact per day of delay for the 2017 Chilean cherries export trade value to China ranges from 0.12% per day, when reducing speed from 20 to 19 knots, or 3.54% per day, when reducing speed from 20 to 10 knots.

Because of the special characteristics of fresh, perishable products such as cherries, the consulting team modified the economic impact model to permit non-linear changes in depreciation rates depending on the number of days of delay. Form Chilean cherries, we have assumed 30% to 75% depreciation**.** Note that the user can modify the depreciation rates over time to reflect the particular characteristics of the perishable commodity, such as fruit.

Evaluating the 2012 Global Average Speed Scenario the results are: slow steaming from 16.3 to 10.0 knots will generate a delay range from 1.15 to 16.63 days in transit time from San Antonio, Chile, to Shanghai, China in the CFCX Service. This delay will represent an additional cost ranging from 0.12% to 2.44% per extra travel day of delay on this trade (2017). Using an average vessel speed of 15.0 knots, the additional time is 2.39 days and an additional cost of 0.26% per day of delay.

Evaluating the High Baseline Speed Scenario, the total increase in the voyage transit time ranges from 1.15 to 21.94 days and the economic impact per day of delay ranges from 0.12% to 3.54%, which, when multiplied by the numbers of days, is an impact of 0.14% to 77.67% of total fresh apricots, cherries, peaches, plums and sloes exports for the year 2017. Under Average Speed IMO 2014 Scenario, the impact is lower speed reduction from 16.3 knots to 10.0 knots, will increase transit time from 1.15 to 16.63 days and the economic impact per day of delay ranges from 0.12% to 2.44%, which multiplied by the numbers of days is an impact of 0.14% to 40.58% of total fresh apricots, cherries, peaches, plums and sloes exports for the year 2017. The table below summarizes the results. It should be noted that the 10 knots included in the GHG and economic impact models is the lower range of speeds used to show the impact of slow steaming, but it is not a recommended slow steaming speed at sea for the faster vessels.

Scenarios and Speed Comparison Output for Chilean Cherries

Scenario	GSA	@ 10 knots			@ 15 knots		
		days of delay	Economic impact/day	Total economic impact	days of delay	Economic impact/day	Total economic impact
2012 Global Average Speed	16.3	16.63	2.44%	40.58%	2.39	0.26%	0.62%
High Baseline Speed	20.0	21.94	3.54%	77.67%	7.31	1.19%	11.23%

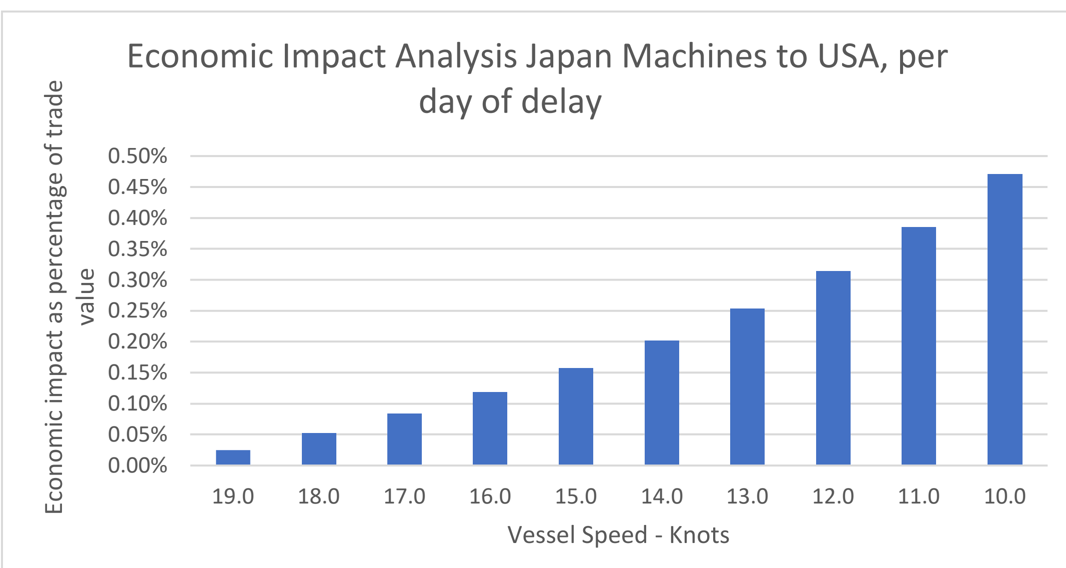
The impact of 16.63 to 21.94 days of delay on fresh fruits' shelf life, like cherries, is considerable. Cherries are a very sensitive product to handle and transport. After harvest, the product is immediately fast cooled to -0.5°C, and the pulp temperature should not exceed 0°C while handled or during transport. The product should be in the final retail market within 21 days after picking, as shelf life is very limited.[19] Thus, cherries are one of the cases of a product whose shelf life is certainly affected by slow steaming.

Shippers' alternative to export their products from Chile is by air to the same destination, incurring extra transport costs. In the season 2017-2018, about 7% of the total cherries exported from Chile were shipped via air, while 89% went by sea. If the delay in transit time were to become longer, there is a possibility that the 7% share going by air freight could significantly increase. Almost 90% of total Chilean exports are destined to Far East Asia. Alternative sources of products for the China market are the United States, currently with a share of 22.02%, Canada with 2.93%, and New Zealand and Australia with 2.46%. Together, these economies represent 98.58% of cherries imported by China. In order to capture the higher rate of obsolescence, or a selling price reduction of the fruit, a depreciation rate of 30% was used in the impact model, as presented in the Decofruit paper.

C. Japanese machines to the United States

In 2017, Japan exported 8.5 million kilograms of "Machines for manufacturing, semiconductor device, electronics" or USD$2.6 billion, which represents 0.0527% of that economy's GDP, or 8.8% of its manufacturing sector GDP. Reducing the vessel speed from 20.0 to 10.0 knots using the High Baseline Speed Scenario, will add 0.53 to 10.11 transit days. This delay will represent an additional cost ranging from 0.02% to 0.47% per extra travel day for all machines and devices used solely for the manufacture of semiconductor devices exported from Japan to the United States in 2017. At an average vessel speed of 15.2 knots, the additional voyage time is 3.37 days with an additional cost of 0.16%.

Figure 17: Economic Impact as a Percentage of Trade Value: Machines, Japan to the United States, High Baseline Speed Scenario



The above figure indicates that the economic impact per day of delay for 2017 Japanese machines export trade value to the United States ranges from 0.02% per day, when reducing speed from 20 to 19 knots, to 0.47% per day of total value of yearly transaction when reducing speed from 20 to 10 knots.

Evaluating the 2012 Global Average Speed Scenario the results are: slow steaming from 16.3 to 10.0 knots will generate a delay range from 0.53 to 7.66 days in transit time from Tokyo, Japan, to Los Angeles, the United States in the Fuji Service. This delay will represent an additional cost ranging from 0.02% to 0.36% per extra travel day of delay on this trade (2017). Using an average vessel speed of 15.0 knots, the additional time is 1.10 days and an additional cost of 0.05% per day of delay.

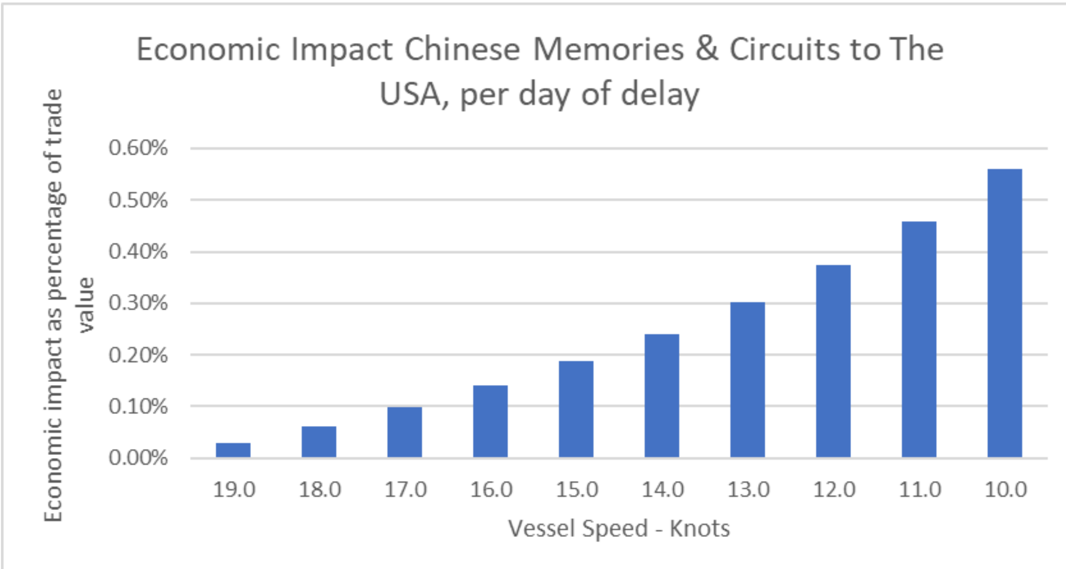
Evaluating the High Baseline Speed Scenario, the total increase in the voyage transit time ranges from 0.53 to 10.11 days and the economic impact per day of delay ranges from 0.02% to 0.47%, which, when multiplied by the numbers of days, is an impact of 0.01% to 4.76% of total machines for man. semiconductor devices/electronic exports for the year 2017. Under Average Speed IMO 2014 Scenario, the impact is lower speed reduction from 16.3 knots to 10.0 knots, will increase transit time from 0.53 to 7.66 days and the economic impact per day of delay ranges from 0.02% to 0.36%, which multiplied by the numbers of days is an impact of 0.01% to 2.73% of total machines for man. semiconductor devices/electronic exports for the year 2017.

Extended transit time should not impact "product shelf life" due to 4.31 extra days of transit time. Japan is the largest supplier of semiconductor devices to the United States and has a 36.41% share of the total product imports into the U.S. Other sources of these devices include the Netherlands (19.08%), China (10.12%), Singapore (9.05%), and the Republic of Korea (7.96%). The total share of the top five sources of machines for manufacturing semiconductor devices for the United States is 82.62%. Almost all of these are distant economies.

D. Chinese memories & circuits to the United States

Chinese exports of "memories, electronic integrated circuits" totaled 505,000 kilograms worth a total of USD$491.1 million in 2017. Total memories & circuits as a percentage of China's GDP is 0.004%, or 0.01% of its industry sector GDP. Using "Hangzhou Bay Bridge" service as reference, reducing the vessel speed from 20.0 to 10.0 knots using the High Baseline Speed Scenario, will add 0.63 to 12.04 transit days, or an additional expense from 0.03% to 0.56% (interest, depreciation, and insurance cost) for all such products exported from China to the United States that year. Using as reference an average of 15.0 knots as the lower vessel speed, the delay time is 4.01 days and cost impact is 0.19%.

Figure 18: Economic Impact as a Percentage of Trade Value: Memories and Circuits, China to the United States, High Baseline Speed Scenario



The above figure indicates that the economic impact per day of delay for 2017 Chinese memories export trade value to the United States ranges from 0.03% per day, when reducing speed from 20 to 19 knots, or 0.56% per day when reducing speed from 20 to 10 knots.

Evaluating the 2012 Global Average Speed Scenario the results are: slow steaming from 16.3 to 10.0 knots will generate a delay range from 0.61 to 9.31 days in transit time from Shanghai, China, to Los Angeles, The United in the Hangzhou Bay Bridge Service. This delay will represent an additional cost ranging from 0.03% to 0.43% per extra travel day of delay on this trade (2017). Using an average vessel speed of 15.0 knots, the additional time is 1.28 days and an additional cost of 0.06% per day of delay.

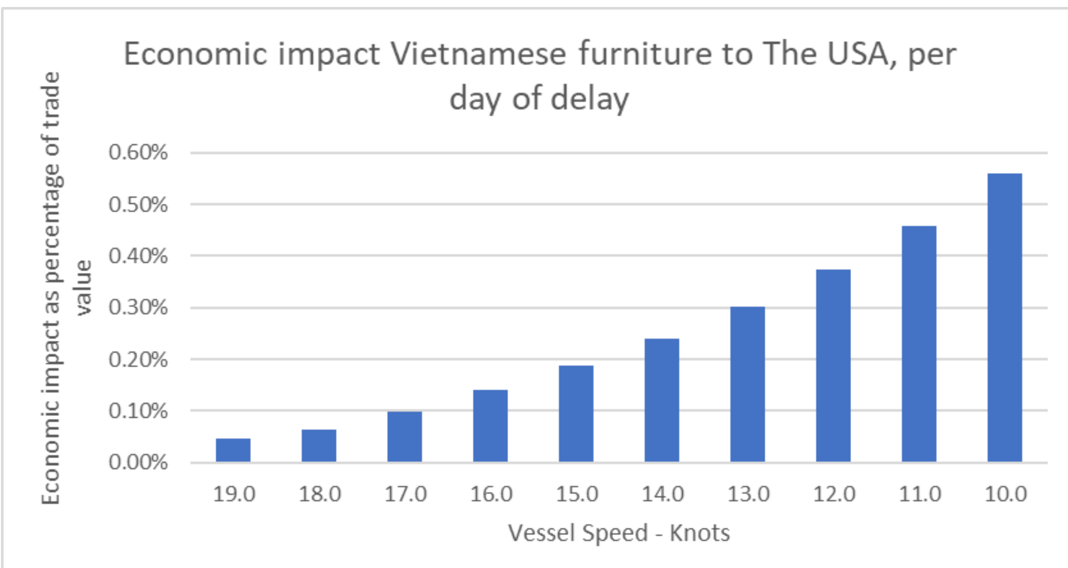
Evaluating the High Baseline Speed Scenario, the total increase in the voyage transit time ranges from 0.63 to 12.04 days and the economic impact per day of delay ranges from 0.03% to 0.56%, which, when multiplied by the numbers of days, is an impact of 0.02% to 6.75% of total memories, electronic integrated circuits meet exports for the year 2017. Under Average Speed IMO 2014 Scenario, the impact is lower speed reduction from 16.3 knots to 10.0 knots, will increase transit time from 0.61 to 9.31 days and the economic impact per day of delay ranges from 0.03% to 0.43%, which multiplied by the numbers of days is an impact of 0.02% to 4.03% of total memories, electronic integrated circuits exports for the year 2017.

China is the fifth largest supplier of “memories, electronic integrated circuits” to the United States (USA), sharing 5.33% of total US imports of these products. Other suppliers are Malaysia with 52.13%, Ireland with 10.37%, Viet Nam with 10.19%, other Asian economies with 6.75%; and China. The top five suppliers represent 84.76% of total USA imports, and all are long distance economies. A delay of 5.13 days would have a minimal impact on Chinas exports, and no impact on shelf life.

E. Vietnamese furniture to the United States

Viet Nam is the second largest supplier of furniture to the United States; in the year 2017, total volume exported to the United States reached 696.5 million kilograms with a value of USD$2.5 billion. Exports of furniture to the United States represents 1.13% of Viet Nam GDP, or 7.4% of its manufacturing sector GDP. Reducing the vessel speed from 20.0 to 10.0 knots using the High Baseline Speed Scenario, will add 1.02 to 12.04 transit days, or an impact ranging from 0.05% to 0.56% of additional expenses (interest, depreciation and insurance) for all such cargo exported from Viet Nam to the United States in 2017. At 15.0 knots of speed, the delay time amounts to 4.01 days with an additional cost impact of 0.19%.

Figure 19: Economic Impact as a Percentage of Trade Value: Furniture, Viet Nam to the United States, High Baseline Speed Scenario



The above figure indicates that the economic impact per day of delay for 2017 Vietnamese furniture export trade value to the United States ranges from 0.05% per day, when reducing speed from 20 to 19 knots, or 0.56% per day when reducing speed from 20 to 10 knots.

Evaluating the 2012 Global Average Speed Scenario the results are: slow steaming from 16.3 to 10.0 knots, will add 0.98 to 9.31 additional transit days on the South China Sea service, and that will represent an additional cost ranging from 0.05% to 0.43% per extra travel day of delay. At 15.0 knots, the time differential will be 1.28 days and 0.06% of additional cost per day.

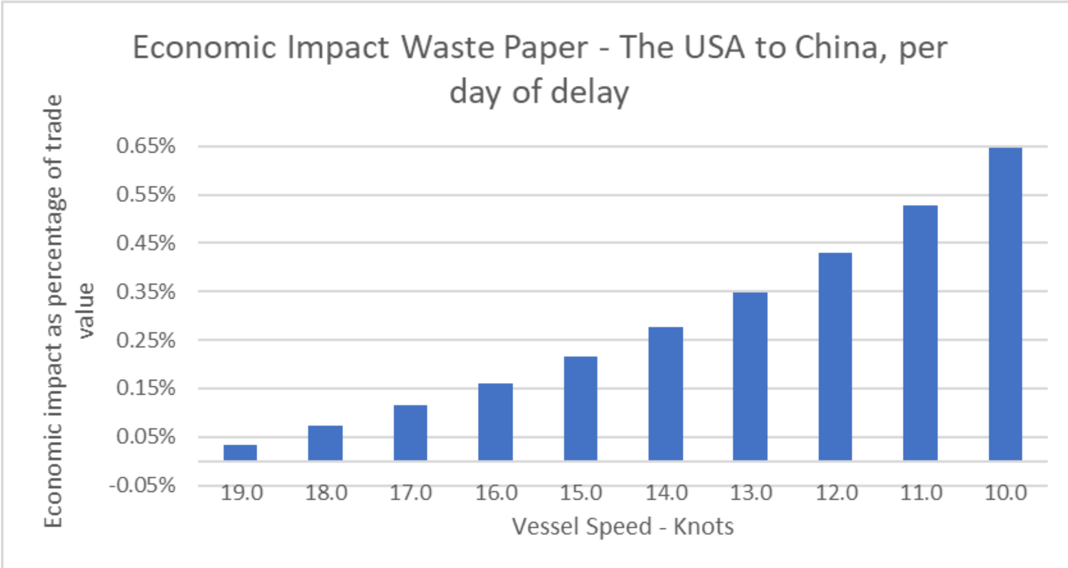
Evaluating the High Baseline Speed Scenario, the total increase in the voyage transit time ranges from 1.02 to 12.04 days and the economic impact per day of delay ranges from 0.05% to 0.56%, which, when multiplied by the numbers of days, is an impact of 0.05% to 6.75% of total furniture and parts exports for the year 2017. Under Average Speed IMO 2014 Scenario, the impact is lower speed reduction from 16.3 knots to 10.0 knots, will increase transit time to 0.98 to 9.31 days and the economic impact per day of delay ranges from 0.05% to 0.43%, which multiplied by the numbers of days is an impact from 0.04% to 4.03% of total furniture and parts meet exports for the year 2017.

Slow steaming will have almost no impact on furniture shelf life. The top five exporting economies of furniture to the United States share 81.20% of US total imports; these economies are China with 48.73%, Viet Nam with 15.07%, Canada with 9.71%, Mexico with 4.41% and Malaysia with 3.28%. Neighboring economies such as Canada and Mexico are among the top five.

F. The United States Wastepaper to China

Total wastepaper exports from the United States to China, in the year 2017, amounted to 13.2 billion kilograms with a total value of USD$1.9 billion, representing 0.088% of the United States GDP or 0.05% of its industry sector GDP. In order to measure the impact of slow steaming we have selected the “Bohai” service, reducing the vessel speed from 20.0 to 10.0 knots using the High Baseline Speed Scenario, will add 0.73 to 13.89 days of transit time from Los Angeles to Shanghai, or the equivalent of 0.03% to 0.65% of additional expenses (interest, depreciation and insurance) for all the United States wastepaper exports in 2017. When using 15.0 knots of speed, the delay time is 4.63 days and the additional cost impact is 0.22%.

Figure 20: Economic Impact as a Percentage of Trade Value: Wastepaper from the United States to China, High Baseline Speed Scenario



The above figure indicates that the economic impact per day of delay for 2017, the United Stated waste paper export trade value to China ranges from 0.03% per day, when reducing speed from 20 to 19 knots, or 0.65% per day of total value of yearly transaction when reducing speed from 20 to 10 knots.

Evaluating the 2012 Global Average Speed Scenario the results are: slow steaming from 16.1 to 10.0 knots, will add 0.73 to 10.53 additional transit days on the Bohai service, and that will represent an additional cost ranging from 0.03% to 0.49% per extra travel day of delay. At 14.8 knots, the time differential will be 1.52 days and 0.07% of additional cost per day.

Evaluating the High Baseline Speed Scenario, the total increase in the voyage transit time ranges from 0.73 to 13.89 days and the economic impact per day of delay ranges from 0.03% to 0.65%, which, when multiplied by the numbers of days, is an impact of 0.02% to 8.98% of total waste and scrap paper exports for the year 2017. Under Average Speed IMO 2014 Scenario, the impact is lower speed reduction from 16.3 knots to 10.0 knots, will increase transit time to 0.75 to 10.53 days and the economic impact per day of delay ranges from 0.03% to 0.49%, which multiplied by the numbers of days is an impact from 0.02% to 5.16% of total waste and scrap paper exports for the year 2017.

A delay of 19.06 days in transit time will, most likely, not affect the product shelf life. The United States is the largest source of wastepaper for China, with a share of 46.44%, followed by the UK 11.02%, Japan 10.20%, Canada 5.07% and the Netherlands 4.91%. Almost all wastepaper suppliers, except for Japan, are long distant economies.

3.4 Economic Impact Conclusion

It is widely recognized that slow steaming is a method used by the ship operator to reduce fuel consumption costs, primarily when the bunker price is high. During the 2008 economic crisis, and since then, shipping lines have adopted slow steaming in several of their main trade lanes, as an effective way to reduce fuel consumption costs.

<u>Impact on the economies of APEC members:</u>

- The at-sea global speed averages (GSA) used in developing the present report should guide decision makers to evaluate ships' optimal speed considering both the economic impact on shippers and economies, as well as the environmental impact gains when implementing slow steaming.
- The economic impact of the products under analysis, as a percentage of economies' GDP, vary from 0.004%, in the case of Chinese memories and electronic integrated circuits to the United States, to 3.397% in the case of Peruvian copper ore to China.
- The importance of agricultural products for the Peruvian and Chilean economies is evident, and these exports may be transported up to 13,600 kilometres. Thus, the outcome of future policies for slow steaming is critical for distant economies such as Peru and Chile, whose main export markets for agricultural perishables exports are in Asia. Approximately 90% of Chilean exports are seaborne.

<u>Impact on cargo:</u>

- As presented in several papers reviewed, if the bunker price for fuel is at a high level where the cost of an additional vessel is offset, then slow steaming is beneficial, and may be sustainable.[20] As fuel cost is almost 50% of a ship's operating costs, any additional crew cost during the delay will not have a significant impact in the overall cost of running the ship.
- In terms of ports operations, if or when slow steaming is mandated, berthing port windows will have to be reviewed and adapted to the new operating scheme; thus there should not be port charges for slow steaming when all actors in the supply chain will adjust to slow steaming.
- Surcharges are a common method in the maritime industry to pass the fuel price (bunker price) increase from ship operator to shippers, any fuel increase will be applied to compensate for a bunker price differential.
- As presented in the model output, ultraslow steaming at 12 knots is not beneficial for shippers since the inventory costs and time delay will become too high, as compared to sailing at 15 knots. The purpose of this study is not to identify the optimal speed, but rather to measure impact on cargo, shippers and economies.
- Fresh perishable products, traveling long distances, would have an impact from longer transit times.

<u>Impact on Supply Chain & Logistics:</u>

- Shipping lines use slow steaming when oil price is high and freight rates are down.[21]

- Reduction of speed decreases the supply and demand balance for vessels.[22] When freight rates are high, vessel speed goes up and when freight rates are low, vessel speed declines.
- A mandatory regulation on slow steaming will impact shippers' supply chains and they will have to adjust to the new rules.
- International trade relies on and will continue to rely on ocean transport as the preferred mode of transportation, even with slow steaming.
- Shippers will have to adapt their supply chain to the new standard of slow steaming, and as indicated in the model, it will delay cargo up to almost 15 days in the case of liner services sailing at 12 knots; or almost up to five days for dry bulk carriers, in the trade routes and commodities selected in this report. Using a target speed of 15.2 knots for container ships will reduce the gap considerably.
- For shippers, slow steaming, represent that it will take more time for them to receive their cargo; thus, interest rates for financing international trade operations, depreciation, and insurance costs for extra days of voyage will impact overall cost.

Longer vs shorter routes:

- The issue when comparing longer and shorter routes is not only the distance and cost, the consumption plays an important role. That means that closer markets may absorb a smaller percentage of the total export production.
- Another point to consider is that closer economies or markets must probably have similar production, in the case of agricultural products, for example.

Exporters alternatives:

- As there are very limited options for intra APEC long distance economies. Exporters' alternatives are shipping cargo by air, with the respective difference in transport cost and emissions, using sea-air or air-sea transportation. Due to geography, rail transportation is not a feasible option in our analysis of distant markets.
- In terms of product substitution, as seen in the trades from the economic impact analysis, there is a limited number of sources of products that can meet the demand
- In the case of bulk cargo, the economic analysis indicates that the impact of slow steaming is minimal; in the cases examined in this study there are no main issues of substitution or cargo deviation. The commodities under analysis will have almost no depreciation or obsolescence impact.
- For perishable goods, for example cherries, seasonality is a key issue. When certain perishable products are harvested in the northern hemisphere, the southern hemisphere is out of season and vice versa.

Bulk cargo:

- As presented in the model output, the impact of slow steaming on bulk carriers, or in bulk cargo, will be minimal compared to container vessels. Reducing bulk ship average speed from 14 knots to 10 knots will not be as drastic as reducing container ship speed from 20-26 knots to 15-17 knots.

4.0 GHG EMISSIONS IMPACT ANALYSIS

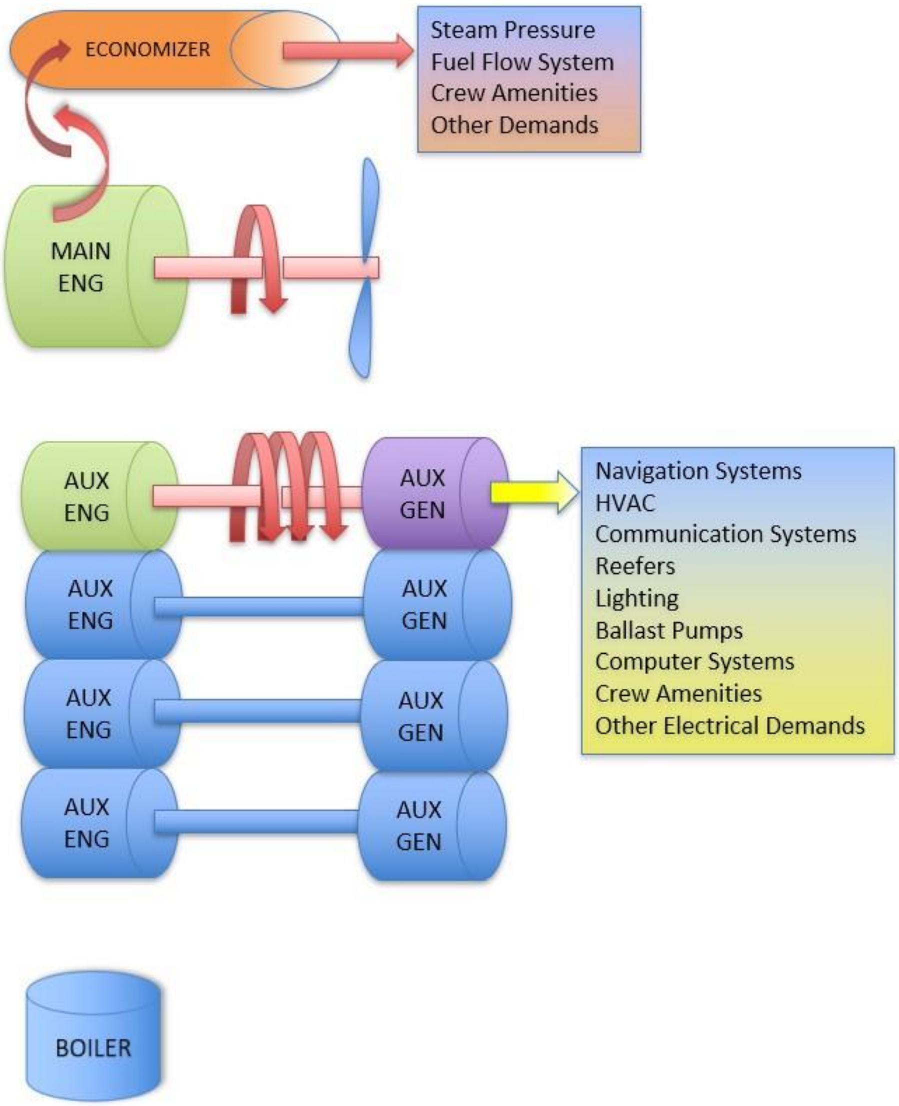
4.1 Introduction

Slow steaming continues to be discussed as a near-term greenhouse gas (GHG) emission reduction strategy at the International Maritime Organisation (IMO) Marine Environmental Protection Committee (MEPC) meetings and during the Intercessional Workgroup on GHGs meetings. From a global perspective, slow steaming as an emission reduction strategy is ultimately a balance between reducing emissions, increasing transit times, and balancing these with cargo customer's tolerance for longer transit times. If the balance is lost, and the customer's tolerance is exceeded, then modal shifts to significantly higher carbon intensity transportation modes, such as air cargo, could occur or in the extreme worse case, the potential loss in trade for highly time sensitive cargos. Slow steaming also raises significant questions for economies that are fully dependent on shipborne commerce for critical cargos that are vital to the life and welfare of their citizens.

As with all emission reduction strategies, each strategy has its strengths, limitations, and their effectiveness is typically not the same across ship types and operational modes. The primary strength of slow steaming from an emission reduction strategy perspective is that all ships can implement the measure with no modifications to the ship. The primary limitation of slow steaming is that speed over ground does not indicate what the ship is actually turning for with regard to speed through the water. For example, a ship maybe turning for 18 knots but only making 15 knots over ground due to hull fouling, wind, and sea state. The other significant challenge with slow steaming is that the potential benefits can vary significantly depending on the baseline speed, between various ship types, across ship sizes even within the same type, and across different distances due to the addition of ships to maintain acceptable arrival frequencies.

From the emission reduction strategy perspective, slow steaming targets propulsion-related energy and emissions by reducing a ship's speed within a geographical domain. As the ship slows down, the strategy takes advantage of the cubic relationship between speed and propulsion power demand to move the ship through the water, known as the Propeller Law.[23] At the same time within the same geographical domain, the auxiliary engines' total power and emissions increase due to the longer transit times. The same is true for the boilers for ships without waste heat recovery systems. For ships with waste heat recovery systems, depending on what the target speed is, these recovery systems can become ineffective and trigger the boilers to turn on during transit. The figure below illustrates the emissions sources for a typical direct-drive ship with a waste heat recovery system (note, equipment in blue is not operational). Finally, to maintain acceptable arrival frequencies, there may come a point when additional ships are needed due to longer transit times.

Figure 21: Illustration of a Typical Direct-Drive Ship in Transit with Waste Heat Recovery



Notes: ENG – engine, AUX – auxiliary, GEN - generator
Source: *https://glomeep.imo.org/wp-content/uploads/2019/03/port-emissions-toolkit-g1-online_New.pdf*

The potential emissions changes for slow steaming is derived by evaluating a fleet of ships performance over a set distance, at a baseline speed, versus how the fleet operates over the same distance at a slower speed. The basic equation is presented below:

Equation 1

$$\text{Potential Emissions Benefits (\%)} = 1 - \left[\sum \text{Emissions (Propulsion + Auxiliary + Boiler)}_{\text{target speed}} \,/ \sum \text{Emissions (Propulsion + Auxiliary + Boiler)}_{\text{baseline speed}} \right]$$

As expected, the potential benefits are dependent on physical and operating characteristics of each ship type, size category, and distance combination. The potential emission changes from slow steam can range from either emission reductions to emission increases, so the strategy needs to be evaluated considering specifics about each scenario.

It should be noted that due to lack of the global merchant fleet's physical condition and real time operational data for the world fleets, the potential benefits estimated from an emissions inventory standpoint, do not generally take into account: real time weather, sea state, wind, hull/propeller/rudder fouling, hull cleaning/painting cycles, and other parameters that would directly affect the magnitude of the energy consumption of ships moving ships through water at observed speeds. The current state of the art emission estimating methodology for the IMO greenhouse gas emission inventory utilizes a top-down approach based on reported fuel consumption and a bottom-up method based on positional data, such as automated identification system (AIS) data, which provides data on position and speed over ground which can be different from what a ship is turning through the water. It also accounts for weather and hull fouling by simple efficiency factors that impact propulsion energy output, which is all that can be done until comprehensive datasets with these parameters are available. The approach of this study and the model provided are consistent with the bottom-up methods, as detailed below and in Appendix B.

4.2 Slow Steaming Context from a Port Emissions Reduction Strategy Perspective

Port authorities were the first organizations in the world to evaluate, define, and implement slower ships speeds as an emission reduction strategy focusing on minimizing emissions impact due to ship operations and contribute towards meeting the local and regional air quality improvement goals. The first case of a programmatic vessel speed reduction (VSR) strategy was at the Port of Los Angeles (POLA)[25] and the Port of Long Beach (POLB).[26] The two ports were working with the numerous regulators including: the state regulator, California Air Resources Board; the federal regulator, the United States Environmental Protection Agency; and the local regulator, South Coast Air Quality Management District. The VSR concept was developed during discussions on how oxides of nitrogen (NOx) and particulate matter (PM) can be reduced from ship operations to help South Coast Air Basin (the basin) to attain federal National Ambient Air Quality Standards (NAAQS). The Port of Los Angeles and the Port of Long Beach ship operations near the coast and at berth occur within the basin.

Emissions inventories developed for the air basin and by the two ports suggested that the emissions from ships running along the coast to the ports contributed significant amounts of mass emissions to the basin to a level that ship emission reductions could not be left to international regulations compliance only. The program targeted the area near the human population where the emissions needed to be reduced. The ports and the regulatory agencies developed methods for establishing baseline speeds, estimating method for emission benefits, data requirements, and reporting requirements for the emission reduction strategy. The geographical boundary for the VSR program was established at a 40 nautical-miles (nm) distance from Point Fermin, California, which is located just outside both ports. A VSR speed of 12 knots was established which means in order to comply with the VSR program, the ship has to reduce its speed to 12 knots or below within 40 nm boundary. The program was started by both ports in 2001 on a voluntary-incentive basis and has been incorporated into the baseline emissions inventories for the area's State Implementation Plan to meet the NAAQS.

The VSR program has been continuously operated as a voluntary-incentive emission reduction strategy under the San Pedro Bay Ports Clean Air Action Program[27] at both ports and has been highly successful with participation rates in the mid 90% for the last decade and half. Over the course of the VSR program, as additional ship operation data was made available and further analyses were conducted, it became apparent that the VSR program with 12 knots or lower speed was not optimal to reduce emissions from all vessel types. Therefore, an Alternative Compliance Plan concept was introduced to develop ship-specific speed limits to maximize the emissions. For example, ships with a high 'house' load or auxiliary load, like cruise ships, it is better to move those ships through the zone faster as their auxiliary load dominates emissions over propulsion within the zone. Therefore, even though the POLA and POLB programs are called VSR, they are actually Vessel Speed Optimization (VSO) programs.

The next port authority to establish a VSR program was the Port Authority of New York and New Jersey (PANYNJ), initially as part of their Low Sulphur Fuel Program in 2010 and eventually as part of their Clean Vessel Incentive Program[28] which was established in 2013 and continues operation today. The program is also operated as a voluntary-incentive emission reduction strategy and has achieved high participation rates. The PANYNJ VSR zone is 20 nm from the entrance to the Ambrose Channel.

Most recently, the Santa Barbara Air Quality Control District[29] initiated a VSR zone in the Santa Barbara Channel, north of the POLA/POLB program with support from the Ventura Air Pollution Control District. The program was implemented as both an emission reduction strategy and a whale strike reduction measure. The program has been expanded to include the Bay Area Air Quality Management District and represents the largest geographical extent of any of the VSR/VSO programs.

The key findings from the programs described above to date are:

- ✓ The implementation of VSR programs have resulted into reduced ship emissions within the geographical zones (locally) and are cost effective from an air quality emission reduction strategy perspective.
- ✓ The emissions benefits vary depending on ship class and related propulsion, auxiliary, and boiler operational characteristics.
- ✓ The programs in general may have not reduced total carbon emissions as the ships make up the participation time loss by adding incremental speed to their voyage outside of VSR zone.
- ✓ VSR/VSO efforts are being further improved with initiatives such as "just in time arrival."

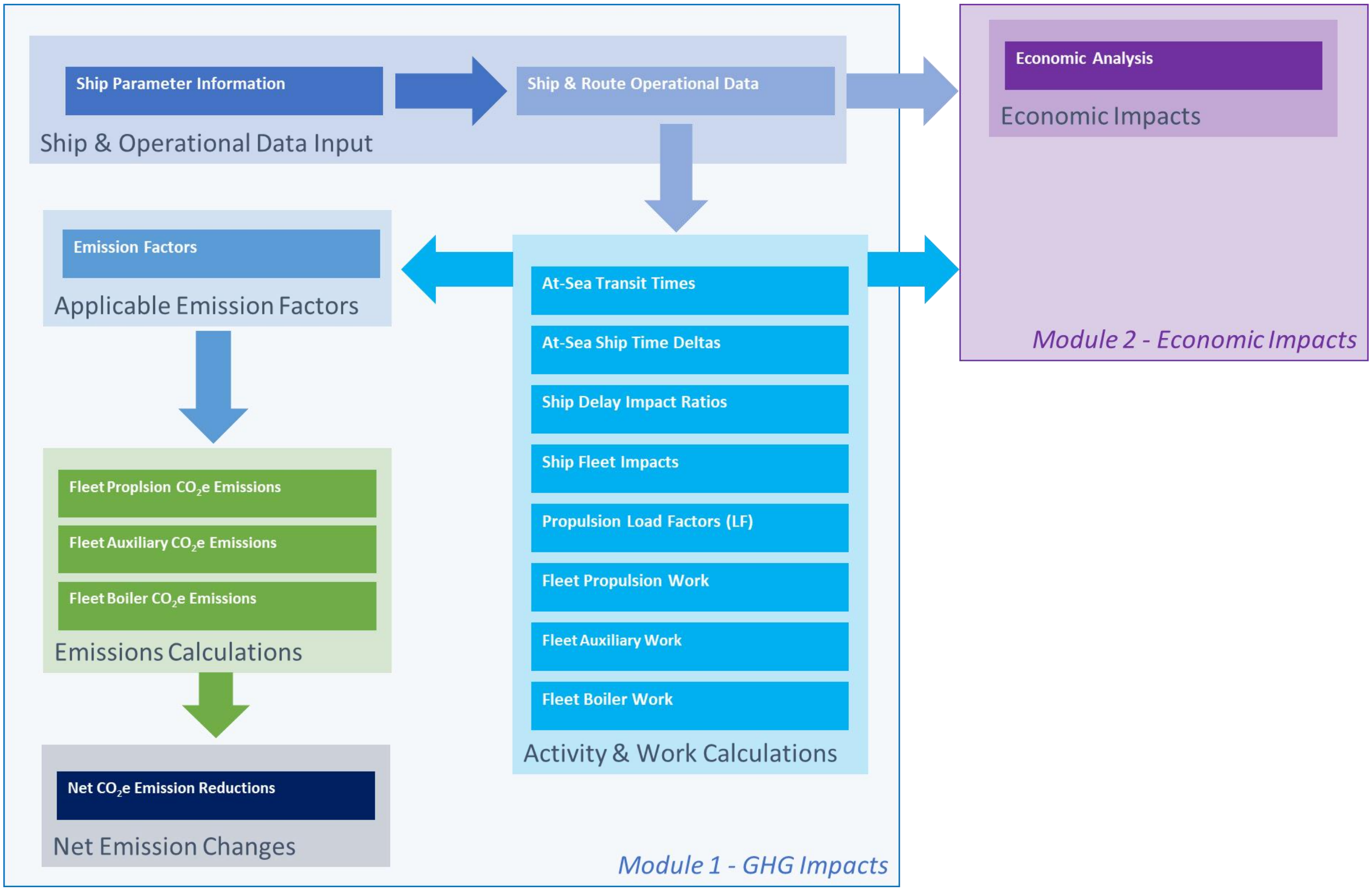
It is important to note that each of these VSR/VSO programs were assessed using a series of scenarios prior to implementation to determine the optimal speeds, using a similar approach to this study and the tool provided. As an emissions reduction strategy, VSR/VSO programs need to take into account the specific conditions around each port as the strategy's effectiveness is critically tied to those conditions. These conditions include: the physical approaches to and from the port, configuration of the VSR/VSO geographical domain, ship's transit safety, tides, currents, local weather conditions, transit windows, and other local conditions that will impact the viability of such a strategy. All of the existing VSR/VSO programs set ship safety as paramount and as an exemption to the program.

4.3 Analysis Approach

For this study, noting that each APEC member economy has their own specific trading partners, commodities, ship characteristics, ship operation profiles and routes plus considering that slow steaming potential benefits and impacts are specific to those combinations, the approach taken was to create a Slow Steaming Analysis (SSA) Model[30] which consists of Module 1 – GHG Impacts (Module 1), and Module 2 – Economic Impacts (Module 2) that users could input distances, speeds, ship sizes for two class (container and bulk ships), and ship physical and operational characteristics to estimate across distances and fleets the potential impacts from slow steaming. Impacts included for each speed/distance/ship size combination are additional sailing time, additional ship population requirements, and percent change in carbon dioxide equivalent (CO_2e).

As described previously in Section 1.4, there are two modules where each member economy can input their own specific scenarios and evaluate how specific fleets performs over a wide range of reduced speeds (in Module 1). The results can then be input into the economic model to assess corresponding economic impacts (in Module 2). An illustration of the of the two modules is provided in Figure 22.

Figure 22: SSA Model Modules 1 and 2



The emission calculations are consistent with the methods and emission factors used in the *Third IMO Greenhouse Gas Study 2014* (IMO 2014).[31] Where updated data was available, it was incorporated into the model as indicated in Appendix B.

Within the Ship & Route Operational Data input, identified in Figure 22 above, the tool incorporates an ‘arrival delay tolerance’ factor, in hours, that allows the user to set an acceptable time delay tolerance association with ship arrivals. For the APEC study, 48 hours was used, which means that a delay of less than 48 hours for a ship on any of the routes does not result in an additional ship being added to the fleet. Setting this value to zero means that any slowing of a ship, even by a minute, would add a ship to the fleet, which is not realistic nor practicable. The arrival delay tolerance factor varies by scenario being assessed and is not a constant value. For example, shipments arriving prior to significant economy holiday may have a much tighter timeframe and for products that are not time sensitive, they could have a much longer timeframe; it all depends on the scenario being evaluated.

The model was developed using Microsoft Excel so it could be easily used by a wide range of users. It should be noted that the models were divided into two different files because of size and with regard to performance of user’s computers.

The Module 1 inputs and methodology are described in detail, in Appendix B. The model was designed to illustrate how emissions change between a baseline speed and incrementally reduced speeds by distance, vessel type, and size. This allows the user to evaluated potential emission changes over a broad set of speeds to help inform policy decisions.

4.4 Slow Steaming Illustrative Emission Impacts

This section illustrates that the potential range of emission reductions associated with slow steaming which depends on a wide range of variables. One of the key variables is ship type and associated ship parameters. Ship types that haver relatively high operational speeds and large propulsion engines, like container ships, will have a higher potential to reduce emissions than those ship types that operate at relatively slow speeds with smaller engines, like bulk ships. Another key variable is size and configuration of the ship, as presented in the table below. Finally, one of the most important key variables in determining the potential emissions benefits is the baseline global average speed (GSA). Two baseline speed scenarios were analysed for the APEC study to illustrate this point:

1. High baseline speed scenario, with speeds ranging from 20.0 to 10.0 knots
2. 2012 annual average speeds from IMO 2014 scenario (2012 Global Average Speed Scenario), with speeds ranging from 16.3 to 10.0 knots

The IMO 2014 is the latest document with detailed speeds by vessel type and size combinations. These averages speeds were based on the comprehensive positional data used in the inventory and 2012 was the year that had the highest AIS resolution. These average speeds represent the world's fleet transiting of a calendar year in all weather, sea states, and ship conditions. Since the publication of IMO 2014, there have been a limited number of other studies that have reported average speeds, indicating that speeds may have slightly increased since 2012, however the transparency of those speeds is not at the same level as IMO 2014. The higher baseline speed scenario was based on published routes by selected carriers and back calculating the average speeds to make the various routes. Establishing new global average speeds was outside the scope of this project, so both baseline scenarios were used for the APEC study.

Both scenarios assume that if the propulsion load drops below 25% then the ship's boilers will be activated as the waste heat recover systems go offline due to the loss of exhaust temperature from the lower speeds. Both scenarios assume the same distances by ship type and size. The difference between the two scenarios are the baseline GSA speeds (based on each scenario) and associated incremental speeds (GSA-1 through GSA-9), however both end with GSA-10 at 10.0 knots using different speed reduction increments for each ship type and size combination. This provides a broad range of speed reduction increments to illustrate that the reductions are not always increasing in a uniform manner and that sometimes, a faster speed results in higher reductions than slower speeds. The authors are not suggesting a global speed limit of 10 knots, it is used to illustrate the changes in benefits across a wide speed range. All other parameters are the same and are identified in detail in the tables below and in Appendix B.

Table 17: Ship Parameters for Both Baseline Speed Scenarios

Ship Types	Ship Sizes	Average Maximum Rated Speeds knots	Percent of Maximum Draft	Hull Fowling Variable	Route Option: Coastal At-Sea	Weather Impact Variable	Average Propulsion Ratings kW	Engine Type MSD/SSD	At-Sea Avg Aux Loads kW	At-Sea Avg Boiler Loads kW	At-Sea GSA Speeds knots	At-Sea Published Speeds knots
Container	1,000 teu	18.94	100%	9%	At-Sea	15%	11,974	MSD	750	300	13.9	18.0
Container	3,000 teu	21.97	100%	9%	At-Sea	15%	27,617	SSD	750	400	16.1	20.0
Container	6,000 teu	24.80	100%	9%	At-Sea	15%	57,343	SSD	1,000	650	16.3	20.0
Container	9,000 teu	23.43	100%	9%	At-Sea	15%	53,261	SSD	1,100	675	16.3	20.0
Container	14,000 teu	22.65	100%	9%	At-Sea	15%	55,327	SSD	1,200	800	16.1	20.0
Container	17,000 teu	22.56	100%	9%	At-Sea	15%	69,937	SSD	1,400	500	14.8	20.0
Bulk	Handymax	14.13	100%	9%	At-Sea	15%	7,496	MSD	250	65	11.8	12.0
Bulk	Panamax	14.43	100%	9%	At-Sea	15%	9,387	SSD	350	65	11.8	12.0
Bulk	Capesize	14.55	100%	9%	At-Sea	15%	18,149	SSD	400	65	11.7	12.0

Table 18: High Baseline Speed Scenario Inputs

Matrix 1 - Ship & Route Operational Data

Ship Type	Ship Size	Number of Ships	Shortest Distance 1 (nm)	Ocean Transit Distance Distance 2 (nm)	Distance 3 (nm)	Distance 4 (nm)	Longest Distance 5 (nm)	At-Sea Transit Speed Range GSA (knots)	GSA -1 (knots)	GSA -2 (knots)	GSA -3 (knots)	GSA -4 (knots)	GSA -5 (knots)	GSA -6 (knots)	GSA -7 (knots)	GSA -8 (knots)	GSA -9 (knots)	GSA -10 (knots)	Speed Reduction Increment (knots/GSA-X)	Arrival Delay Tolerance (hours)
Container	1,000 teu	12	200	1,650	3,100	4,550	6,000	18.0	17.2	16.4	15.6	14.8	14.0	13.2	12.4	11.6	10.8	10.0	0.80	48.0
	3,000 teu	12	200	1,650	3,100	4,550	6,000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
	6,000 teu	12	600	2,200	3,800	5,400	7,000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
	9,000 teu	12	800	2,600	4,400	6,200	8,000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
	14,000 teu	15	1,000	3,000	5,000	7,000	9,000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
	17,000 teu	15	1,200	4,650	8,100	11,550	15,000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
Bulk	Handymax	12	600	2,700	4,800	6,900	9,000	12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0
	Panamax	12	600	3,450	6,300	9,150	12,000	12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0
	Capesize	12	600	3,950	7,300	10,650	14,000	12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0

Note: values in blue are entered in to SSA Model Module 1

Table 19: 2012 Global Average Speed Scenario

Matrix 1 - Ship & Route Operational Data

Ship Type	Ship Size	Number of Ships	Shortest Distance 1 (nm)	Ocean Transit Distance Distance 2 (nm)	Distance 3 (nm)	Distance 4 (nm)	Longest Distance 5 (nm)	At-Sea Transit Speed Range GSA (knots)	GSA -1 (knots)	GSA -2 (knots)	GSA -3 (knots)	GSA -4 (knots)	GSA -5 (knots)	GSA -6 (knots)	GSA -7 (knots)	GSA -8 (knots)	GSA -9 (knots)	GSA -10 (knots)	Speed Reduction Increment (knots/GSA-X)	Arrival Delay Tolerance (hours)
Container	1,000 teu	12	200	1,650	3,100	4,550	6,000	13.9	13.5	13.1	12.7	12.3	11.9	11.5	11.1	10.7	10.3	10.0	0.40	48.0
	3,000 teu	12	200	1,650	3,100	4,550	6,000	16.1	15.5	14.8	14.2	13.5	12.9	12.2	11.6	10.9	10.3	10.0	0.65	48.0
	6,000 teu	12	600	2,200	3,800	5,400	7,000	16.3	15.7	15.0	14.4	13.7	13.1	12.4	11.8	11.1	10.5	10.0	0.65	48.0
	9,000 teu	12	800	2,600	4,400	6,200	8,000	16.3	15.7	15.0	14.4	13.7	13.1	12.4	11.8	11.1	10.5	10.0	0.65	48.0
	14,000 teu	15	1,000	3,000	5,000	7,000	9,000	16.1	15.5	14.8	14.2	13.5	12.9	12.2	11.6	10.9	10.3	10.0	0.65	48.0
	17,000 teu	15	1,200	4,650	8,100	11,550	15,000	14.8	14.3	13.8	13.3	12.8	12.3	11.8	11.3	10.8	10.3	10.0	0.50	48.0
Bulk	Handymax	12	600	2,700	4,800	6,900	9,000	11.8	11.6	11.4	11.3	11.1	10.9	10.7	10.5	10.4	10.2	10.0	0.18	48.0
	Panamax	12	600	3,450	6,300	9,150	12,000	11.8	11.6	11.4	11.3	11.1	10.9	10.7	10.5	10.4	10.2	10.0	0.18	48.0
	Capesize	12	600	3,950	7,300	10,650	14,000	11.7	11.5	11.3	11.2	11.0	10.8	10.6	10.4	10.3	10.1	10.0	0.18	48.0

Note: values in blue are entered in to SSA Model Module 1

For reference, the selected trade flows illustrated in Section 2 and the associated economic analysis in Section 3, their associated distances (in nm), and associated tables and figures are presented in the following table.

Table 20: Selected Trade Flow Distances

Ship Type	Selected Trade Flows	Section 2 Associated Tables	Section 3 Associated Figures	Distance nm
Container	Melbourne, Australia to Shanghai, China	2, 5	15	6,660
	San Antonio, Chile to Shanghai, China	2, 6	16	10,531
	Tokyo, Japan to Los Angeles, United States	2, 9	17	4,854
	Shanghai, China to United States	2, 11	18	5,781
	Vung Tau, Viet Nam to Long Beach, United State	2, 13	19	9,257
	Los Angeles, United States to Shanghai, China	2, 15	20	6,668
Bulk	Dampier, Australia to Qingdao, China	3	12	3,582
	Matarani, Peru to Shanghai, China	3	13	9,739
	Tacoma, United States to Qingdao, China	3	14	5,119

4.4.1 Container Ships

Module 1 was used to determine the net emissions changes of each fleet over the five distances in Tables 18 and 19, above. Illustrative high baseline speed scenario results for the 14,000 teu container ships are provided in the following figures and include the change in emissions and another set of figures that illustrate the additional ships needed to make the acceptable arrival delay tolerance of 48 hours. For the emission change figures, the baseline GSA speed (in knots) is stated in the upper left corner, the specific distance for the ship type and size combination is provided below the title, the size of the ship is provided in the upper right corner, and the speed ranges are across the x-axis. The y-axis shows the net CO_2e emission changes, negative being reductions and positive numbers being emission increases.

Note that all tables and figures are provided in the SSA Model Module 1 file.

Figure 23: Illustrative Results for Net Fleet Emission Changes, Container 14,000 teu, 1,000 nm, High Baseline Speed Scenario

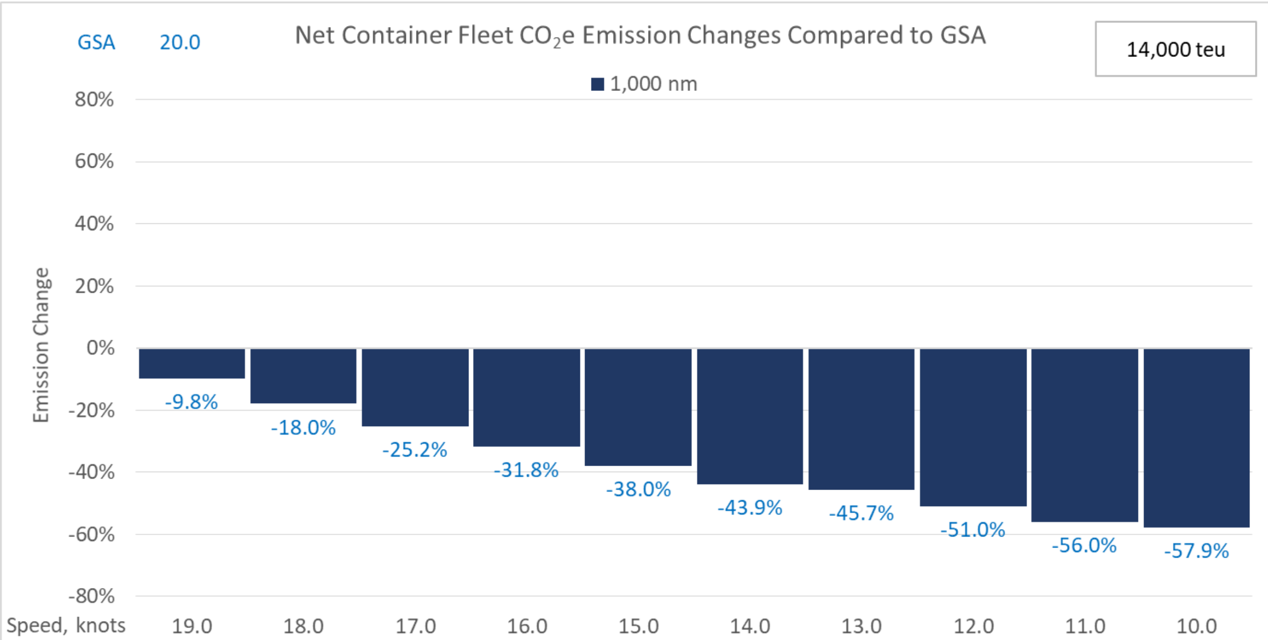


Figure 24: Illustrative Results for Net Fleet Emission Changes, Container 14,000 teu, 3,000 nm, High Baseline Speed Scenario

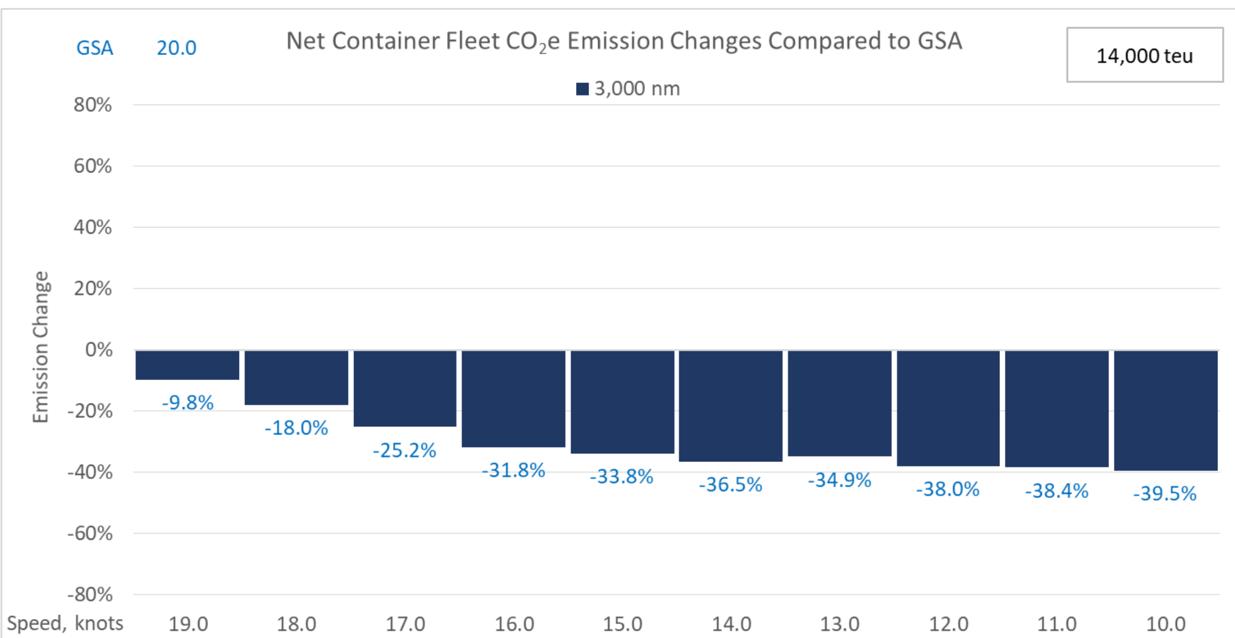


Figure 25: Illustrative Results for Net Fleet Emission Changes, Container 14,000 teu, 5,000 nm, High Baseline Speed Scenario

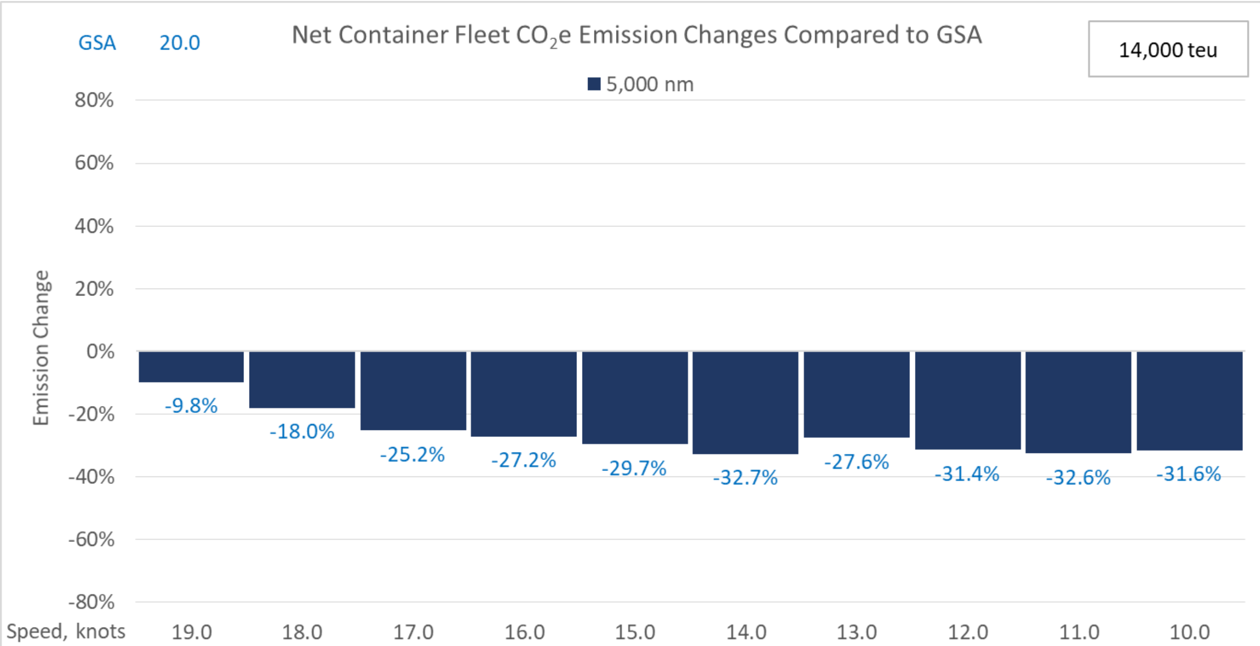


Figure 26: Illustrative Results for Net Fleet Emission Changes, Container 14,000 teu, 7,000 nm, High Baseline Speed Scenario

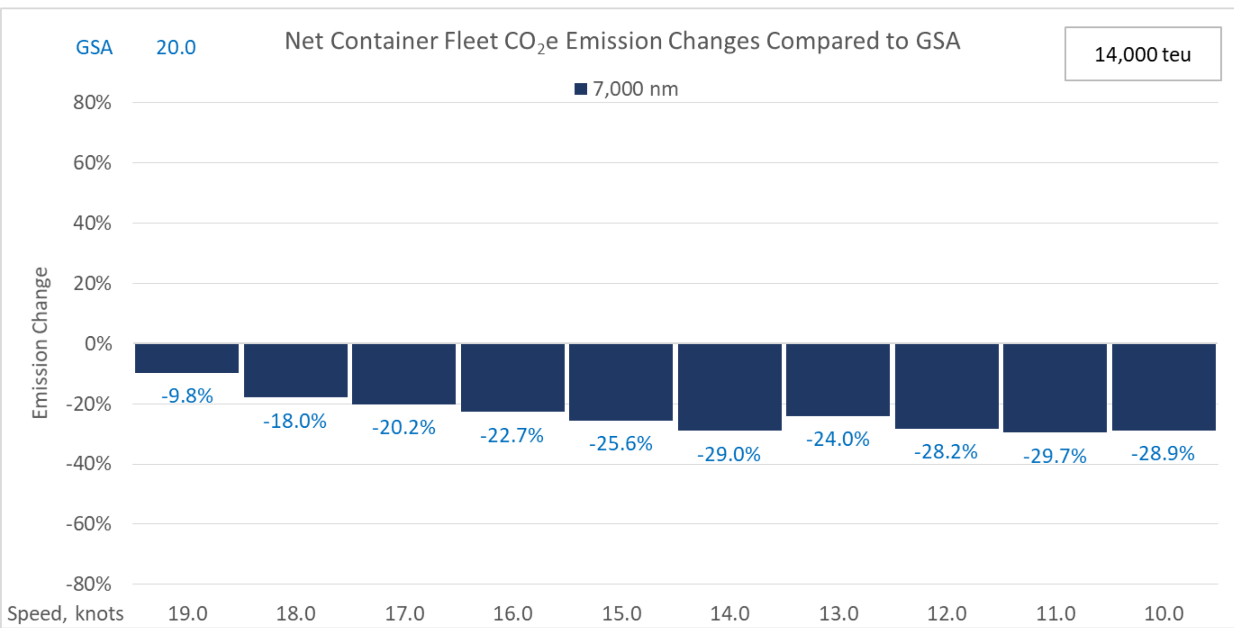
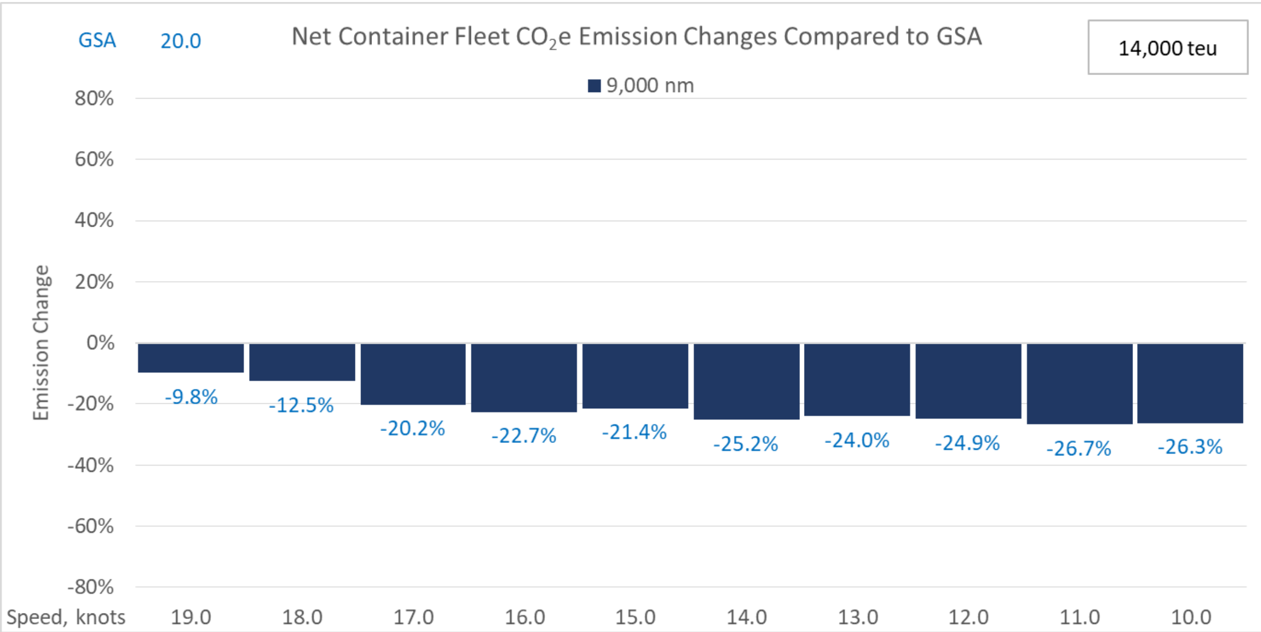


Figure 27: Illustrative Results for Net Fleet Emission Changes, Container 14,000 teu, 9,000 nm, High Baseline Speed Scenario



For the above 14,000 teu container ship high baseline speed scenario example, using a baseline speed of 20 knots and the speed reduction in increments of 1.0 knots, the emissions changes vary widely depending on distance, if the boilers are activated, and the number of ships that need to be added to the fleet to maintain the acceptable arrival delay tolerance of 48 hours. The maximum potential emission reductions for this high baseline speed scenario are:

1,000 nm – maximum reduction of 58%, at 10 knots
3,000 nm – maximum reduction of 40%, at 10 knots
5,000 nm – maximum reduction of 33%, at 14 and 11 knots
7,000 nm – maximum reduction of 30%, at 11 knots
9,000 nm – maximum reduction of 26%, at 11 knots

For context, in addition to the applicable routes listed in Table 20, the above distances are similar to the following inter-APEC routes:

Manila, Philippines to Shanghai, China	1,128 nm
Callao, Peru to Long Beach, United States	3,654 nm
Sydney, Australia to Bangkok, Thailand	4,990 nm
Singapore to Vancouver, Canada	7,078 nm
Valparaiso, Chile to Yokohama, Japan	9,282 nm

Note that as the distance extends the benefits reduced, going from 58% to 26% or halved. This is due to the addition of ships to the fleet based on the acceptable arrival delay factor. For many distances, 14 through 16 knots provides nearly the same reductions as the maximum reductions at slower speeds. This is due to the impact of ships needing to be added and at the slower speed the boilers coming online. The additional ships required for the high baseline speed scenario 14,000 teu container ship fleet and using a 48-hour acceptable arrival delay, are presented in the following series of figures below.

Figure 28: Illustrative Results for Additional Ships Needed, Container 14,000 teu, 1,000 nm, High Baseline Speed Scenario

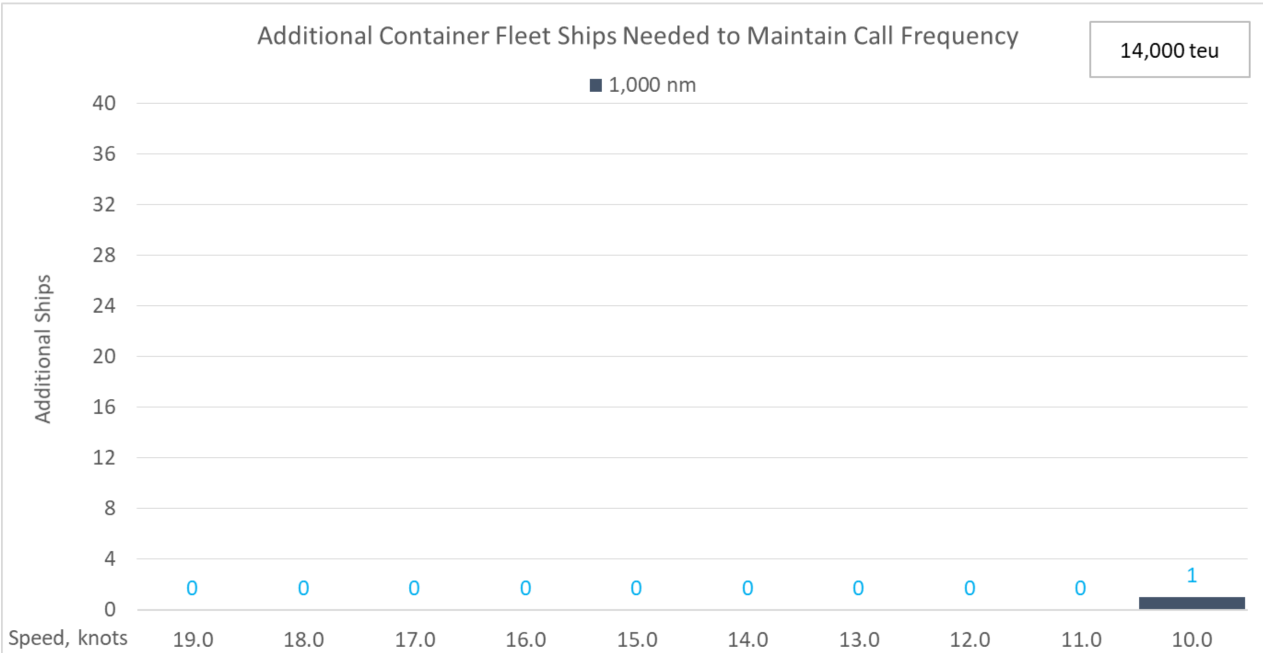


Figure 29: Illustrative Results for Additional Ships Needed, Container 14,000 teu, 3,000 nm, High Baseline Speed Scenario

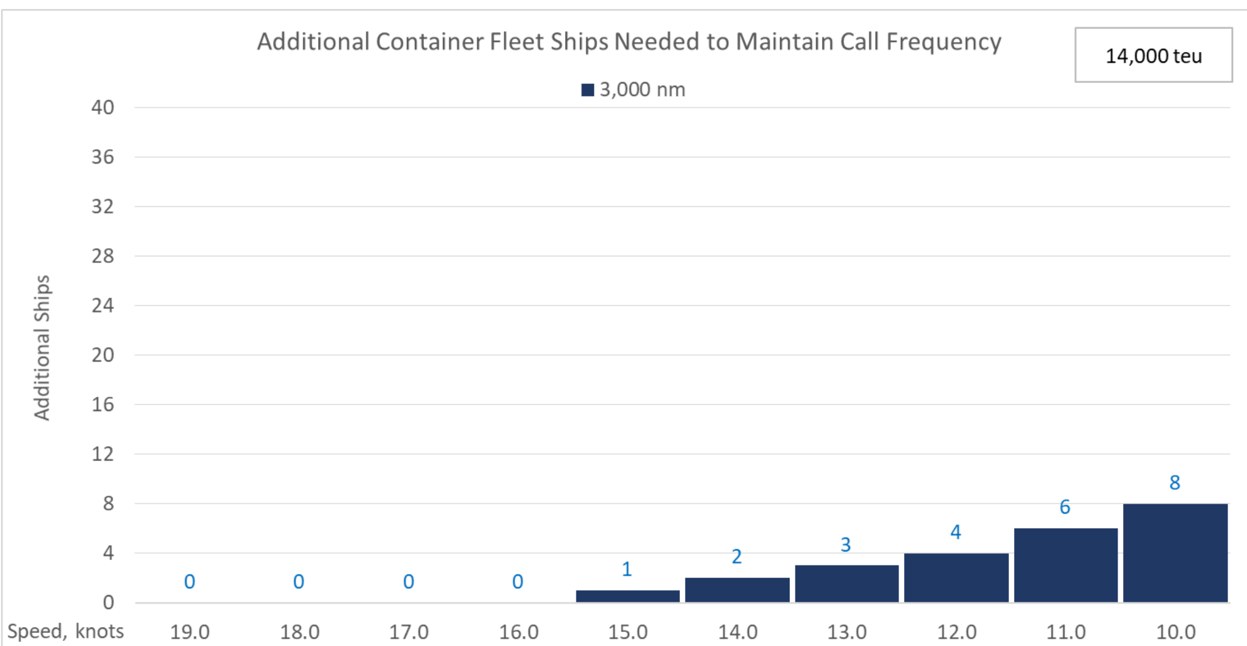


Figure 30: Illustrative Results for Additional Ships Needed, Container 14,000 teu, 5,000 nm, High Baseline Speed Scenario

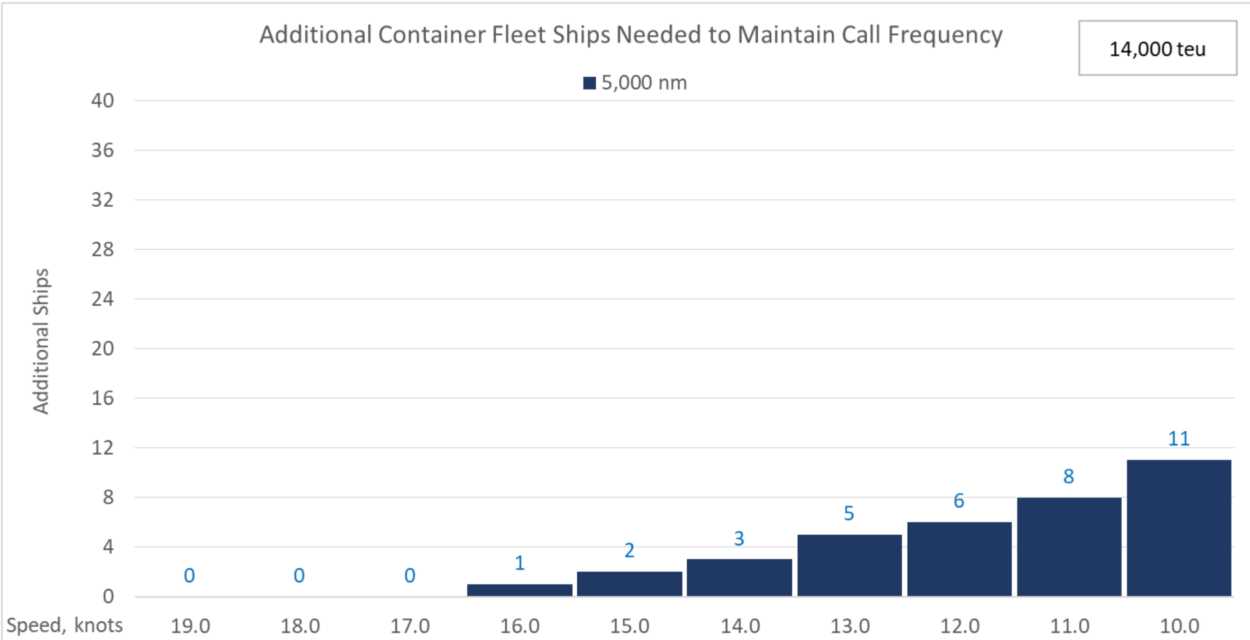


Figure 31: Illustrative results for Additional Ships Needed, Container 14,000 teu, 7,000 nm, High Baseline Speed Scenario

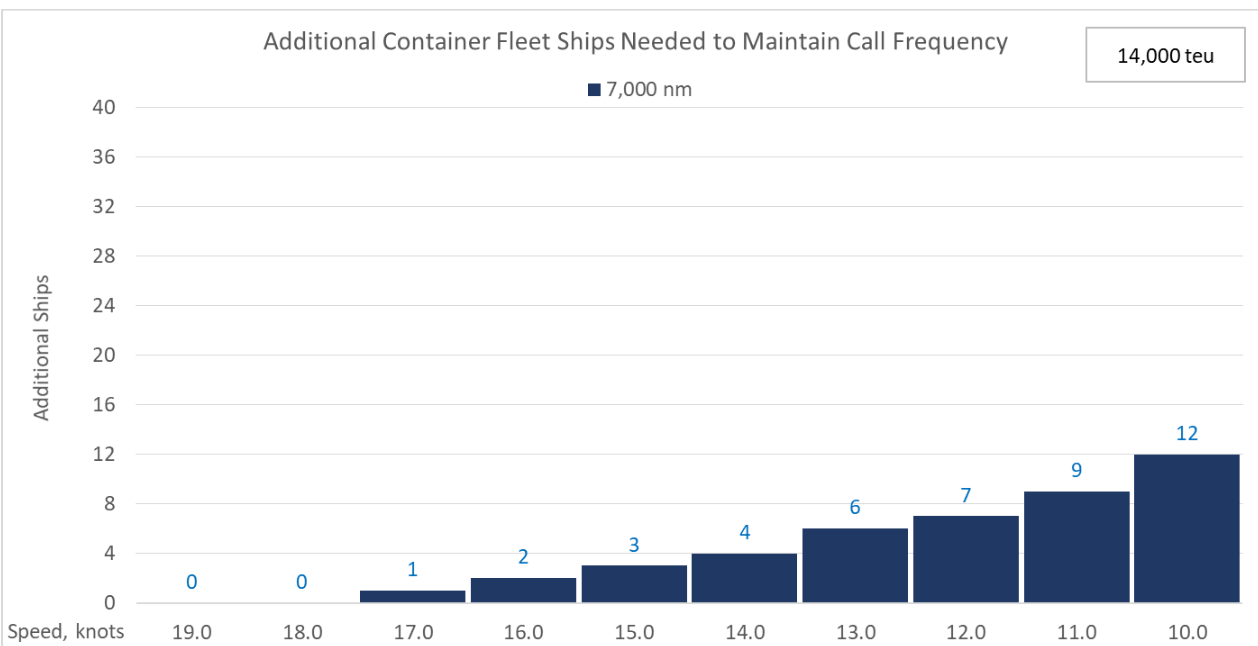
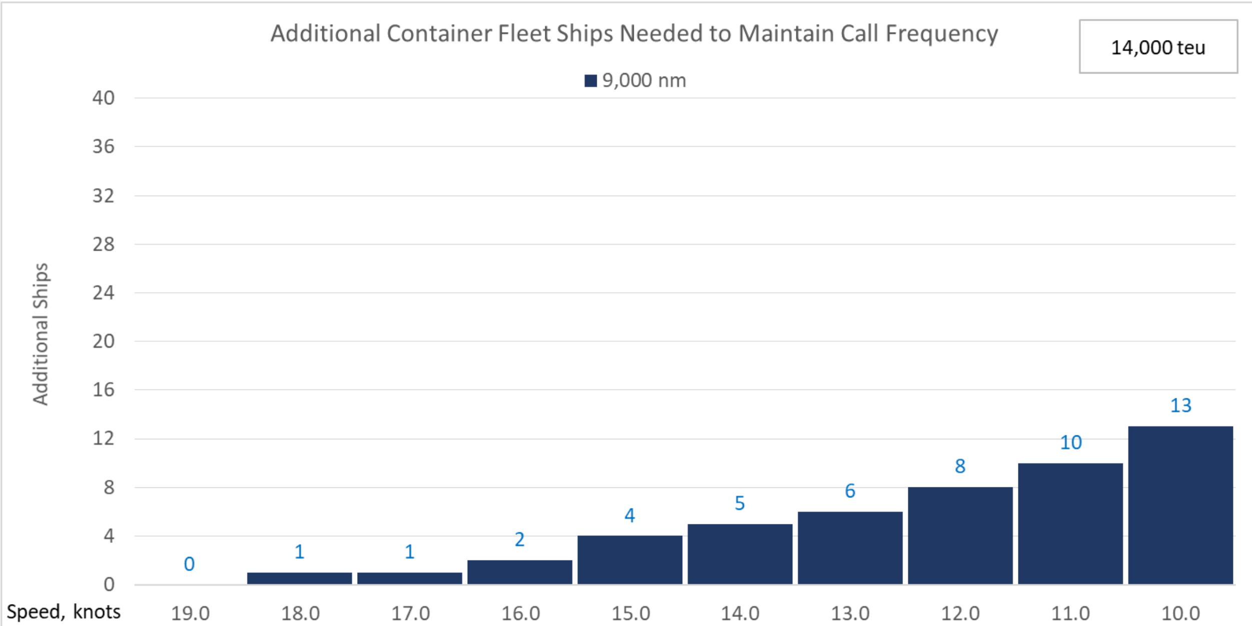


Figure 32: Illustrative Results for Additional Ships Needed, Container 14,000 teu, 9,000 nm, High Baseline Speed Scenario



The additional number of ships needed to maintain the acceptable call frequency ranges from 1 to 13.

Looking at the same ship type and size setup parameters as the analysis high baseline speed scenario above, but changing the baseline GSA speed to the 2012 annual average speed IMO 2014 scenario of 16.1 knots, the reduction in the magnitude of the results compared to the high baseline speed scenario are significant, as shown in the following series of figures.

Figure 33: Illustrative Results for Net Fleet Emission Changes, Container 14,000 teu, 1,000 nm, 2012 Global Average Speed Scenario

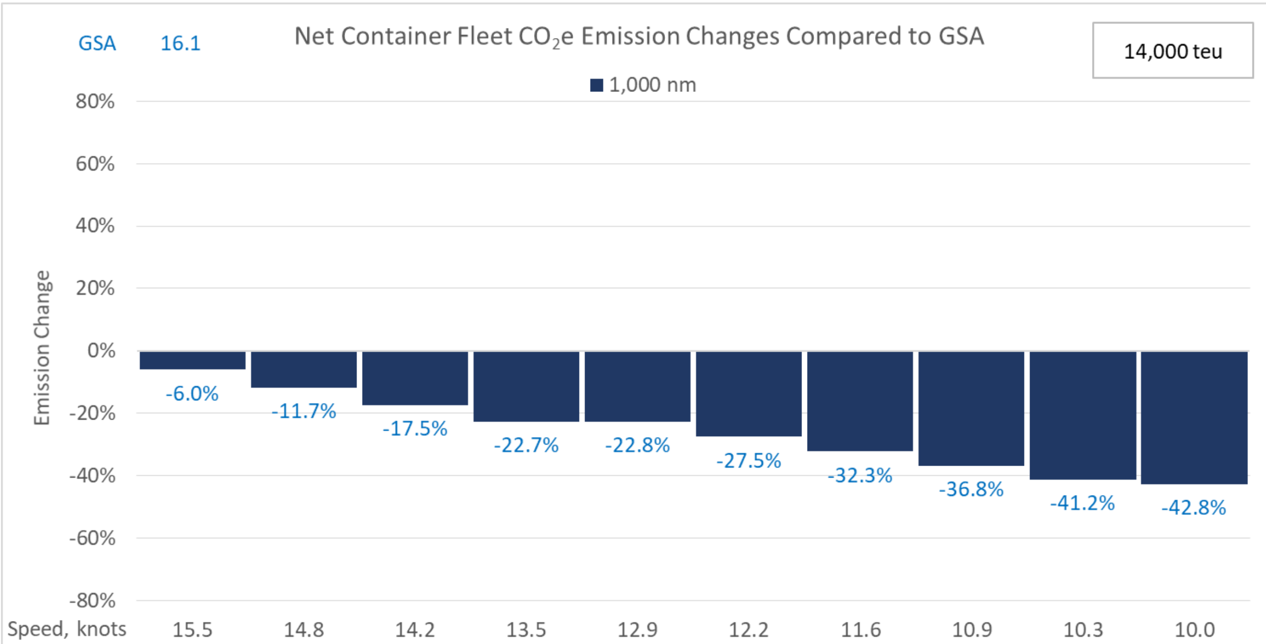


Figure 34: Illustrative Results for Net Fleet Emission Changes, Container 14,000 teu, 3,000 nm, 2012 Global Average Speed Scenario

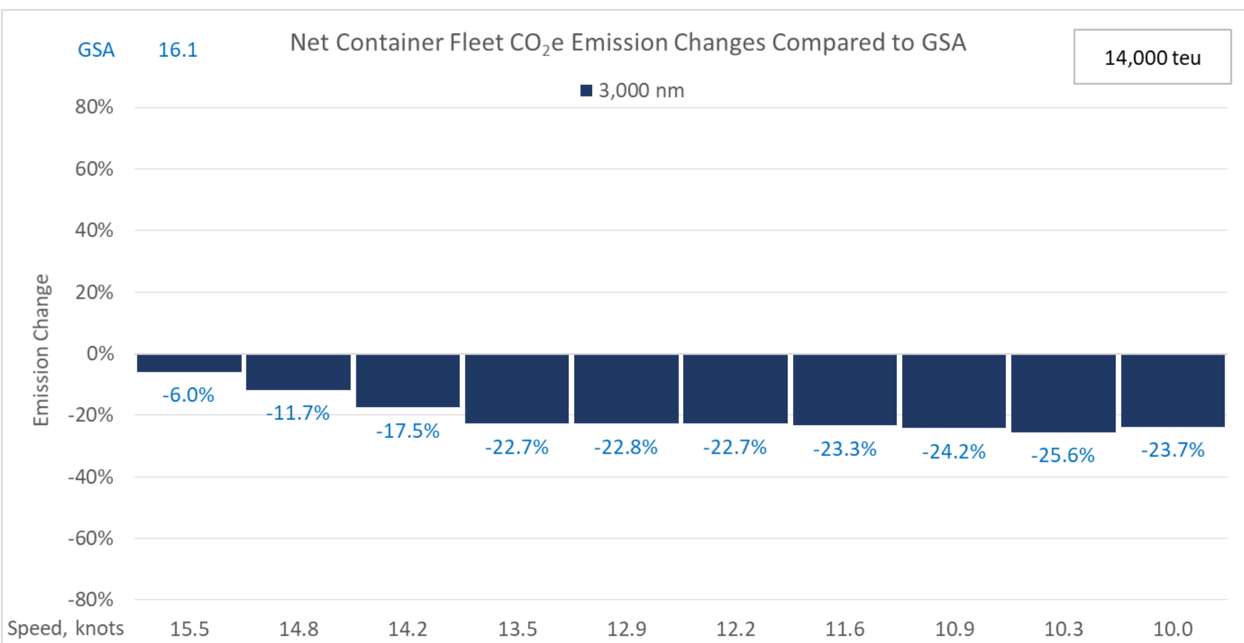


Figure 35: Illustrative Results for Net Fleet Emission Changes, Container 14,000 teu, 5,000 nm, 2012 Global Average Speed Scenario

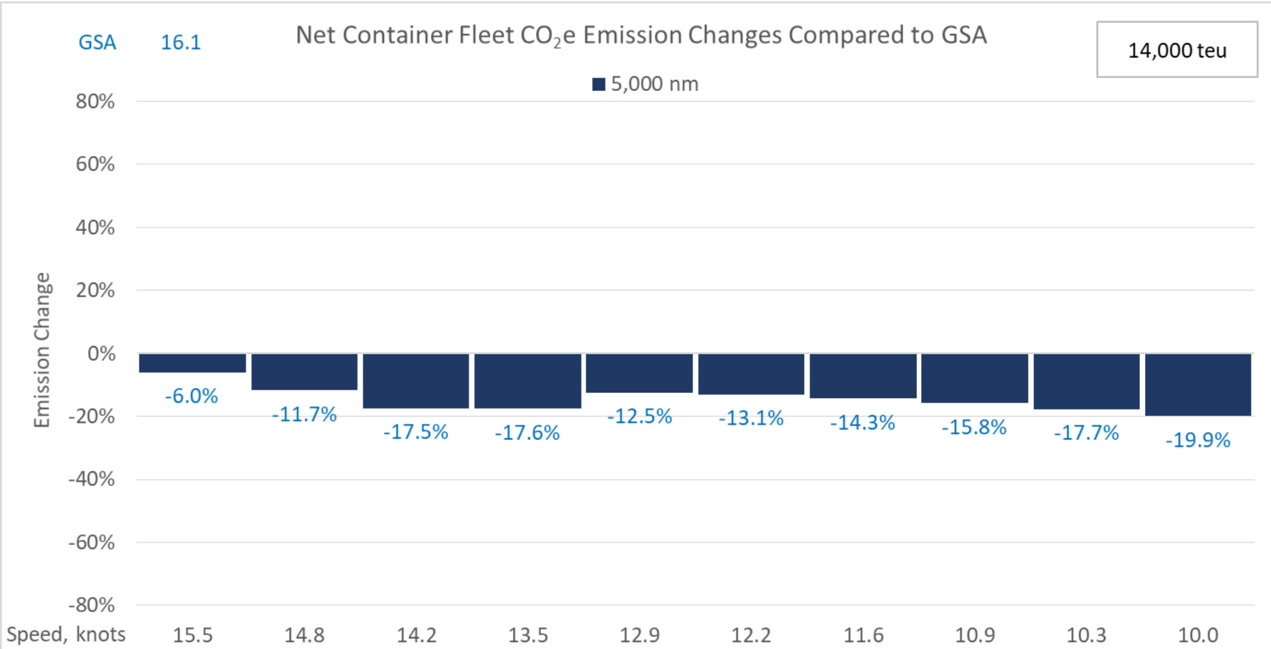


Figure 36: Illustrative Results for Net Fleet Emission Changes, Container 14,000 teu, 7,000 nm, 2012 Global Average Speed Scenario

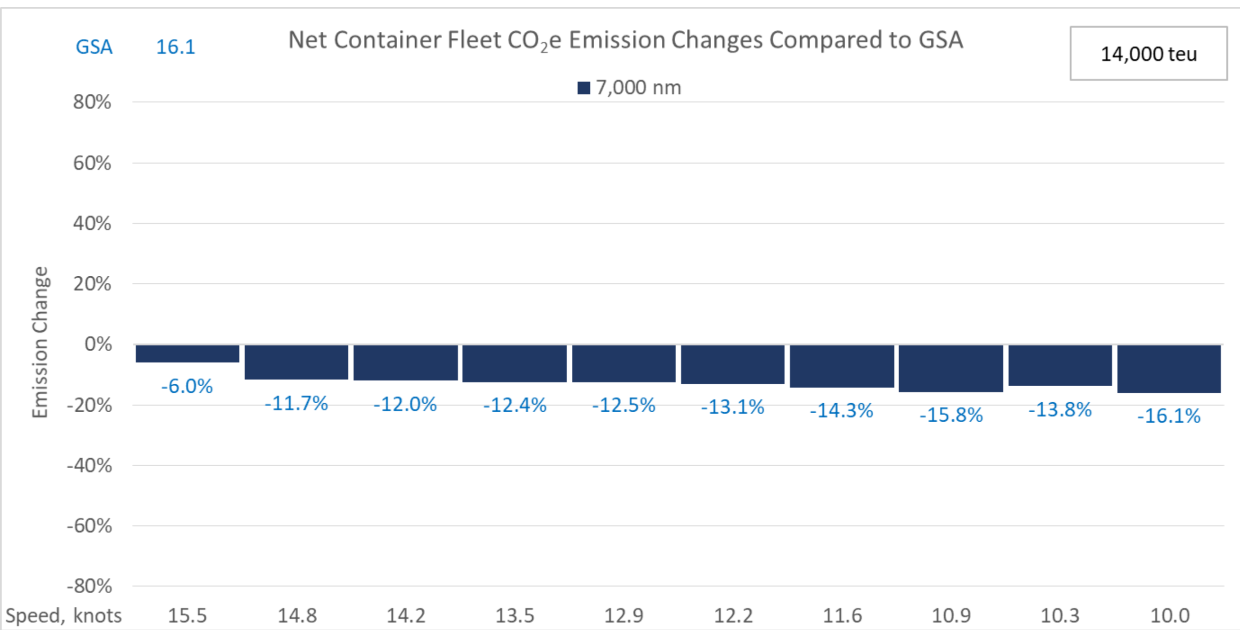
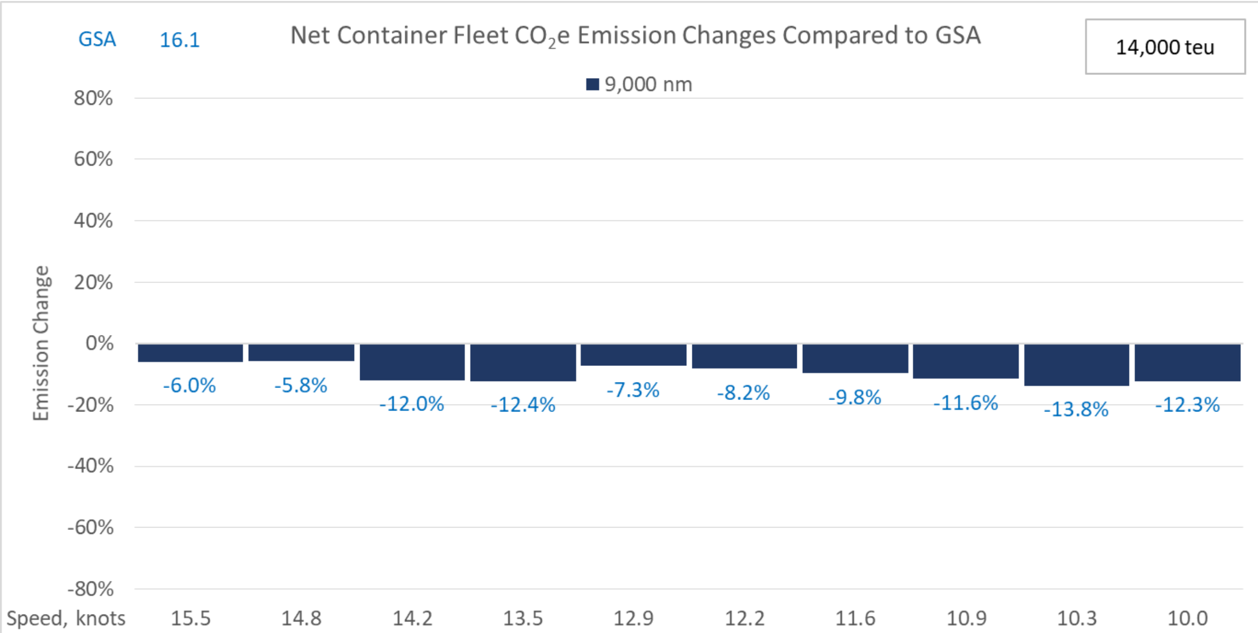


Figure 37: Illustrative Results for Net Fleet Emission Changes, Container 14,000 teu, 9,000 nm, 2012 Global Average Speed Scenario



Comparing the results of the two scenarios illustrates the significance of the baseline GSA speed. The emission reduction magnitude changes vary widely depending on distance and the number of ships that need to be added to the fleet to maintain the acceptable call frequency. As expected, potential emission reductions are lower for the slower 2012 annual average speed IMO 2014 scenario as the baseline speed is 20% lower than the high baseline speed scenario. Comparing the maximum emission reductions between the two scenarios, the results are as follows:

1,000 nm – $GSA_{20.0}$ 58% → $GSA_{16.1}$ 43% a 26% erosion in potential benefit
3,000 nm – $GSA_{20.0}$ 40% → $GSA_{16.1}$ 26% a 35% erosion in potential benefit
5,000 nm – $GSA_{20.0}$ 33% → $GSA_{16.1}$ 20% a 39% erosion in potential benefit
7,000 nm – $GSA_{20.0}$ 30% → $GSA_{16.1}$ 16% a 47% erosion in potential benefit
9,000 nm – $GSA_{20.0}$ 26% → $GSA_{16.1}$ 14% a 46% erosion in potential benefit

The additional ships required for the 2012 Global Average Speed Scenario for the 14,000 teu container ship fleet, using a 48-hour acceptable arrival delay, are presented in the following series of figures below. Note that for the 1,000 nm distance, no additional ships were needed so that figure has been omitted.

Figure 38: Illustrative Results for Additional Ships Needed, Container 14,000 teu, 3,000 nm, 2012 Global Average Speed Scenario

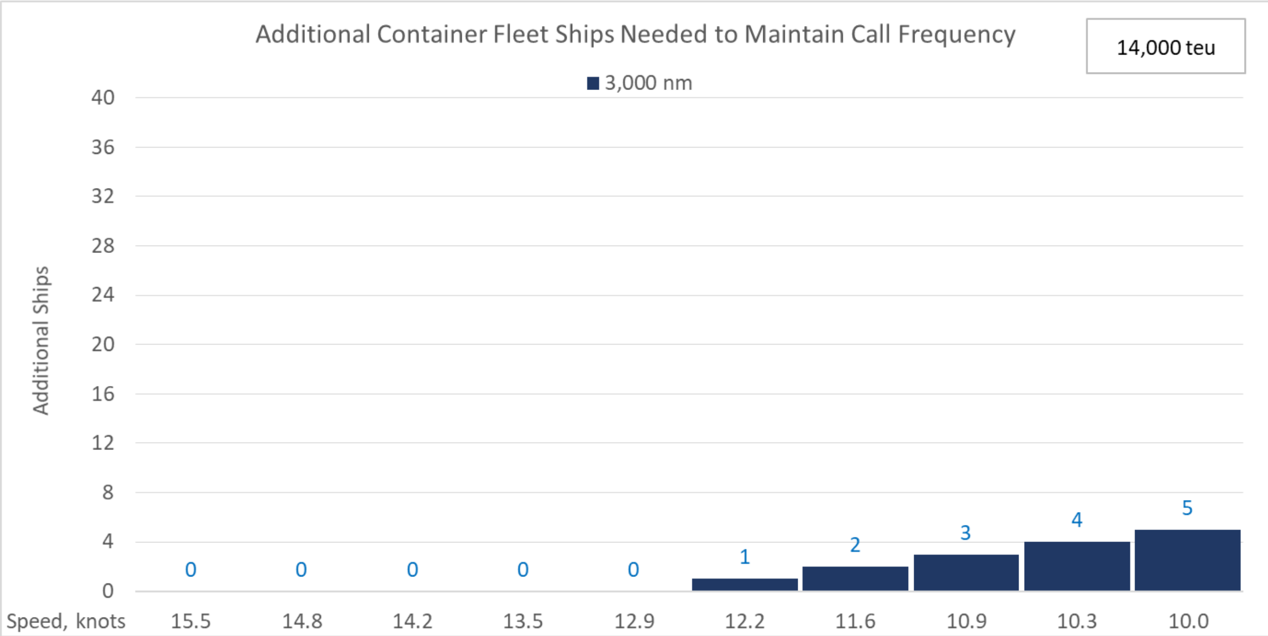


Figure 39: Illustrative Results for Additional Ships Needed, Container 14,000 teu, 5,000 nm, 2012 Global Average Speed Scenario

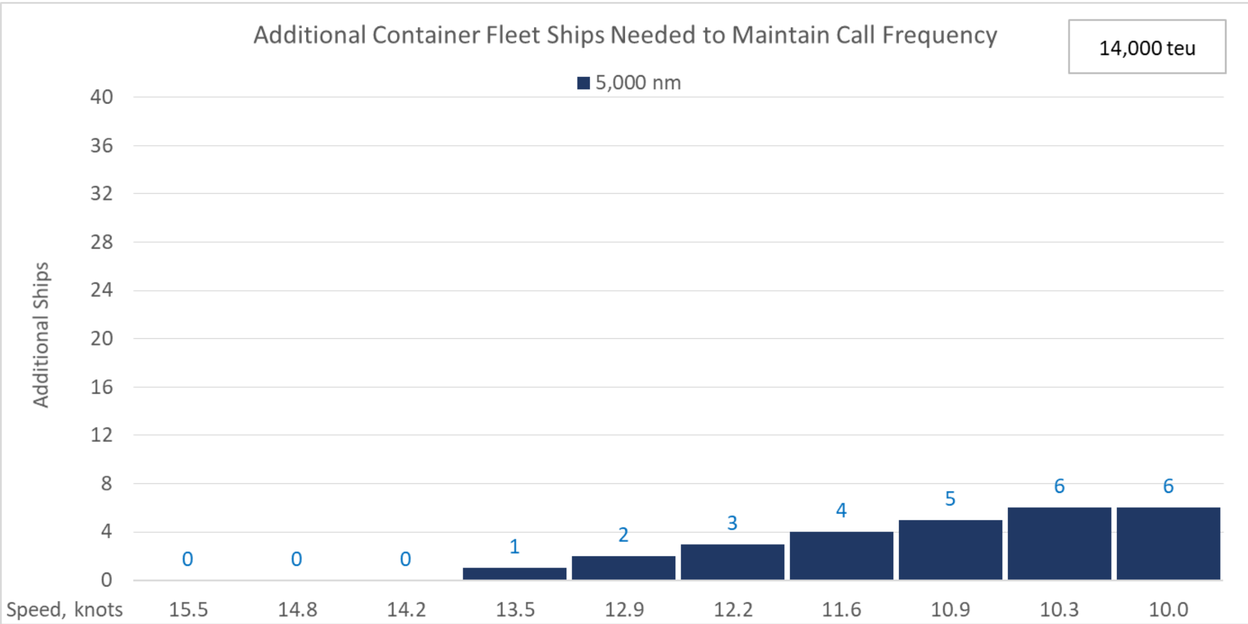


Figure 40: Illustrative results for Additional Ships Needed, Container 14,000 teu, 7,000 nm, 2012 Global Average Speed Scenario

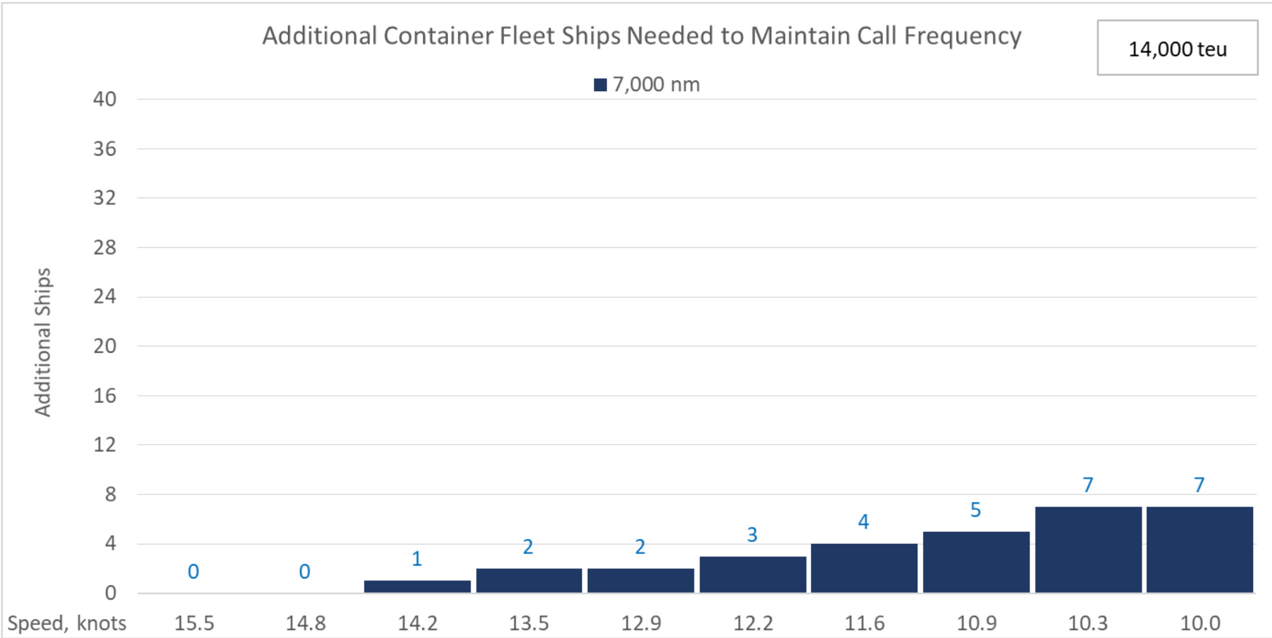
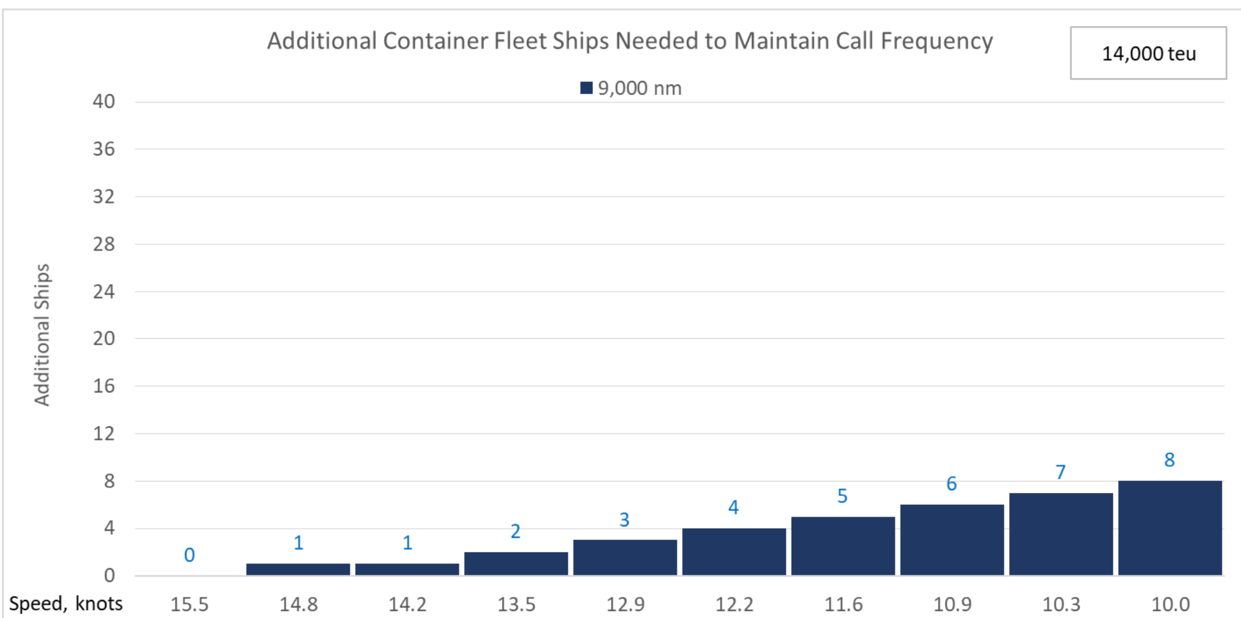


Figure 41: Illustrative Results for Additional Ships Needed, Container 14,000 teu, 9,000 nm, 2012 Global Average Speed Scenario



In both scenarios, the reduction magnitude diminishes with distance. As expected, the number of additional ships needed for each distance is reduced as well because the speed delta is reduced. With 2012 Global Average Speed Scenario, zero to eight additional ships are needed, instead of one to 13 additional ships for the high baseline speed scenario.

The variability of the selected baseline speed and a specific speed reduction increment and distance combination, the following tables present the potential change in emissions for each baseline speed scenario and for each container ship size and distance combination. These changes are illustrated in the following series of tables with both baseline speed scenarios on the same page for comparison.

Table 21: Illustrative Results for Net Fleet Emission Changes, Container Ships, 1,000 nm, High Baseline Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change									
		Distance 1									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-6.2%	-11.8%	-16.7%	-21.5%	-26.0%	-30.1%	-34.2%	-38.3%	-35.9%	-39.1%
	3,000 teu	-8.7%	-16.2%	-22.9%	-29.2%	-34.9%	-40.7%	-42.2%	-47.2%	-52.0%	-56.2%
	6,000 teu	-8.1%	-15.5%	-22.6%	-29.3%	-35.8%	-38.4%	-44.4%	-49.9%	-55.0%	-59.6%
	9,000 teu	-9.0%	-16.9%	-23.8%	-30.4%	-36.7%	-42.9%	-45.0%	-50.3%	-55.4%	-60.1%
	14,000 teu	-9.8%	-18.0%	-25.2%	-31.8%	-38.0%	-43.9%	-45.7%	-51.0%	-56.0%	-57.9%
	17,000 teu	-9.9%	-18.2%	-25.4%	-32.0%	-38.2%	-44.2%	-48.2%	-53.5%	-55.9%	-58.6%

Note: GSA-1 through GSA-10 are the incremental speeds listed in Table 18 for each ship type and size combination

Table 22: Illustrative Results for Net Fleet Emission Changes, Container Ships, 1,000 nm, 2012 Global Average Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change									
		Distance 1									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-3.9%	-7.5%	-11.1%	-14.4%	-17.9%	-21.3%	-24.5%	-19.8%	-22.8%	-24.7%
	3,000 teu	-5.9%	-11.6%	-17.1%	-22.3%	-27.6%	-27.3%	-32.0%	-36.5%	-40.6%	-42.2%
	6,000 teu	-5.6%	-11.7%	-17.2%	-17.8%	-23.0%	-27.9%	-32.9%	-37.5%	-41.8%	-44.5%
	9,000 teu	-5.8%	-11.4%	-17.1%	-22.5%	-22.6%	-27.6%	-32.3%	-37.0%	-41.2%	-44.1%
	14,000 teu	-6.0%	-11.7%	-17.5%	-22.7%	-22.8%	-27.5%	-32.3%	-36.8%	-41.2%	-42.8%
	17,000 teu	-4.8%	-9.8%	-14.2%	-16.1%	-20.5%	-24.8%	-29.1%	-33.3%	-37.2%	-39.6%

Note: GSA-1 through GSA-10 are the incremental speeds listed in Table 19 for each ship type and size combination

Table 23: Illustrative Results for Net Fleet Emission Change, Container Ships, 3,000 nm, High Baseline Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change									
		Distance 2									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-6.2%	-11.8%	-16.7%	-21.5%	-26.0%	-30.1%	-34.2%	-38.3%	-30.5%	-29.0%
	3,000 teu	-8.7%	-16.2%	-22.9%	-29.2%	-34.9%	-40.7%	-42.2%	-42.8%	-43.9%	-45.3%
	6,000 teu	-8.1%	-15.5%	-22.6%	-29.3%	-35.8%	-38.4%	-39.7%	-41.6%	-40.0%	-42.8%
	9,000 teu	-9.0%	-16.9%	-23.8%	-30.4%	-36.7%	-38.1%	-35.9%	-37.9%	-40.5%	-40.1%
	14,000 teu	-9.8%	-18.0%	-25.2%	-31.8%	-33.8%	-36.5%	-34.9%	-38.0%	-38.4%	-39.5%
	17,000 teu	-9.9%	-18.2%	-25.4%	-27.5%	-30.0%	-33.0%	-30.9%	-34.8%	-36.7%	-39.1%

Note: GSA-1 through GSA-10 are the incremental speeds listed in Table 18 for each ship type and size combination

Table 24: Illustrative Results for Net Fleet Emission Changes, Container Ships, 3,000 nm, 2012 Global Average Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change									
		Distance 2									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-3.9%	-7.5%	-11.1%	-14.4%	-17.9%	-21.3%	-24.5%	-19.8%	-22.8%	-24.7%
	3,000 teu	-5.9%	-11.6%	-17.1%	-22.3%	-27.6%	-27.3%	-32.0%	-31.2%	-35.7%	-32.5%
	6,000 teu	-5.6%	-11.7%	-17.2%	-17.8%	-23.0%	-27.9%	-27.3%	-32.3%	-32.1%	-30.6%
	9,000 teu	-5.8%	-11.4%	-17.1%	-22.5%	-22.6%	-21.5%	-26.7%	-26.5%	-26.5%	-25.5%
	14,000 teu	-6.0%	-11.7%	-17.5%	-22.7%	-22.8%	-22.7%	-23.3%	-24.2%	-25.6%	-23.7%
	17,000 teu	-4.8%	-9.8%	-14.2%	-10.6%	-15.2%	-14.7%	-14.9%	-19.9%	-20.5%	-19.4%

Note: GSA-1 through GSA-10 are the incremental speeds listed in Table 19 for each ship type and size combination

Table 25: Illustrative Results for Net Fleet Emission Changes, Container Ships, 5,000 nm, High Baseline Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change									
		Distance 3									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-6.2%	-11.8%	-16.7%	-21.5%	-26.0%	-24.3%	-23.3%	-28.1%	-19.9%	-18.8%
	3,000 teu	-8.7%	-16.2%	-22.9%	-29.2%	-29.5%	-35.7%	-32.6%	-34.0%	-31.9%	-34.4%
	6,000 teu	-8.1%	-15.5%	-22.6%	-29.3%	-30.5%	-28.1%	-30.5%	-33.2%	-32.4%	-32.7%
	9,000 teu	-9.0%	-16.9%	-23.8%	-24.6%	-26.2%	-28.6%	-26.7%	-29.7%	-33.1%	-33.4%
	14,000 teu	-9.8%	-18.0%	-25.2%	-27.2%	-29.7%	-32.7%	-27.6%	-31.4%	-32.6%	-31.6%
	17,000 teu	-9.9%	-18.2%	-20.4%	-22.9%	-25.9%	-25.6%	-27.4%	-28.6%	-31.2%	-34.2%

Note: GSA-1 through GSA-10 are the incremental speeds listed in Table 18 for each ship type and size combination

Table 26: Illustrative Results for Net Fleet Emission Changes, Container Ships, 5,000 nm, 2012 Global Average Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change									
		Distance 3									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-3.9%	-7.5%	-11.1%	-14.4%	-17.9%	-21.3%	-18.2%	-13.2%	-9.9%	-12.2%
	3,000 teu	-5.9%	-11.6%	-17.1%	-22.3%	-21.6%	-21.2%	-20.7%	-20.6%	-20.8%	-22.9%
	6,000 teu	-5.6%	-11.7%	-17.2%	-17.8%	-16.6%	-15.9%	-21.7%	-21.9%	-22.4%	-21.3%
	9,000 teu	-5.8%	-11.4%	-17.1%	-16.0%	-16.1%	-15.5%	-15.4%	-21.3%	-21.6%	-20.8%
	14,000 teu	-6.0%	-11.7%	-17.5%	-17.6%	-12.5%	-13.1%	-14.3%	-15.8%	-17.7%	-19.9%
	17,000 teu	-4.8%	-9.8%	-8.5%	-10.6%	-9.9%	-9.7%	-10.2%	-15.5%	-16.3%	-15.4%

Note: GSA-1 through GSA-10 are the incremental speeds listed in Table 19 for each ship type and size combination

Table 27: Illustrative Results for Net Fleet Emission Changes, Container Ships, 7,000 nm, High Baseline Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 4									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-6.2%	-11.8%	-16.7%	-14.9%	-19.8%	-18.5%	-23.3%	-22.9%	-14.5%	-13.7%
	3,000 teu	-8.7%	-16.2%	-22.9%	-23.3%	-24.1%	-30.8%	-27.8%	-25.2%	-27.9%	-30.7%
	6,000 teu	-8.1%	-15.5%	-22.6%	-23.4%	-25.2%	-23.0%	-25.8%	-29.0%	-28.7%	-29.4%
	9,000 teu	-9.0%	-16.9%	-17.4%	-24.6%	-26.2%	-28.6%	-26.7%	-25.5%	-29.4%	-30.1%
	14,000 teu	-9.8%	-18.0%	-20.2%	-22.7%	-25.6%	-29.0%	-24.0%	-28.2%	-29.7%	-28.9%
	17,000 teu	-9.9%	-12.8%	-15.4%	-18.4%	-21.7%	-25.6%	-24.0%	-25.5%	-28.4%	-31.8%

Note: GSA-1 through GSA-10 are the incremental speeds listed in Table 18 for each ship type and size combination

Table 28: Illustrative Results for Net Fleet Emission Changes, Container Ships, 7,000 nm, 2012 Global Average Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 4									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-3.9%	-7.5%	-11.1%	-14.4%	-11.1%	-14.7%	-11.9%	-6.5%	-3.4%	-5.9%
	3,000 teu	-5.9%	-11.6%	-17.1%	-15.9%	-21.6%	-15.2%	-15.0%	-15.3%	-15.9%	-18.1%
	6,000 teu	-5.6%	-11.7%	-17.2%	-11.0%	-10.2%	-15.9%	-16.1%	-16.7%	-17.6%	-16.7%
	9,000 teu	-5.8%	-11.4%	-10.1%	-16.0%	-9.6%	-9.5%	-15.4%	-16.0%	-16.7%	-16.1%
	14,000 teu	-6.0%	-11.7%	-12.0%	-12.4%	-12.5%	-13.1%	-14.3%	-15.8%	-13.8%	-16.1%
	17,000 teu	-4.8%	-3.8%	-8.5%	-5.0%	-4.6%	-9.7%	-10.2%	-11.0%	-12.1%	-15.4%

Note: GSA-1 through GSA-10 are the incremental speeds listed in Table 19 for each ship type and size combination

Table 29: Illustrative Results for Net Fleet Emission Changes, Container Ships, 9,000 nm, High Baseline Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change									
		Distance 5									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-6.2%	-11.8%	-16.7%	-14.9%	-13.6%	-18.5%	-17.8%	-17.8%	-9.2%	-8.7%
	3,000 teu	-8.7%	-16.2%	-16.5%	-23.3%	-24.1%	-25.9%	-23.0%	-25.2%	-23.9%	-27.1%
	6,000 teu	-8.1%	-15.5%	-16.2%	-17.5%	-19.8%	-17.9%	-21.2%	-24.9%	-24.9%	-26.0%
	9,000 teu	-9.0%	-16.9%	-17.4%	-18.8%	-20.9%	-23.9%	-22.1%	-25.5%	-25.7%	-26.8%
	14,000 teu	-9.8%	-12.5%	-20.2%	-22.7%	-21.4%	-25.2%	-24.0%	-24.9%	-26.7%	-26.3%
	17,000 teu	-9.9%	-12.8%	-15.4%	-18.4%	-21.7%	-21.9%	-24.0%	-25.5%	-28.4%	-29.3%

Note: GSA-1 through GSA-10 are the incremental speeds listed in Table 18 for each ship type and size combination

Table 30: Illustrative Results for Net Fleet Emission Changes, Container Ships, 9,000 nm, 2012 Global Average Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change									
		Distance 5									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-3.9%	-7.5%	-11.1%	-7.3%	-11.1%	-8.1%	-11.9%	0.2%	-3.4%	0.4%
	3,000 teu	-5.9%	-11.6%	-10.2%	-15.9%	-15.5%	-9.1%	-15.0%	-15.3%	-15.9%	-13.2%
	6,000 teu	-5.6%	-11.7%	-10.3%	-11.0%	-10.2%	-9.9%	-16.1%	-16.7%	-17.6%	-16.7%
	9,000 teu	-5.8%	-11.4%	-10.1%	-9.6%	-9.6%	-9.5%	-9.7%	-10.8%	-11.8%	-16.1%
	14,000 teu	-6.0%	-5.8%	-12.0%	-12.4%	-7.3%	-8.2%	-9.8%	-11.6%	-13.8%	-12.3%
	17,000 teu	-4.8%	-3.8%	-8.5%	-5.0%	-4.6%	-9.7%	-10.2%	-11.0%	-12.1%	-11.4%

Note: GSA-1 through GSA-10 are the incremental speeds listed in Table 19 for each ship type and size combination

Examining the results of the two baseline speed scenarios, for container ships, the tables illustrate that the combination of baseline speed, average propulsion rating, average maximum rated speed, number of added ships, when the boilers are triggered, distance sailed, and allowable delay tolerance of arrival of the ship for each ship type and size combination, which all can have significant impacts on the potential emission reduction benefits. As shown above, for a single reduced speed, even within the same ship type category, slow steaming does not equate to consistent reduction levels across the various sizes.

This is why the SSA Model approach was proposed for this project. The model allows the user to set all these key variables from ship parameters, fleet size, distances, baseline and incremental speeds, and the allowable delay tolerance of arrival across all ship type and size combinations, so that each APEC economy or stakeholder can evaluate their own specific scenarios to determine the range of potential emission reductions and/or optimal speed. In addition, due to the wide array of variables that can be set by the user, the SSA model can be used if IMO agrees to a new baseline speed scenario.

These comparisons also help demonstrate one of the more significant challenges with slow steaming from an emission reduction strategy standpoint, setting of the optimal baseline GSA speeds across multiple ship type and size combinations, as it has direct consequences on the potential magnitude of reductions. At the ports that implement VSR, to determine emissions benefits, they used a baseline speed based on at least three years of pre-VSR speed data and then have supplemented that data set each year with observed non-compliant ship speeds in the same geographical domain.

A further challenge is the accuracy of compliance due to the land based and/or satellite AIS data. Setting a slow steaming speed limit even to a specific knot, say 15 knots, would have to take into account the variance of AIS with actual speed over ground. The magnitude of actual reductions is further dependent on what speed the ship is turning for versus its speed overground, hull/propeller/ruder condition, draft, weather, and sea conditions. The data parameters to cover all these uncertainties do not exist for the international fleet. The only presumption that can be made is that over a large enough population and time period, these uncertainties tend to mitigate themselves. For example, for every ship that experiences adverse weather conditions, there is a ship that experiences beneficial weather conditions, and so those differences cancel each other out. For now, this is what the land-based regulatory agencies have agreed to accept, until better data is available. The model estimates ship emissions based on the same approached used in IMO 2014 and includes the same factors for weather and hull conditions. When comparing the same fleet's performance over a given distance and speeds, the model assumes the fleet is transiting all the incrementally slower speeds with the same weather and hull conditions, therefore these conditions generally cancel out.

4.4.2 Dry Bulk Ships

Dry bulk or bulk ships compared to container ships are equipped with smaller engines and lower maximum rated speeds. From an emission strategy standpoint, this ship type provides significantly less potential for emission reductions.

For the APEC study analysis, the same two baseline speed scenarios were used for dry bulk ships. For the high baseline speed scenario, 12.0 knots were used which is slightly higher than the 2012 Global Average Speed Scenario, which ranged from 11.7 and 11.8 knots depending on ship size. The ship parameters and arrival delay tolerances used for both scenarios are presented in Tables 17 and 18, above.

The dry bulk ships were analysed using the SSA Model Module 1 and the following figures illustrate the changes in emissions for a fleet of 12 dry bulk capesize ships compared to their high baseline speed scenario for each speed reduction increment of 0.2 knots and over each distance. Note that all tables and figures are provided in the SSA Model file.

Figure 42: Illustrative Results for Net fleet Emission Changes, Dry Bulk Capesize, 600 nm, High Baseline Speed Scenario

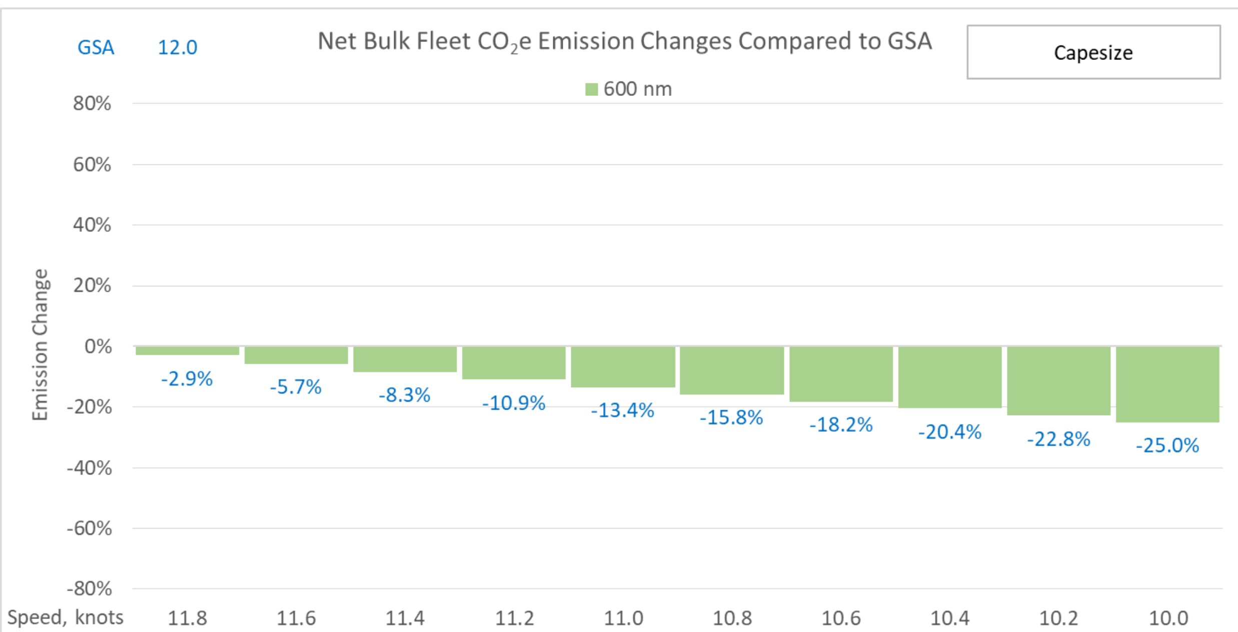


Figure 43: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Capesize, 3,950 nm, High Baseline Speed Scenario

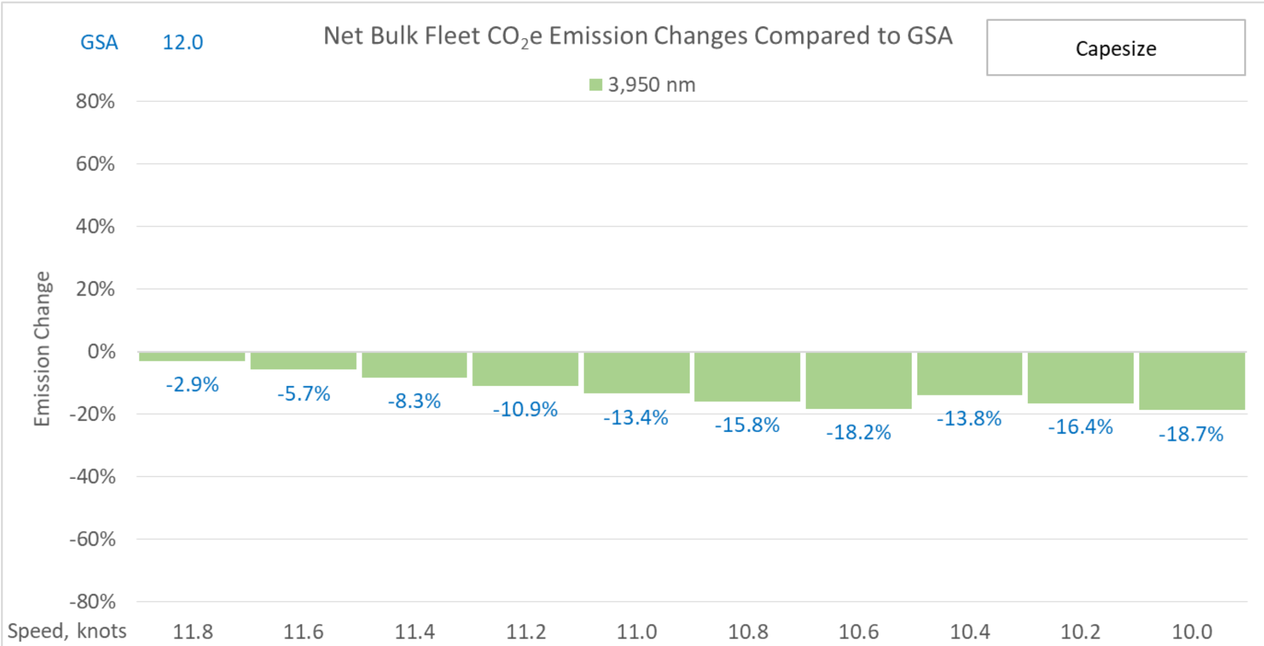


Figure 44: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Capesize, 7,300 nm, High Baseline Speed Scenario

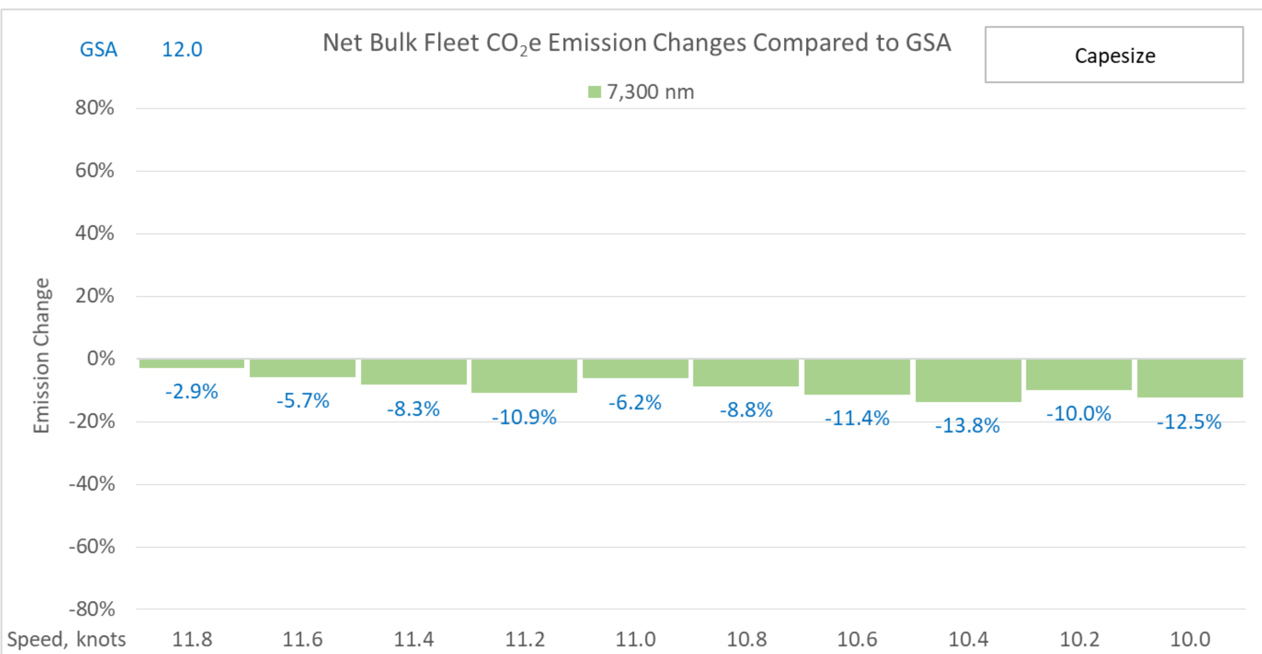


Figure 45: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Capesize, 10,650 nm, High Baseline Speed Scenario

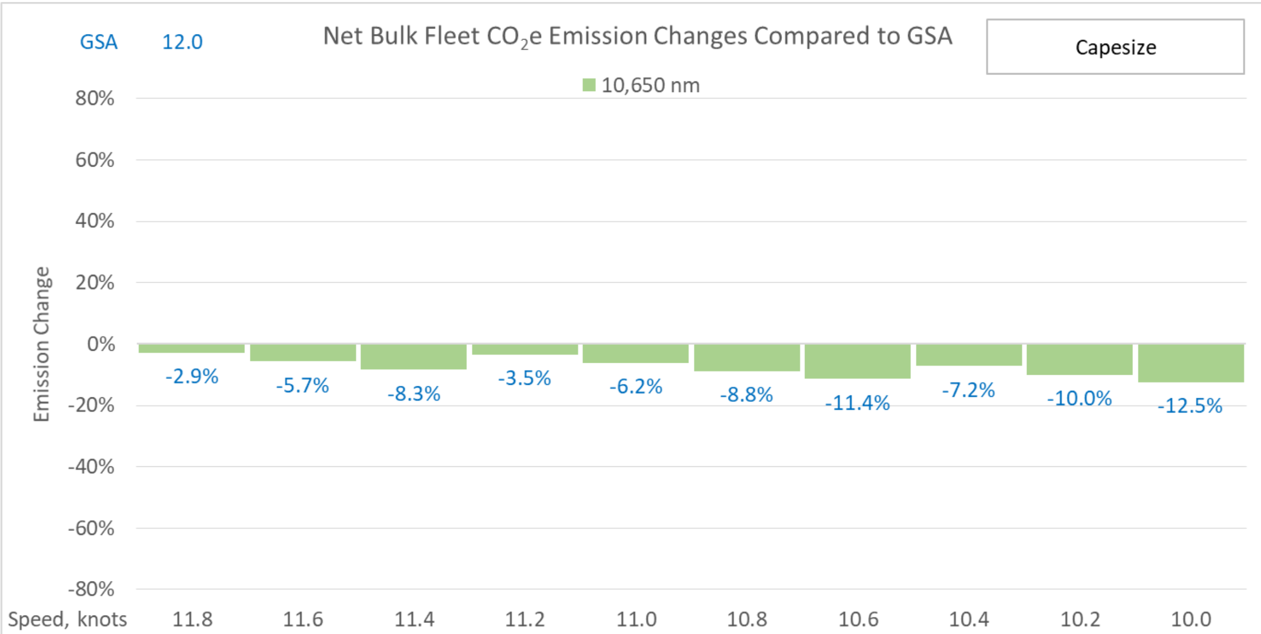
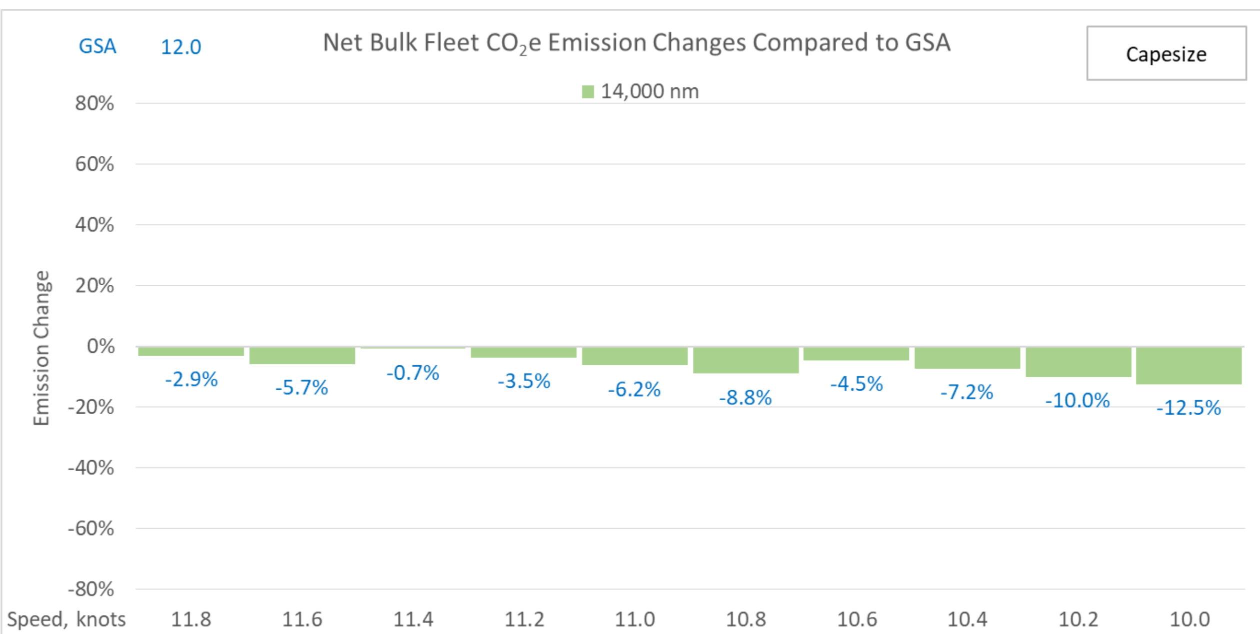


Figure 46: Illustrative results for Net Fleet Emission Changes, Dry Bulk Capesize, 14,000 nm, High Baseline Speed Scenario



Examining the capesize dry bulk ship example, using a baseline GSA speed of 12.0 knots, the emissions changes vary widely depending on distance and the number of ships that need to be added to the fleet to maintain the acceptable call frequency. The maximum emission reductions for the scenario are:

Distance 1 – 600 nm, maximum reduction of 25%, at 10.0 knots
Distance 2 – 3,950 nm, maximum reduction of 19%, at 10.0 knots
Distance 3 – 7,300 nm, maximum reduction of 14%, at 10.4 knots
Distance 4 – 10,650 nm, maximum reduction of 13%, at 10.0 knots
Distance 5 – 14,000 nm, maximum reduction of 13%, at 10.0 knots

Note that as the distance extends the benefits are reduced from 25% to 13% or almost halved. This is due to the addition of ships to the fleet based on the acceptable arrival delay factor, as illustrated in the figures below. Note that no addition ships were need for the 600 nm range and the associated figure was omitted. Starting at the 3,950 nm transit and beyond there are one to two points in the speed range that provide almost the same benefits as the speed listed above (at faster speeds) and there are also incremental speeds that offer no benefit from the baseline speed. This is due to the impact of the emissions associated with the new ship coming into the fleet.

Note, that both baseline speed scenarios have a narrow spread on the baseline speed, with erosion ranging from no change to 25% reduction in emissions benefits. Also note that on some of the figures, the addition of another ship to the fleet, due to time delays, results in the emission reduction trend to break and start over again. All tables are provided in the attached SSA Model Module 1 files accompanying this report.

For context, in addition to the applicable routes listed in Table 20, the above distances are similar to the following inter-APEC routes:

Singapore to Jakarta, Indonesia	525 nm
Gladstone, Australia to Guangzhou, China	3,885 nm
Vancouver, Canada to Bangkok, Thailand	7,170 nm
Valparaiso, Chile to Shanghai, China	10,134 nm
Montreal, Canada to Bangkok, Thailand (via Panamá Canal)	13,535 nm

From a bulk ship perspective, slow steaming is most effective over shorter transit distances as the erosion of benefits from added ships has a greater impact compared to faster-higher powered ships such as container ships.

Figure 47: Illustrative Results for Additional Ships Needed, Dry Bulk Capesize, 3,950 nm, High Baseline Speed Scenario

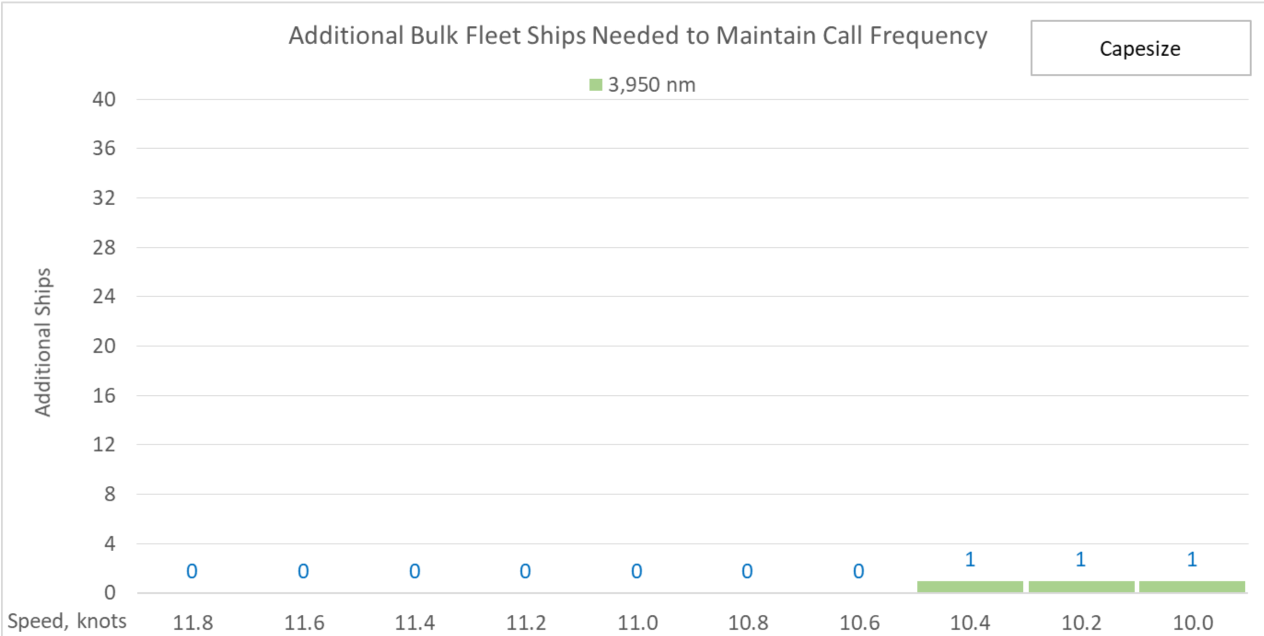


Figure 48: Illustrative Results for Additional Ships Needed, Dry Bulk Capesize, 7,300 nm, High Baseline Speed Scenario

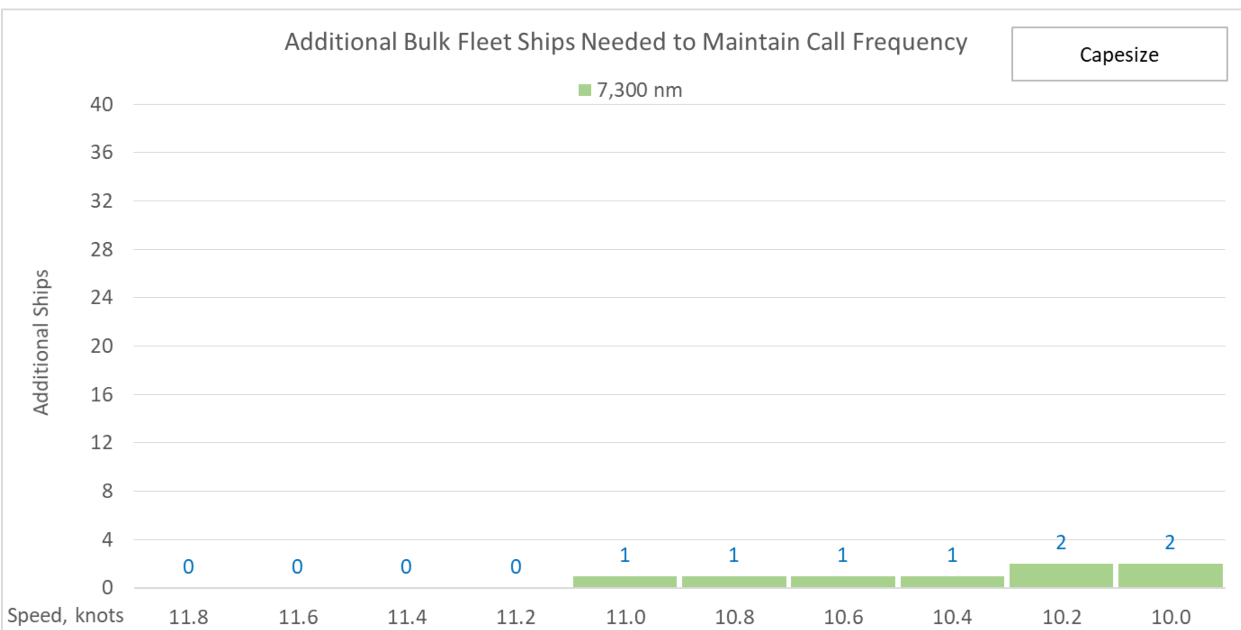


Figure 49: Illustrative Results for Additional Ships Needed, Dry Bulk Capesize, 10,650 nm, High Baseline Speed Scenario

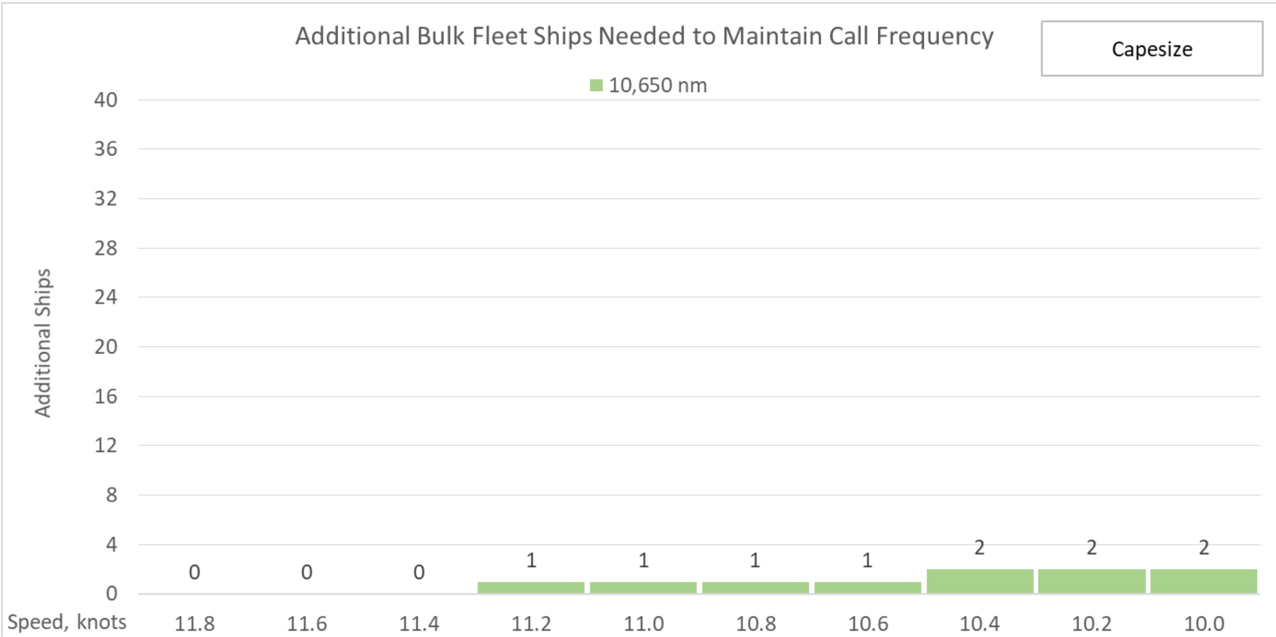
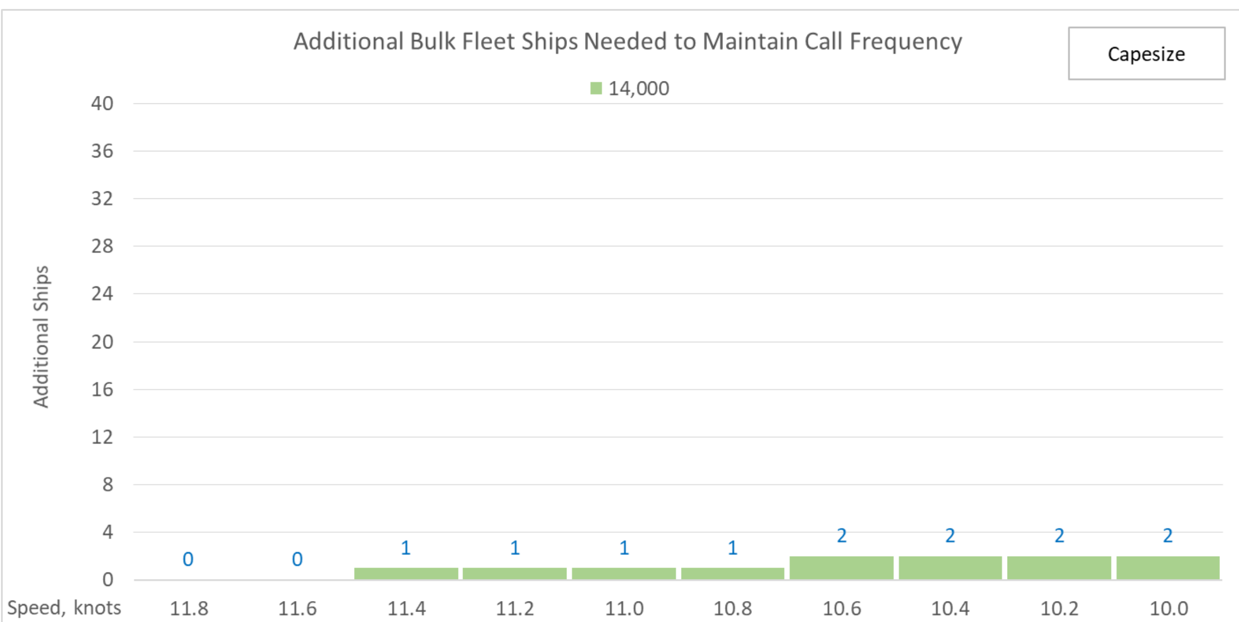


Figure 50: Illustrative results for Additional Ships Needed, Dry Bulk Capesize, 14,000 nm, High Baseline Speed Scenario



The challenge with the compressed speed reduction range of two knots (baseline GSA speed of 12 slowing down to 10 knots) is that this range of speed falls well within the uncertainty associated with AIS accuracy, weather, ship operations, the ability of the ship's captain to maintain such slight reduction, and other parameters discussed above. Because of these factors, the actual realized reductions from a slow steaming strategy for these slower ships, is marginal at best over longer distances requiring the addition of extra ships to maintain call frequency.

Note that the incremental speed reduction speeds used for the dry bulk ship scenarios is presented in Tables 18 and 19, above. Detailed results related to the change in emissions for both modelled scenarios are presented in the tables below.

Table 31: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Ships, 600 nm, High Baseline Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change – Distance 1									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Bulk	Handymax	-3.1%	-6.0%	-8.7%	-11.3%	-13.9%	-16.3%	-18.7%	-21.0%	-23.2%	-25.3%
	Panamax	-2.9%	-5.6%	-8.2%	-10.6%	-13.1%	-15.4%	-17.7%	-19.8%	-22.1%	-24.2%
	Capesize	-2.9%	-5.7%	-8.3%	-10.9%	-13.4%	-15.8%	-18.2%	-20.4%	-22.8%	-25.0%

Table 32: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Ships, 600 nm, 2012 Global Average Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change – Distance 1									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Bulk	Handymax	-2.7%	-5.3%	-7.7%	-10.1%	-12.3%	-14.5%	-16.8%	-18.9%	-20.8%	-23.0%
	Panamax	-2.6%	-4.9%	-7.2%	-9.6%	-11.8%	-13.9%	-15.9%	-18.0%	-19.9%	-21.9%
	Capesize	-2.6%	-5.0%	-7.4%	-9.9%	-12.1%	-14.2%	-16.5%	-18.5%	-20.7%	-21.6%

Table 33: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Ships, 3,950 nm, High Baseline Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 2 GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Bulk	Handymax	-3.1%	-6.0%	-8.7%	-11.3%	-13.9%	-16.3%	-18.7%	-21.0%	-23.2%	-25.3%
	Panamax	-2.9%	-5.6%	-8.2%	-10.6%	-13.1%	-15.4%	-17.7%	-19.8%	-15.6%	-17.9%
	Capesize	-2.9%	-5.7%	-8.3%	-10.9%	-13.4%	-15.8%	-18.2%	-13.8%	-16.4%	-18.7%

Table 34: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Ships, 3,950 nm, 2012 Global Average Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 2 GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Bulk	Handymax	-2.7%	-5.3%	-7.7%	-10.1%	-12.3%	-14.5%	-16.8%	-18.9%	-20.8%	-23.0%
	Panamax	-2.6%	-4.9%	-7.2%	-9.6%	-11.8%	-13.9%	-15.9%	-18.0%	-19.9%	-15.4%
	Capesize	-2.6%	-5.0%	-7.4%	-9.9%	-12.1%	-14.2%	-16.5%	-18.5%	-14.1%	-15.1%

Table 35: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Ships, 7,300 nm, High Baseline Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 3									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Bulk	Handymax	-3.1%	-6.0%	-8.7%	-11.3%	-13.9%	-16.3%	-11.9%	-14.4%	-16.8%	-19.1%
	Panamax	-2.9%	-5.6%	-8.2%	-10.6%	-13.1%	-8.3%	-10.8%	-13.1%	-15.6%	-11.5%
	Capesize	-2.9%	-5.7%	-8.3%	-10.9%	-6.2%	-8.8%	-11.4%	-13.8%	-10.0%	-12.5%

Table 36: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Ships, 7,300 nm, 2012 Global Average Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 3									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Bulk	Handymax	-2.7%	-5.3%	-7.7%	-10.1%	-12.3%	-14.5%	-9.9%	-12.1%	-14.3%	-16.5%
	Panamax	-2.6%	-4.9%	-7.2%	-9.6%	-11.8%	-6.7%	-8.8%	-11.2%	-13.2%	-15.4%
	Capesize	-2.6%	-5.0%	-7.4%	-9.9%	-4.8%	-7.1%	-9.5%	-11.7%	-14.1%	-8.5%

Table 37: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Ships, 10,650 nm, High Baseline Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 4									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Bulk	Handymax	-3.1%	-6.0%	-8.7%	-11.3%	-6.7%	-9.3%	-11.9%	-14.4%	-10.4%	-12.9%
	Panamax	-2.9%	-5.6%	-8.2%	-3.2%	-5.8%	-8.3%	-10.8%	-6.5%	-9.2%	-11.5%
	Capesize	-2.9%	-5.7%	-8.3%	-3.5%	-6.2%	-8.8%	-11.4%	-7.2%	-10.0%	-12.5%

Table 38: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Ships, 10,650 nm, 2012 Global Average Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 4									
		GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Bulk	Handymax	-2.7%	-5.3%	-7.7%	-10.1%	-5.0%	-7.4%	-9.9%	-12.1%	-14.3%	-10.1%
	Panamax	-2.6%	-4.9%	-7.2%	-2.1%	-4.4%	-6.7%	-8.8%	-11.2%	-6.5%	-8.9%
	Capesize	-2.6%	-5.0%	-7.4%	-2.4%	-4.8%	-7.1%	-9.5%	-11.7%	-7.5%	-8.5%

Table 39: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Ships, 14,000 nm, High Baseline Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 5 GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Bulk	Handymax	-3.1%	-6.0%	-8.7%	-3.9%	-6.7%	-9.3%	-11.9%	-7.8%	-10.4%	-12.9%
	Panamax	-2.9%	-5.6%	-0.6%	-3.2%	-5.8%	-8.3%	-10.8%	-6.5%	-9.2%	-11.5%
	Capesize	-2.9%	-5.7%	-0.7%	-3.5%	-6.2%	-8.8%	-4.5%	-7.2%	-10.0%	-12.5%

Table 40: Illustrative Results for Net Fleet Emission Changes, Dry Bulk Ships, 14,000 nm, 2012 Global Average Speed Scenario

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 5 GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Bulk	Handymax	-2.7%	-5.3%	-7.7%	-2.6%	-5.0%	-7.4%	-9.9%	-12.1%	-7.7%	-10.1%
	Panamax	-2.6%	-4.9%	0.5%	-2.1%	-4.4%	-6.7%	-8.8%	-4.3%	-6.5%	-8.9%
	Capesize	-2.6%	-5.0%	0.3%	-2.4%	-4.8%	-7.1%	-9.5%	-4.9%	-7.5%	-8.5%

Examining both the container ships and dry bulk ship scenarios, the key findings related to slow steaming as an emission reduction strategy are the following:

1. As illustrated from the container and dry bulk scenarios evaluated above, there is ***not*** a single speed that results in consistently the highest reductions across all container or dry bulk ship size and distance combinations.

2. The baseline GSA speeds are critical in determining the potential magnitude of emissions reductions from a slow steaming emission reduction strategy. For container ships, changes of less than four knots had significant impacts on potential magnitude of emission reduction benefits.

3. Slow steaming is most effective for ships designed to transit the ocean at high-speeds, like container ships, vehicle carriers, etc. That being said, the magnitude of potential reductions is not the same even across same ship type when considering size and distance.

4. Under both the high baseline speed and 2012 Global Average Speed Scenarios, container ship and dry bulk scenarios showed eroding emission reduction benefits with longer transit distances.

5. Additional ships will most likely be needed to ensure that services maintain the cargo owner's acceptable arrival tolerances, however, as noted above, there comes a point when the speeds maybe too slow and thus option of transporting goods by ship untenable. The result is either a modal shift to a higher carbon intensive form of transportation with a net result of higher GHG emissions or loss of trade.

6. Trying to determine and set an optimal slow steaming speed will be challenging as demonstrated above. Slight changes in speeds can have a dramatic impact on the effectiveness of a slow steaming strategy. Compounding this difficulty are the uncertainties associated with the AIS signal accuracy, weather conditions, sea conditions, hull/propeller/rudder fouling conditions, ship operational parameters, and other variables.

7. A global slow steaming strategy that is not well thought out could adversely impact other stakeholder strategies targeting improvements in efficiencies such as strengthening the IMO Ship Energy Efficiency Management Plan, could in some cases render IMO Tier III ships to operate in conditions where their Tier III technologies are inoperable, and adversely impact port authority and shipping line initiatives such as 'just in time arrival' and other efficiency improvements. With regards to Tier III, if the minimum operating exhaust temperatures needed for either an exhaust gas recirculation or selective catalytic reduction systems is not achieved, due to complying with a slow steaming regulation, the equipment will no longer operate. Engine exhaust temperatures are dependent on engine load.

5.0 RECOMMENDATIONS

Based on the work conducted for the APEC study, the following recommendations are provided by the authors relating to additional work that may be considered to further develop a better understanding of the impact from slow steaming:

1. This study has been developed using a high-level approach and it is a base to define further research to be conducted, as for example, an in-depth economic impact analysis on particular economies and products, including employment, infrastructure, hectares planted and harvested, taxes, etc. The GHG impacts methods are consistent with the methods used in IMO 2014.

2. APEC member economies should use the SSA Model to determine the GHG emissions and economic impacts for their specific trade scenarios of concern. The results can be used to inform their inputs, discussions and interventions at IMO MEPC and the Intersessional Working Group – Greenhouse Gases (ISWG-GHG) meetings.

3. In order to better understand the overall potential impacts from slow steaming, an additional analysis of moving diverted ship cargo to air freight would be beneficial. This would help inform APEC economies on the broader impacts from diverting cargo to higher GHG intensity transportation modes and help inform their inputs, discussions and interventions at IMO MEPC and the ISWG-GHG meetings.

4. This study clearly illustrates that a single speed for all ship types, let alone particular ship types is not the optimal solution. In fact, doing so can be contrary to other industry and port efforts to increase efficiencies in the supply chain and could ultimately result in net emissions increases across the entire supply chain. Therefore, it is recommended that an optimal solution be evaluated by IMO MEPC as opposed to a single speed for all ships. Further, based on the Ports' experience and as illustrated with the SSA Model, a phased approach should be considered targeting ship types and trade services that have substantial contributions to the overall international fleet emissions, while ships that service and supply small island developing states should be exempted.

5. In order to expand the understanding of slow steaming and broaden the analysis completed as part of this APEC study, an additional study could be undertaken that incorporates impacts on the broader supply chains in both the exporting and importing economies. Such a study could also include any savings that could occur as a result of slow steaming, such as lower fuel costs, and perhaps even the impact of sea conditions which might affect voyage routing and voyage time. Such a study could also include variables such as the charter cost of added vessels, the characteristics of the added vessels, and the operating costs.

6. There is a theory that slow steaming could create more transshipment especially for products that are not perishable. For the perishable goods, if shipping lines start to increase transshipment activities, the transit time for cargo will further lengthen transit time in addition to slow steaming. This could move more perishable cargo to air freight. Further study into how cargo owners would react if this happens, especially on long-distance voyages and if this would put further pressure on diverting cargo to air freight.

7. Conduct a study to engage those port authorities that have been operating their slow steaming incentive programs to better understand the operational, administrative, quantitative, and regulatory aspects and lessons learned. Their experience will be a valuable contribution to the discussions and inputs at IMO MEPC and the ISWG-GHG meetings.

6.0 GLOSSARY AND REFERENCES

6.1 Glossary

AIS	automatic identification system data
APEC	Asia-Pacific Economic Cooperation
ASOEX	Chilean Fruit Exports Association
CA3	China Australia Service 3
CFS	Container Freight Station
CH_4	methane
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
EF	emission factor
FCX	Falcon Express service
FMCG	fast moving consumer goods
FOB	free on board
GDP	gross domestic product
GHG	greenhouse gases
GSA	global speed average, in knots
GSA-X	incremental reductions in speed, in knots (GSA-1 through GSA-10)
g/ton-km	grams per ton kilometer
GWP	global warming potential
IMO	International Maritime Organization
IMO 2014	Third IMO Greenhouse Gas Study 2014
ISWG-GHG	IMO Intersessional Work Group – Greenhouse Gases
IoT	Internet of Things
kW	kilowatt
kWh	kilowatt hours
LF	load factor
NAAQS	National Ambient Air Quality Standards
Nm	nautical miles
MEPC	Marine Environmental Protection Committee
Module 1	GHG Impacts
Module 2	Economic Impacts
MSD	medium speed diesel engines
NOx	oxides of nitrogen
N_2O	nitrous oxide
PANYNJ	Port Authority of New York New Jersey
PM	particulate matter

POLA	Port of Los Angeles
POLB	Port of Long Beach
SSD	slow speed diesel engines
SSA	Slow Steaming Analysis
teu	twenty-foot equivalent units

6.2 Bibliography

1 Lynn, Htut; Wai, Thet, (2014). Impact of Slow Steaming on Shipper's Inventory. *Bachelor Thesis - Erasmus University Rotterdam*.

2 Alcaino, Manuel J.; Visión global de la producción y comercialización de cerezas, Decofrut (2018).

3 Allianz, (2014). Cargo risks with green ship schedules *Allianz Global Corporate & Specialty - Risk Bulletin No. 45 Feb.*

4 America Economía (2019). China es principal destino de cerezas chilenas. Available at: *https://asialink.americaeconomia.com/economia-y-negocios-alimentos/china-es-principal-destino-de-cerezas-chilenas*

5 American Shipper (2019). Drewry foresees more slow steaming and transshipment. Available at*: https://www.americanshipper.com/news/drewry-foresees-more-slow-steaming-and-transshipment?autonumber=847369&via=sharecodev1*

6 Australia Unlimited, (2016). The APEC region trade and investment, *Australia Government - Department of Foreign Affairs and Trade*. Available at *https://dfat.gov.au/about-us/publications/Documents/apec-region-trade-investment.pdf*

7 Carson, J. K.; Kemp, R. M.; East, A. R.; Cleland, D. J. (2015). The Impact of Slow-Steaming on Refrigerated Products from New Zealand. *ICR 2015, August 16-22 - Yokohama, Japan. Available at*

8 Cepeda, Maricruz A. F. S.; Guimares Marujo, Lino; Assis, Luis Felipe; Caprace, Jean-David, (2016). Effects of Slow Steaming Strategies on a Ship Fleet. *26º Congresso Nacional de Transporte Aquaviário, Construção Naval e Offshore – SOBENA.* Available at:
https://www.researchgate.net/publication/311262105_Effects_of_Slow_Steaming_Strategies_on_a_Ship_Fleet

9 Coley, William; Hall, William; Ballenger, Nicole, Transportation technology and the rising share of US perishable food trade.

10 Elzarka, Sara; Morsi, Maha. (2014). The Supply Chain Perspective on Slow Steaming. *College of International Transport & Logistics, Arab Academy for Science, Technology & Maritime Transport, Alexandria, Egypt*
11 Emol (2019). Las distancias que recorren las exportaciones chilenas para llegar a otros países y su comparación con el resto del mundo. Available at:
https://www.emol.com/noticias/Economia/2019/07/27/955991/Cuanto-se-demoran-las-exportaciones-chilenas-en-llegar-a-otros-paises.html

12 Evgenitaki, Maria-Eñeftjeria. (2015). Slow steaming: economic and legal impacts. *University of the Aegean*. Available at *https://core.ac.uk/download/pdf/44289816.pdf* 8 Experts, various. (2012).

13 Regulated Slow Steaming in Maritime Transport, An Assessment of Options, Costs and Benefits. *CE Delft, Univ. of Southampton, and the ICCT, commissioned by Transport and Environment* and *Seas at Risk.* Available at *https://www.cedelft.eu/publicatie/regulated_slow_steaming_in_maritime_transport/1224*

14 Faber, Jasper (CE Delft); Nelissen, Dagmar (CE Delft); Hon, Galen (The ICCT); Wang, Haifeng (The ICCT); Tsimplis, Mikis. (2012). Regulated Slow Steaming in Maritime Transport, an assessment of options, costs and benefits. *CE Delft, The ICCT, Mikis Tsimplis*

15 *Finnsgård, C., Kalantari, J., Raza, Z. et al. J. shipp. trd. (2018) 3: 8.* Available at *https://doi.org/10.1186/s41072-018-0033-2*

16 Finnsgård, Christian, Kalantari, Joakim; Roso, Violeta; Woxenius, Johan. (2015). Slow Steaming from shipper's perspective. *Chalmers University of Technology*

17 Fresh Plaza (2019). Chile: 87 percent of all cherry exports went to China. Available at *https://www.freshplaza.com/article/9135179/chile-87-percent-of-all-cherry-exports-went-to-china/*

18 Gemini Shippers Group. (2019). IMO 2020 - what every shipper needs to know. IHS and JOC white paper. Available at *https://www.seaburycapital.com/wp-content/uploads/2019/02/GeminiWhitepaper2019-v2b-abbb.pdf*

19 Golding, John (2017). Review of international best practice for postharvest management of sweet cherries.

20 González, Sergio, Stone Fruit Annual 2019, Chiles Cherry Exports.

21 Halim, Ronald A.; Smith, Tristant; Englert, Dominik. (2019). Understanding the Economic Impacts of Greenhouse Gas Mitigation Policies on Shipping. What is the State of the Art of Current Modeling Approaches. *World Bank Group.* Available at *http://documents.worldbank.org/curated/en/215561546957017567/pdf/WPS8695.pdf*

22 Healy, Sean; Graichen, Jakob. Impact of slow steaming for different types of ships carrying bulk cargo; Oko-Institut e.V. (2019).

23 Hong Liang, Lee. (2014). The Economics of Slow Steaming. *Seatrade Maritime News*, and comments by Ma Shou, professor at World Maritime Univ., Sweden

24 JOC (2016). Carriers stick with slow-steaming despite fuel-price plunge. Available at: *https://www.joc.com/maritime-news/container-lines/carriers-stick-slow-steaming-despite-fuel-price-plunge_20160401.html*

25 Kalimeris, George. (2016). The viability of slow steaming from a supply chain perspective through a break-even bunker price analysis. *Erasmus School of Economics*

26 Kalimeris, George. (2015-2016). The viability of slow steaming from a supply chain perspective though a break-even bunker price analysis. *Master Thesis - Erasmus University Rotterdam*

27 Karampampa, Iro Christina. (2014). The impact of slow steaming on shippers and on their supply chains: a window of opportunity for other transportation modes. Case Study on China-Europe Route. *Erasmus University Rotterdam*

28 Kloch, Lars. (2013). Is Slow Steaming Good for the Supply Chain? *Inbound Logistics, April 19 2013*

29 Kowalak, Przemysław. (2015). Chief Engineer's Hands-On Experience of Slow Steaming Operation. *Maritime University of Szczecin, Poland*

30 Lee, Chung-Yee; Lee, Hau L.; Zhang ,Jibeng. (2013). The impact of slow steaming on delivery reliability and fuel consumption. *The Hong Kong University of Science and Technology*

31 Maggs, John, Seas At Risk; Bill Hemmings, Transport & Environment Members of the Clean Shipping Coalition. (2012). Slow steaming saves money and the climate. *Acid News, No. 3m October 2012*

32 Mallidis, Ioannis; Eleftherios Iakovou; et.al. 2018 The impact of slow steaming on the carriers' and shippers' costs: The case of a global logistics network Elsevier: Transportation Review Part e: Transportation and Logistics Review

33 Maloni, Michael; Aliyas Paul, Jomon; Cligor, David; Slow steaming impacts on ocean carriers and shippers; Maritime Economics & Logistics (2013).

34 McKenzie Atala, Pia Francisca; Análisis de competitividad de cerezas frescas de exportación chilenas; Universidad de Chile (2012).

35 Mundo Maritimo. (2019). Shipping companies and NGOs express support for IMO to regulate the speed of navigation. Available at: *https://www.mundomaritimo.cl/noticias/navieras-y-ongs-expresan-apoyo-a-la-omi-para-regular-la-velocidad-de-navegacion*

36 Pellegrini, Fernando Ariel; Empaque y comercialización de cerezas frescas en Mendoza – Análisis de mercado y costos del sector; Universidad Nacional de Cuyo (2011).

37 Prochile; Estudio de Mercado de cerezas (2017), documento elaborado por la oficina comercial de Chile en Hong Kong, China y Macao RAE's.

38 Produce Report (2019). Chilean cherries enter China in combined sea & air shipments. Available at: *https://www.producereport.com/article/chilean-cherries-enter-china-combined-sea-air-shipments*

39 Psaraftis, Harilaos N., Technical University of Denmark. (2019). Chapter 10, *Optimization for Sustainable Shipping* - Provided by CHILE

40 Putzger, Ian. (2019). Cost Hampers IoT Monitoring in Perishables Supply Chains, Despite Airline Efforts. *The CoolStar*. Available at *https://theloadstar.com/coolstar/cost-hampers-iot-monitoring-in- perishables-supply-chains-despite-airline-efforts/*

41 Seatrade maritime (2014). The economics of slow steaming. Available at: *http://www.seatrade-maritime.com/news/americas/the-economics-of-slow-steaming.html*

42 Smith, Tristan; Hoffman, Jan; Elgert, Dominik; Halim, Ronald. (2019). World Bank Webinar on Effects of GHG Reductions on Shipping World Bank Group, Open Learning Campus

43 Smith, Tristan; Jan Hoffman; Dominik Elgert; Halim, Ronald. (2019). Maritime Transport Costs and Trade Flows - discussion paper for the International Transport Forum. *World Bank Group, Open Learning Campus*. Available at *https://drive.wps.com/d/ADaR7836_7shloCA_f_dEA*

44 Splash 24/7 (2018). Global food trends and advances in reefer technology. Available at: *https://splash247.com/global-food-trends-advances-reefer-technology/*

45 Tezdogan, Tahsin; Atila Incecik. (2016). Assessing the Impact of a Slow Steaming Approach on Reducing the Fuel Consumption of a Containership Advancing in Head Seas. *Elsevier: Transportation Research Procedia, Vol. 14*

46 Thomas, Jasper Faber; Huigen; Dagmar, Neilssen. (2017). Regulating speed: a short term measure to reduce maritime GHG emissions. Delft University. Available at *http://www.cleanshipping.org/download/Slow-steaming-CE-Delft-final.pdf*

47 Todts, William. (2017). Smarter Steaming Ahead. *Transport & Environment*. Available at *https://www.transportenvironment.org/publications/smarter-steaming-ahead*

48 Unece-Unctad. (2010). Climate Change Impacts on International Transport Networks. *UNECE-UNCTAD* Available at *https://studylib.net/doc/10567803/climate-change-impacts-on-international-transport-networks*

49 Van Elswijk, Joey. (2011). Slow steaming in the liner shipping industry. Erasmus Universiteit Rotterdam

50 Wiesmann, Andreas. (2010). Slow steaming – a viable long-term option? Wartsila Technical Journal

51 Zanne, Mariana; Pocuca, Milojka; Bajec Patriciaja. (2013). Environmental and Economic Benefit of Slow Steaming. *University of Ljubljana* 53 2013Slow Steaming Steamship Mutual, a P&I Club

6.3 List of Endnotes

[1] World Shipping Council, *www.worldshipping.org/industry-issues/environment/air-emissions/carbon-emissions*, 2019
[2] World Shipping Council*, www.worldshipping.org/industry-issues/environment/air-emissions/carbon-emissions*, 2019
[3] Tristan Smith, *Maritime transport costs and trade flows* – Discussion paper for the International Transport Forum, 2019
[4] International Transport Forum. *www.morethanshipping.com/fuel-costs-ocean-shipping/; www.transportgeography.org/?page_id=2250; www.livebunkers.com/bunker-prices-worldwide-analysis-trends-historical-bunker-prices-imo-2020* and discussion paper *Maritime transport costs and trade flows,* 2019
[5] Valuing Time in Supply Chains: Establishing Limits of Time-based Competition, 2019
[6] Iro Christina Karamapampa, *The impact of slow steaming on shippers and on their supply chains: a window of opportunity for other transport modes*, 2014
[7] Nesoi means "Not Elsewhere Specified or Indicated"
[8] Hyundai Merchant Marine will join THE Alliance in April 2020
[9] APL, *www.apl.com/products-services/line-services/flyer/CA3APL*, 2019
[10] APL, *www.apl.com/products-services/line-services/flyer/ACSA2*, 2019
[11] CMA CGM, *www.cma-cgm.com/products-services/line-services/flyer/FUJI*, 2019
[12] CMA CGM*, www.cma-cgm.com/products-services/line-services/flyer/HBB,* 2019
[13] CMA CGM, *www.cma-cgm.com/products-services/line-services/flyer/SCS*, 2019
[14] CMA CGM, *www.cma-cgm.com/products-services/line-services/flyer/BOHAI*, 2019
[15] International Maritime Organization, *www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx*, 2019
[16] Michael Maloni, Jomon Aliyas Paul and David M. Gligor, *Slow steaming impacts on ocean carriers and shippers*, 2013
[17] CE Delft, a similar approach and methodology is presented in *Regulating speed: a short-term measure to reduce maritime GHG emissions*, October 2017
[18] Asia Link America Economia, *www.asialink.americaeconomia.com/economia-y-negocios-alimentos/china-es-principal-destino-de-cerezas-chilenas*, 2019
[19] Cargo Handbook, *www.cargohandbook.com/index.php?title=Cherries*, 2019
[20] Joey van Elswijk, *Slow steaming in the liner shipping industry*, July 2011
[21] Refinitiv, *www.refinitiv.com/perspectives/future-of-investing-trading/speed-matters-container-shipping/*, 2019
[22] Refinitiv, *www.refinitiv.com/perspectives/future-of-investing-trading/speed-matters-container-shipping/*, 2019
[23] MAN Energy Solutions, *Basic principles of ship propulsion*, *www.marine.man-es.com/docs/librariesprovider6/propeller-aftship/5510-0004-04_18-1021-basic-principles-of-ship-propulsion_web.pdf?sfvrsn=c01858a2_8*, 2018
[25] Port of Los Angeles, *www.portoflosangeles.org/environment/progress/initiatives/vessel-speed-reduction-program/*, 2019
[26] Port of Los Angeles, *www.portoflosangeles.org/environment/progress/initiatives/vessel-speed-reduction-program/*, 2019
[27] Port of Long Beach, *www.polb.com/environment/air/greenflag.asp*, 2019
[28] Port of Los Angeles, Port of Long Beach, *www.cleanairactionplan.org/*, 2019
[29] Port Authority of New York New Jersey, *www.panynj.gov/about/clean-vessel-incentive-program.html*, 2019

[30] Santa Barbara Air Pollution Control District, *www.ourair.org/air-pollution-marine-shipping/*, 2019

[31] Starcrest, provided in a separate MS Excel files, as part of this study.

[32] International Maritime Organization, *Third IMO GHG Study 2014*; IMO London, UK, April 2015; Smith, T. W. P.; Jalkanen, J. P.; B. Anderson, et. al. *www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf* [IMO 2014], 2019

APPENDIX A
APEC Economic and Trade Highlights

Economies

In terms of GDP, the APEC economies represent 60% of total world output[1]. As shown in the table below, China and the United States dominate the region economically and represent 2/3 of APEC's economic output. These 2 economies plus Japan represent more than ¾ of APEC's economic output. APEC's share of total world trade was 47% in 2017, the latest year for which data are available. The high level of trade is reflected in the fact that APEC's population was 38% of the world total.

Table A.1: List of APEC Economies

	Economies	Continent	POP	GDP (US$ trillions)	2018 GDP Growth %	GDP (US$) per Capita
1	Australia	Oceania	25 088 636	$1,581,890	3.241	$63,052
2	Brunei Darussalam	Asia	439 336	$14,791	2.311	$33,667
3	Canada	America	37 279 811	$1,908,530	2.066	$51,195
4	Chile	America	18 336 653	$295,844	3.975	$16,134
5	China	Asia	1 420 062 022	$15,543,710	6.595	$10,946
6	Hong Kong, China	Asia	7 490 776	$387,983	3.775	$51,795
7	Indonesia	Asia	269 536 482	$1,152,890	5.137	$4,277
8	Japan	Asia	126 854 745	$5,362,220	1.137	$42,271
9	Malaysia	Asia	32 454 455	$402,605	4.7	$12,405
10	Mexico	America	132 328 035	$1,285,080	2.193	$9,711
11	New Zealand	Oceania	4 792 409	$235,328	3.07	$49,104
12	Papua New Guinea	Oceania	8 586 525	$27,411	-1.082	$3,192
13	Peru	America	32 933 835	$246,714	4.102	$7,491
14	The Philippines	Asia	108 106 310	$355,744	6.517	$3,291
15	Republic of Korea	Asia	51 339 238	$1,777,650	2.7	$34,626
16	Russia	Asia	143 895 551	$1,754,290	1.705	$12,191
17	Singapore	Asia	5 868 104	$367,783	2.926	$62,675
18	Chinese Taipei	Asia	23 758 247	$620,600	2.727	$26,121
19	Thailand	Asia	69 306 160	$520,074	4.596	$7,504
20	United States	America	329 093 110	$21,410,230	2.884	$65,058
21	Viet Nam	Asia	97 429 061	$264,939	6.6	$2,719

Sources:
www.worldpopulationreview.com/countries/countries-by-gdp/
www.statisticstimes.com/economy/countries-by-projected-gdp-growth.php
2018 GDP Growth based on IMF statistics

Intra-APEC Trade Composition

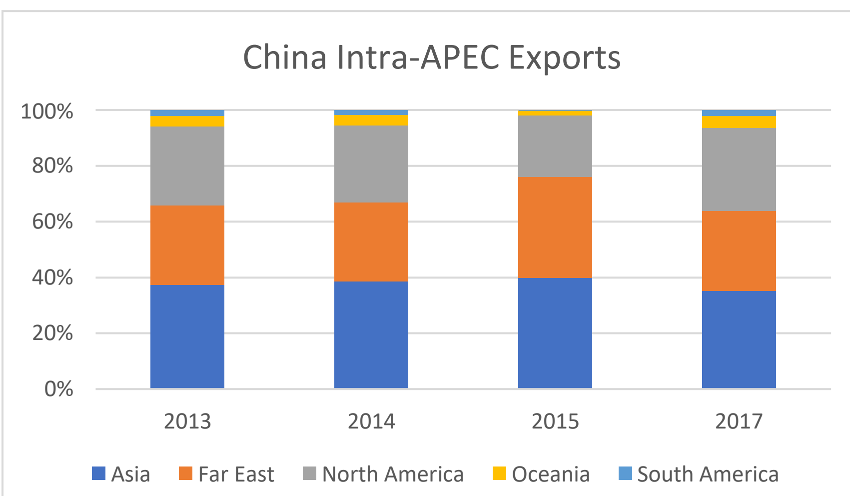
This section briefly describes the main trade indicators among APEC economies, in order to determine the intra-APEC cargo origin (exporters) and main destination economies, used as the basis for the slow steaming impact analysis. For each of the 21 APEC economies, we have identified the main world and -intra-APEC trading partners, the trade balance, and the main export commodity categories. To develop this section our team identified and used various sources: The World Bank, United Nations (UN), and Comtrade figures for economy-specific macroeconomic and trade indicators when they were missing in The World Bank and UN sources. Most of the figures in this section are for 2017; when 2017 data are missing, we indicate the reference year used.

Asia

- **China:** this is by far the largest trading economy in Asia with total exports of USD$2.3 trillion and imports of USD$1.8 trillion, thus generating a positive trade balance ofUSD$419 billion[2]. Five main destinations share 45.11% of total exports, of which the United States represents 19.01% of total exports, and the other four destinations are intra-Asian economies. Given this picture, a considerable amount of China's exports is transported long distance and would be affected by slow steaming. Capital goods account for 45.19% of total exports, consumer goods 36.44%, intermediate goods 16.31% and raw material 1.82%.

  In 2017, Asian economies represented 63.8% of China's intra-APEC exports (Asia 35.2% and Far East Asia 28.7%), the Americas represented 32.0% (North America 29.8% and South America 2.2%), and Oceania 4.2%. For China, the main individual APEC destination economies are the United States 25%, China 11%, Republic of Korea 10%, Japan 10% and Viet Nam 8%.

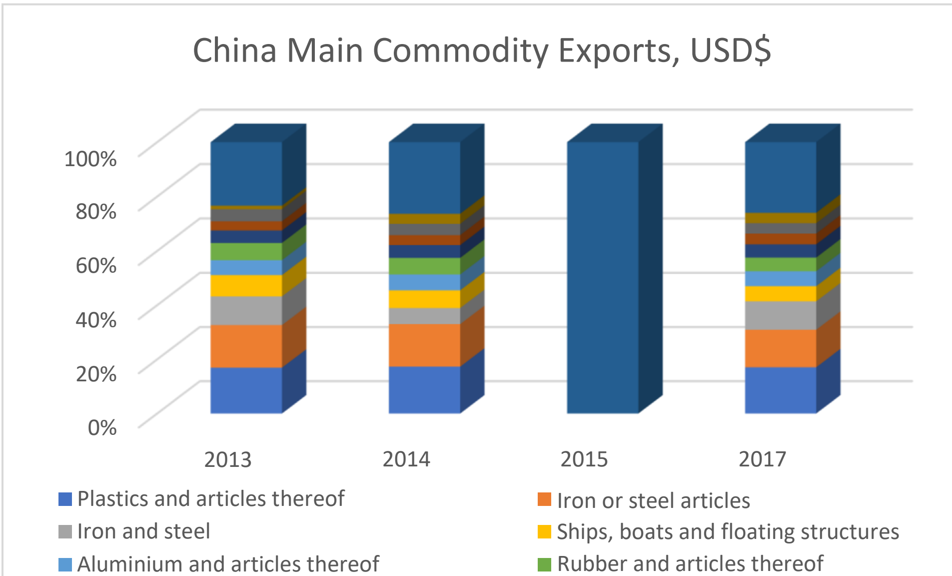
Figure A.1: China – 2016 Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

According to UN Comtrade, in 2017, top 10 commodities shared 74% of total exports worldwide. Plastics and articles share 17%; iron or steel articles 14%; iron and steel 10%; ships, boats and floating structures 6%; and aluminum and articles 6%; as shown in the following graph.

Figure A.2: China – Top 10 Export Commodities Share, by Value USD$

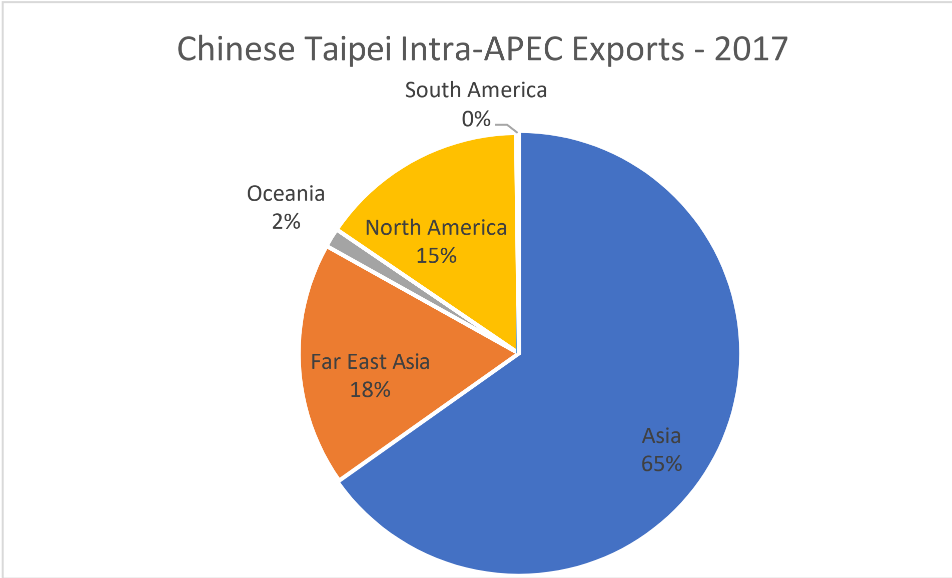


Source: *www.comtrade.un.org/*

- **Chinese Taipei**: in 2017 total exports amounted to USD$317 billion, and imports USD$59 billion, for a positive trade balance of USD$58 billion. Five economies receive 58.63% of total exports. The United States is the third destination with 11.65% and the other four main destinations are Asian economies including China with 24.11%, Hong Kong, China 7.41%, Japan 10.88% and Singapore 4.57%[3].

  According to the Directorate General of Customs, Ministry of Finance, in the year 2017, Chinese Taipei exported 83.1% of its Intra-APEC trade to Asian economies (65.2% Asia and 17.9% Far East Asia), 15.5% to the American economies (15.3% North America and 0.2% South America), and 1.4% Oceania economies. Individual economies of intra-APEC destinations are China with 33%, Hong Kong, China 15%, the United States 14%, Japan 8% and Singapore 7%.

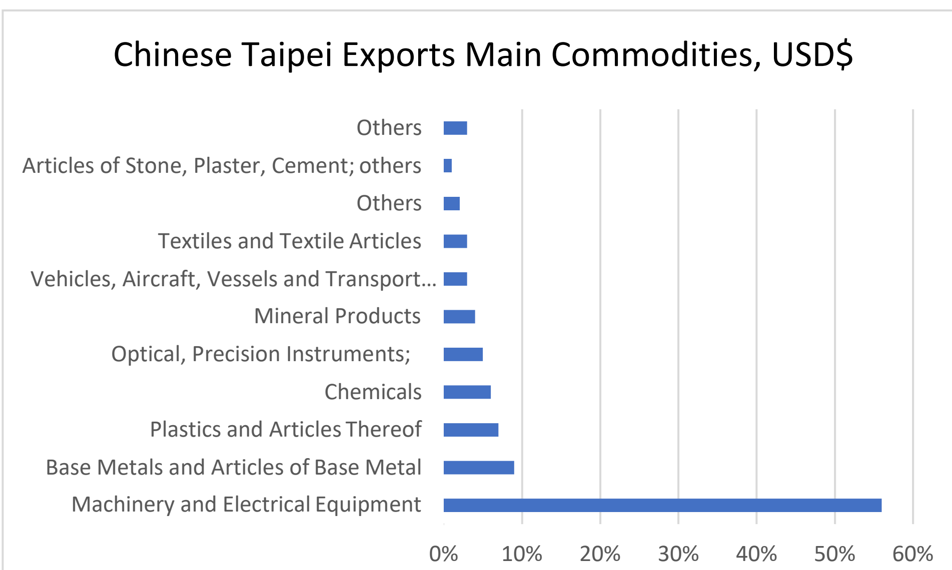
Figure A.3: Chinese Taipei – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: Directorate General of Customs, Ministry of Finance

Some 96% of total exports worldwide were in just 10 commodity groups. Machinery and electrical equipment dominated with a share of 56%; base metals and articles of base metal 9%; plastics and articles 7%; chemicals 6%; and optical, precision instruments 5%; as shown in the following graph.

Figure A.4: Chinese Taipei – Top 10 Exports Commodities Share, by Value USD$, 2017

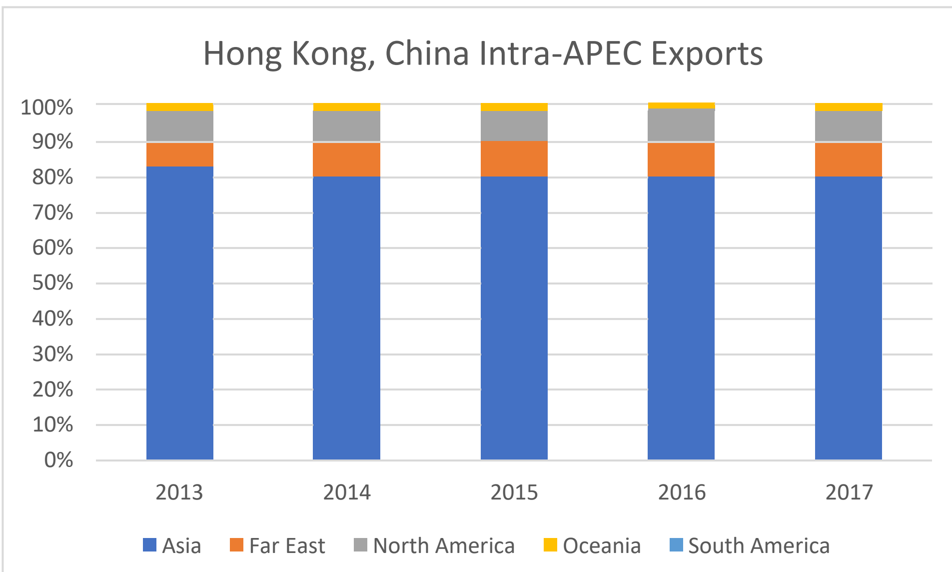


Source: Directorate General of Customs, Ministry of Finance

- **Hong Kong, China**: exports totaled USD$549 billion, and imports USD$589 billion, for a negative trade balance of USD$39 billion. Total service and good exports represent 188% of economy GDP, while imports 187%[4]. Five economies receive 71.13% of total exports. The United States is the second export destination with 7.71% the other four main destinations are Asian economies. Main Hong Kong, China exports are capital goods, sharing 63.24%, intermediate goods 19.54%, consumer goods 14.41% and raw material 2.70%.

In the year 2017, Hong Kong, China exported 89.9% of its intra-APEC trade to Asian economies (82.1% to Asia and 7.8% Far East Asia), 8.7% to the Americas (8.6% to North America and 0.1% to South America), and 1.4% to Oceania. Individual economies of intra-APEC destination are China 66%, the United States 8%, Viet Nam 7%, Republic of Korea 2% and Singapore 2%.

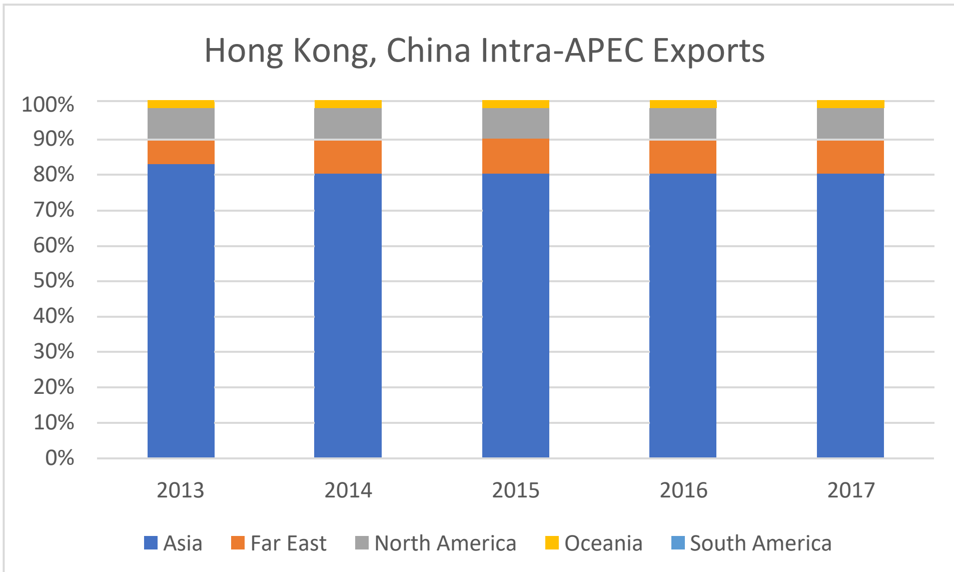
Figure A.5: Hong Kong, China – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities shared 78% of total exports worldwide. Plastics and articles share 29%; clocks and watches 11%; meat and edible meat 10%; glass and glassware 7%; and pharmaceutical products 4%; as shown in the following graph.

Figure A.6: Hong Kong, China – Top 10 Exports Commodities Share, by Value USD$

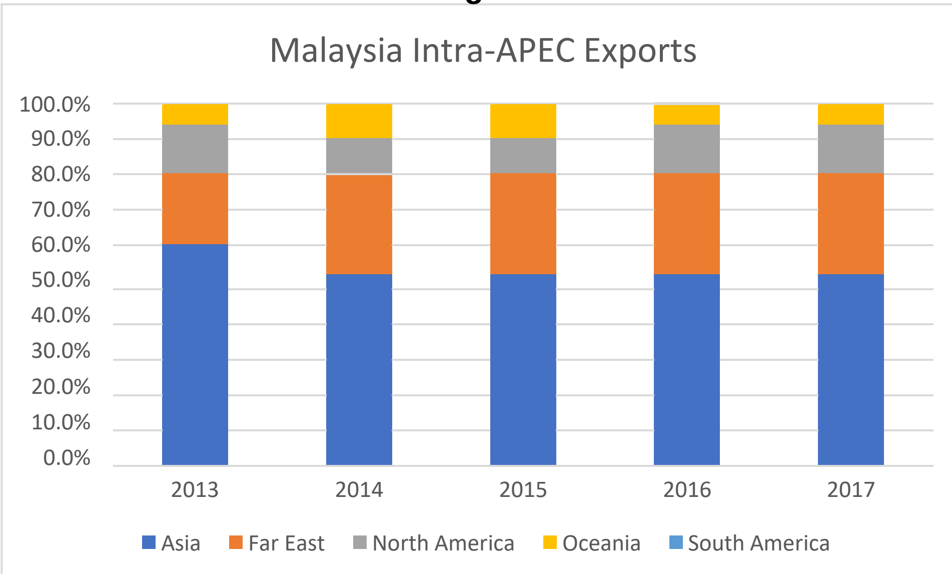


Source: *www.comtrade.un.org/*

- **Malaysia**: total exports reached USD$216 billion and imports USD$193 billion, for a positive trade balance of USD$22 billion. Total exports, as a percentage of GDP is 71.39% and imports 64.45%. The top five destinations of Malaysia exports represent 50.72% of total exports. The United States is ranked number three with 9.51% of total exports. All other four destinations are Asian economies. Capital goods share 41.95% of total exports, consumer goods 31.37%, intermediate goods 19.60% and raw material 6.20%.

  In the year 2017, Malaysia exported 81.5% of its intra APEC trade to Asian economies (53.9% to Asia and 27.6% Far East Asia), 13.3% to the Americas (13.0% to North America and 0.3% to South America), and 5.2% to Oceania. Individual economies of intra-APEC destination are China 24%, Singapore 13%, the United States 11%; Indonesia 10% and Thailand 8%.

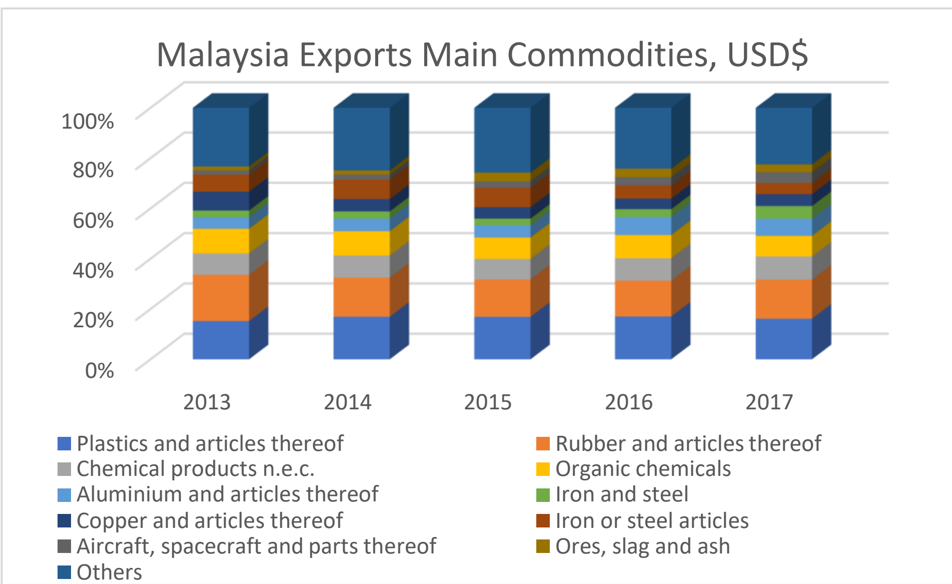
Figure A.7: Malaysia – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities shared 77% of total exports worldwide. Plastics and articles share 16%; rubber and articles 16%; chemical products 9%; organic chemicals 8%; and aluminum and articles 7%; as shown in the following graph.

Figure A.8: Malaysia – Top 10 Exports Commodities Share, by Value USD$

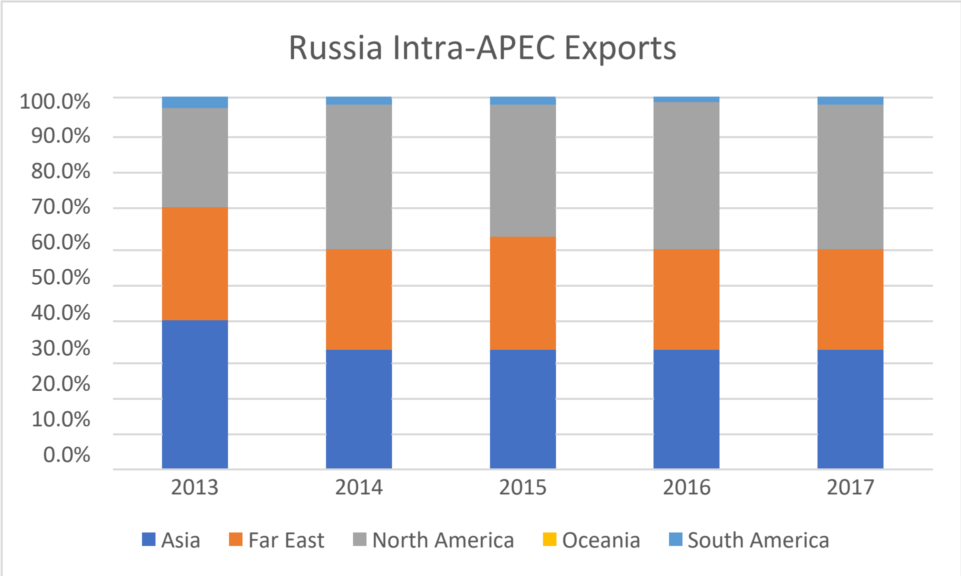


Source: *www.comtrade.un.org/*

- **Russia**: total exports reached USD$359 billion, while imports were USD$228 billion, for a positive trade balance of USD$130 billion in 2017. Total goods and services exports, as a percentage of economy GDP was 26.04% and imports 20.69%[5]. The Russia Federation main export destinations are European economies, four out of the top five are European economies; the second major destination is China with 10.45%. The top five destinations share 43.62% of total exports. Raw material is the main export category with 36.55% share, consumer goods 33.32%, intermediate goods 20.90% and capital goods 5.30%.

  In the year 2017, Russia exported 62.3% of its intra APEC trade to Asian economies (34.1% to Asia and 28.2% Far East Asia), 37.3% to the Americas (36.0% to North America and 1.3% to South America), and 0.4% to Oceania. Individual economies of intra-APEC destination are China 26%, the United States 26%, Republic of Korea 15%, Japan 10% and Mexico 8%.

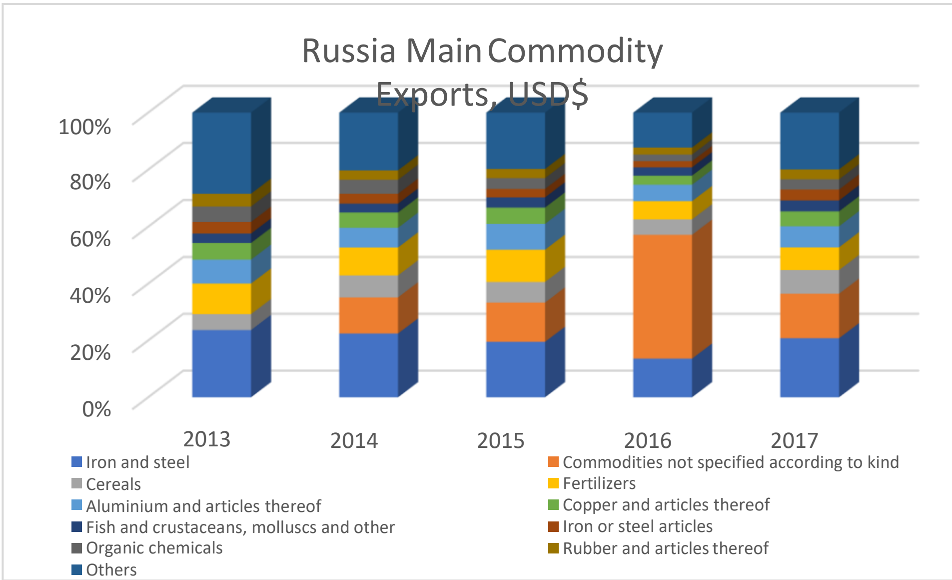
Figure A.9: Russia – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities shared 80% of total exports worldwide. Iron and steel share 21%; cereals 8%; fertilizers 8%; aluminum and articles 7%; and copper and articles 5%; as shown in the following graph.

Figure A.10: Russia – Top 10 Exports Commodities Share, Value USD$

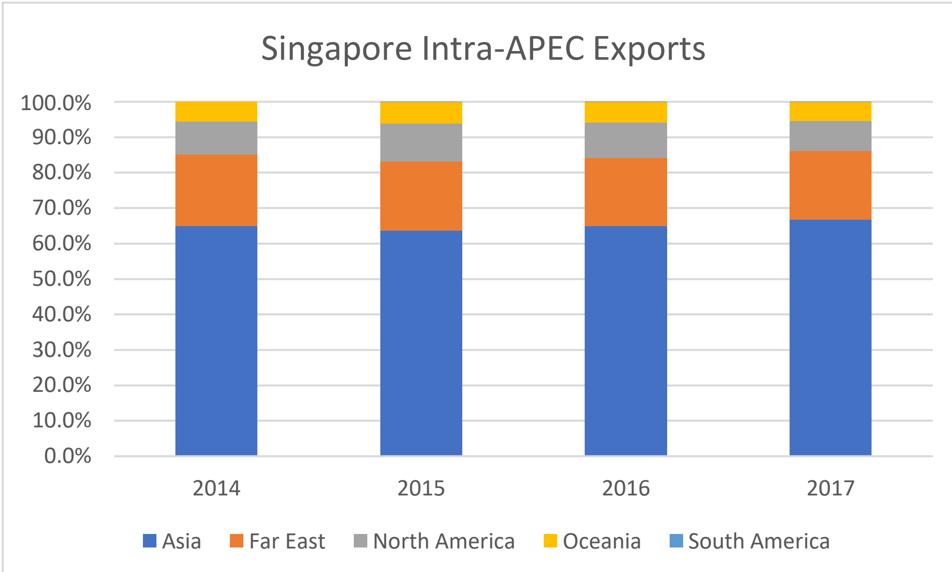


Source: *www.comtrade.un.org/*

- **Singapore**: total exports reached USD$373 billion and imports were USD$327 billion, for a positive trade balance of USD$45 billion. Goods and services exports, as a percentage of GDP is 173.35% and imports 149.08%[6]. Top five destinations share 51.38% of total exports, four of these are Asian economies, and the United States ranks fifth with 6.48% of total exports. Capital goods represents 49.93% of total county exports, consumer goods 24.55%, intermediate goods 18.90% and raw material 0.92%.

  In the year 2017, Singapore exported 86.2% of its intra-APEC trade to Asian economies (66.7% to Asia and 19.5% Far East Asia), 8.5% to the Americas (8.5% to North America and 0.0% to South America), and 5.3% to Oceania. Individual economies of intra-APEC destination are China 25%, Malaysia 12%, Indonesia 12%, Hong Kong, China 9% and the United States 8%.

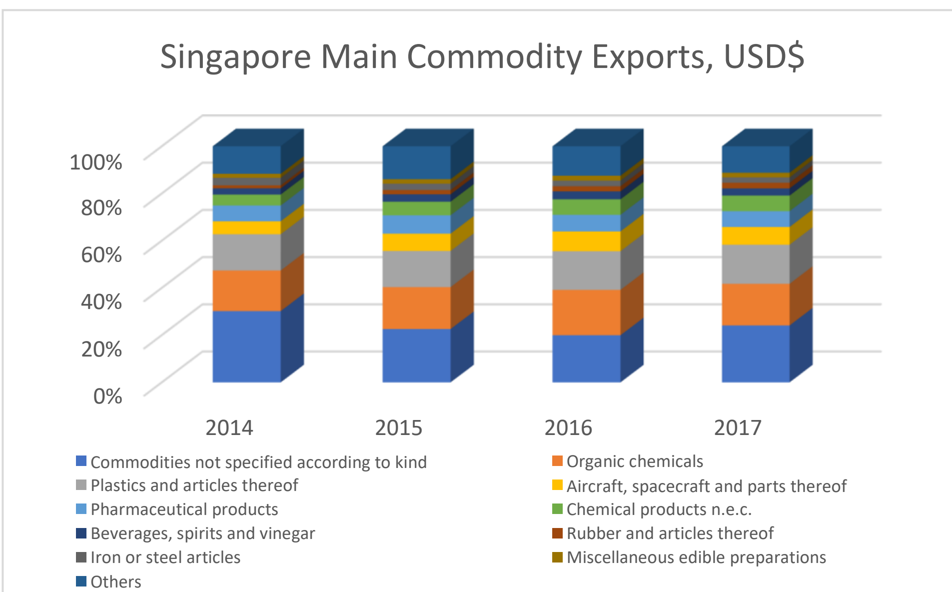
Figure A.11: Singapore – Intra APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities shared 89% of total exports worldwide. Organic chemicals share 18%; plastics and articles 17%; aircraft, spacecraft and parts 8%; pharmaceutical products 7%; chemical products 7%, and beverage, spirits and vinegar 3%; as shown in the following graph.

Figure A.12: Singapore – Top 10 Exports Commodities Share, by Value USD$

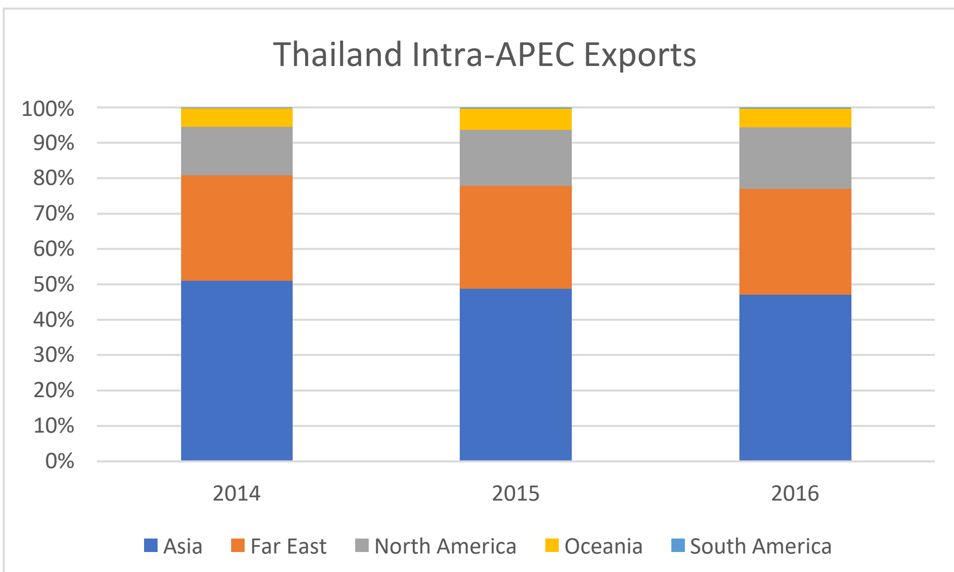


Source: *www.comtrade.un.org/*

- **Thailand**: exports reached USD$213 billion and imports were USD$196 billion, for a positive trade balance of USD$18 billion. Total exports of services and goods, as a percentage of economy GDP, is 68.17% and imports 54.63%[7]. The main economy of destination for Thailand is the United States with a share of 11.41% of total exports, three of the top five are Asian economies and the fifth one is Australia with 4.79%. Top five destination shares 42.13% of total exports. Consumer goods is the main export category with 34.48%, capital goods 38.44%, intermediate goods 21.25% and raw material 5.83%.

  In the year 2016, Thailand exported 77.0% of its intra-APEC trade to Asian economies (47.1% to Asia and 30.0% Far East Asia), 17.7% to the Americas (17.4% to North America and 0.3% to South America), and 5.3% to Oceania. Individual economies of intra-APEC destinations are China 24%, the United States 15%, Japan 15%, Viet Nam 8% and Malaysia 8%.

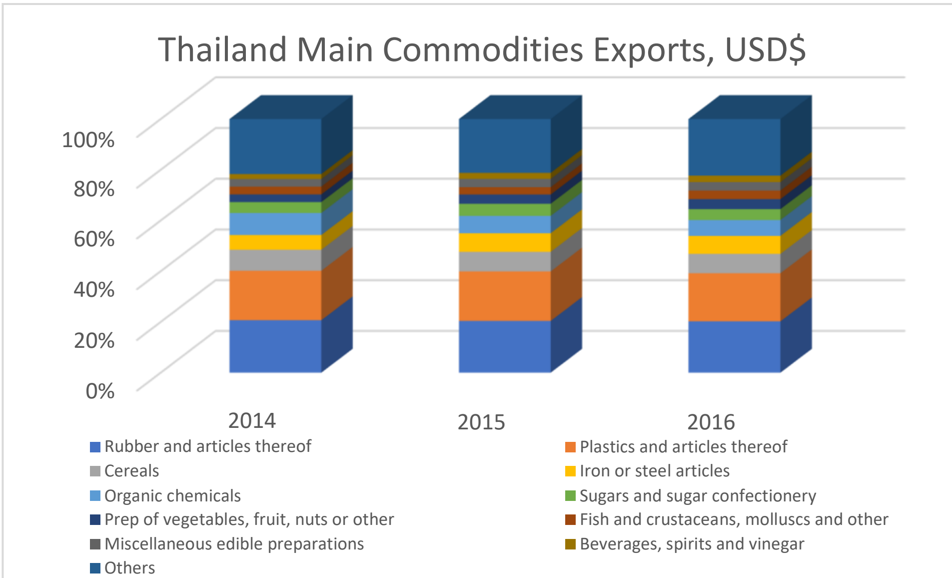
Figure A.13: Thailand – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities shared 78% of total exports worldwide. Rubber and articles share 20%; plastics and articles 19%; cereals 8%; iron or steel articles 7%; and organic chemicals 6%; as shown in the following graph.

Figure A.14: Thailand – Top 10 Exports Commodities Share, by Value USD$

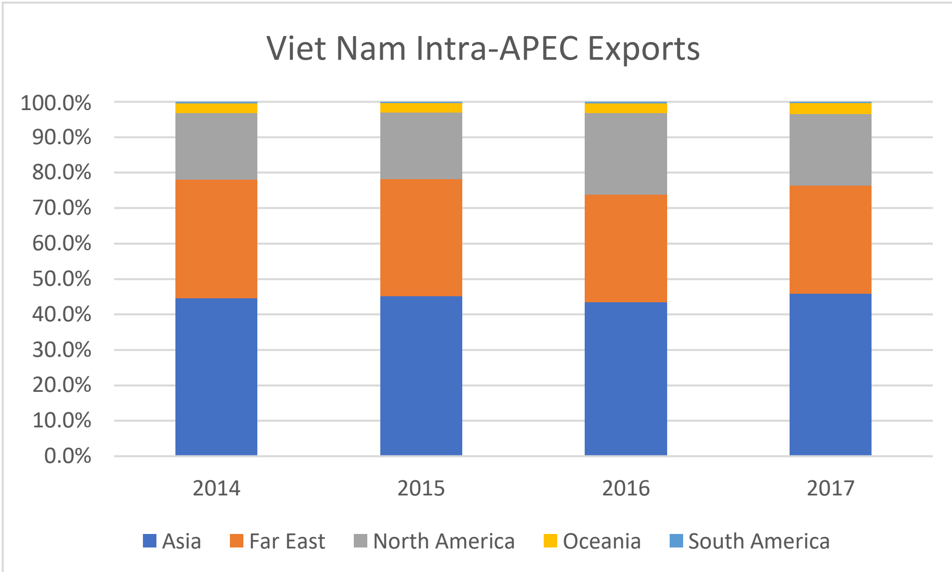


Source: *www.comtrade.un.org/*

- **Viet Nam**: economy total exports reached USD$176 billion, and imports were USD$175 billion for a positive trade balance of USD$1.6 billion. Exports, as a total of economy's GDP, represent 101.59% and imports 98.79%[8]. The United States is the largest destination economy for Viet Nam's exports with 21.79% share; five top destinations share 52.44%, the other four are Asian economies. Consumer goods share 40.07% of total exports, capital goods 38.86%, intermediate goods 12.33% and raw materials 10.60%.

  According to data extracted from UNComtrade webpage, in the year 2017, 76.3% of total Viet Nam intra-APEC trade was destined to Asian economies (45.8% Asia and 30.5% Far East Asia), while 3.0% was commerce with Oceania economies and 20.7% with economies in the Americas (20.3% North and 0.4% South America). Individual economies as main destinations for Viet Nam intra-APEC trade are China 28%, the United States 17%, Japan 13%, Republic of Korea 9% and Malaysia 5%.

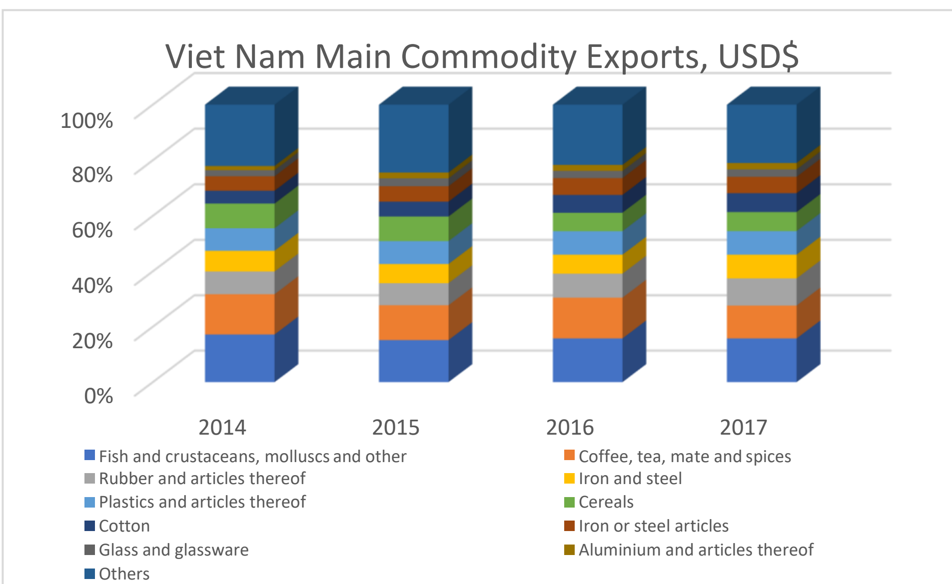
Figure A.15: Viet Nam – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

Viet Nam top 10 exports commodities represents 79% of total economy exports, fish and crustaceans, mollusks and others 16% of 2017 exports, followed by coffee, tea, mate and spices with 9%, rubber and articles 10%, iron and steel 9%, and plastics and articles with 9%. Next graph shows the top 10 commodity exports.

Figure A.16: Viet Nam – Top 10 Exports Commodities Share, by Value USD$



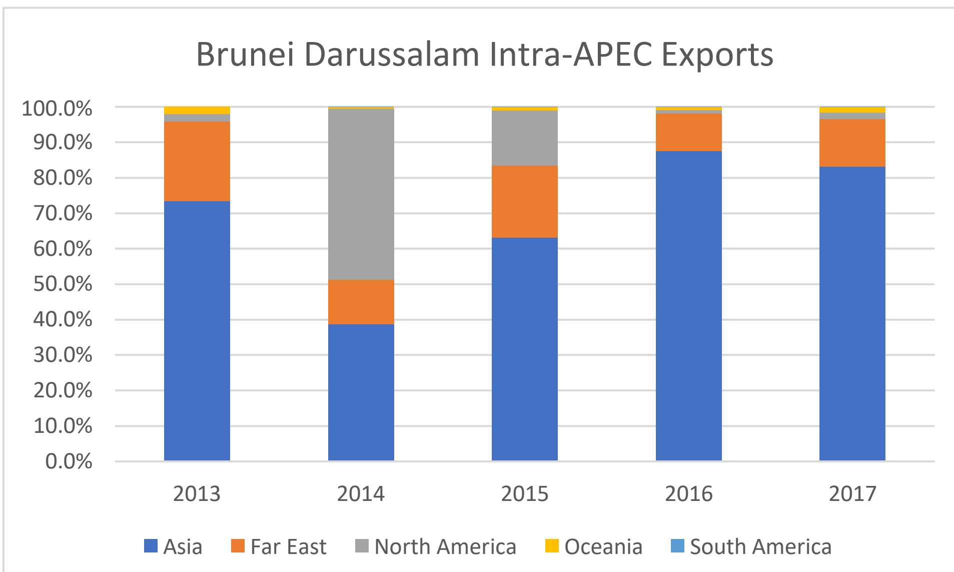
Source: *www.comtrade.un.org/*

Far East Asia

- **Brunei Darussalam:** total exports accounted USD$5.6 billion and imports were USD$3.1 billion, thus its trade balance is USD$2.5 billion positive. Total exports (goods & services), as a percentage of county GDP, accounts for 49.57%, and imports 35.6%[9]. According to World Bank statistics, top five destinations economies receive 75.43% of total exports, all of them in Asia, thus the impact of slow steaming in the economy will be minimum due to exports are transported short distances. Consumer goods accounts for 50.79% of total merchandise exports, raw materials represent 40.09%, intermediate goods 4.50% and capital goods 4.41%.

  Brunei Darussalam intra-APEC exports are basically within Asian economies with 96.6% share (Asia 83.3% and Far East Asia 13.3%), the Americas 1.8% and Oceania 1.6%. individual economies of intra-APEC destination are Singapore 41%, China 16%, Malaysia 12% Thailand 8% and Viet Nam 5%.

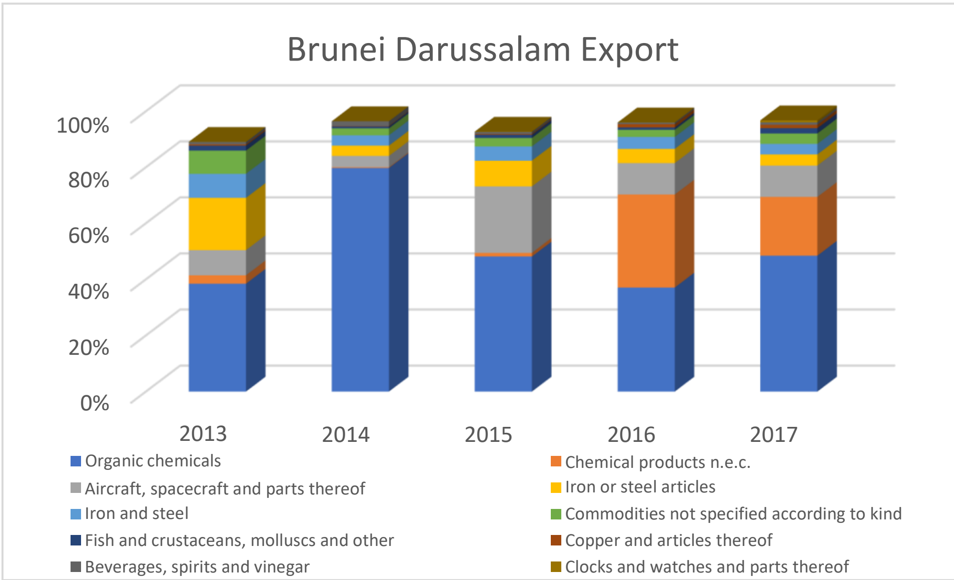
Figure A.16: Brunei Darussalam – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source*: www.comtrade.un.org/*

According to UN Comtrade, in 2017, the top ten commodities shared 97% of total exports worldwide. Organic Chemicals share 48%, Chemical products 21%, aircraft, spacecraft and parts 11%, and iron and steel 4%, as shown in the following graph.

Figure A.17: Brunei Darussalam– Top 10 Exports Commodities Share, by Value USD$

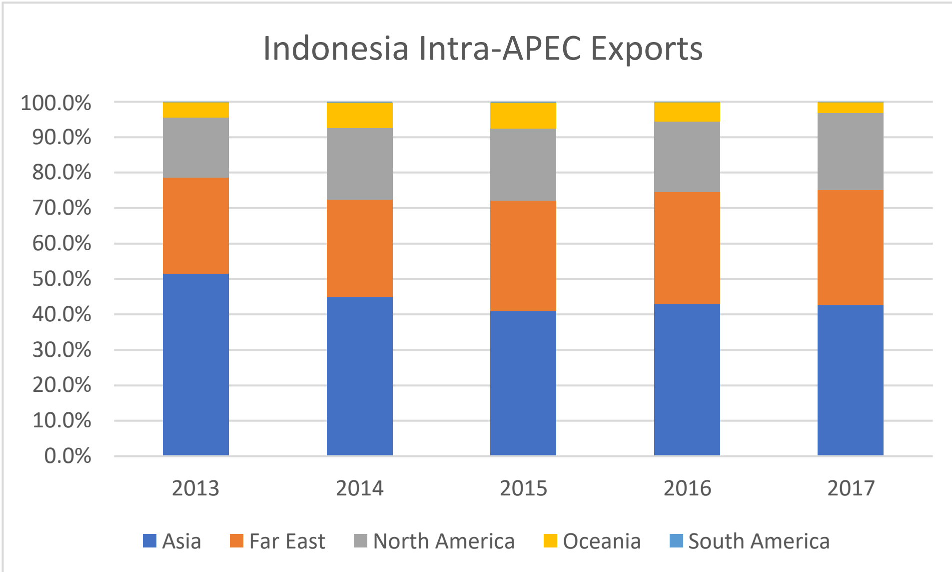


Source: *www.comtrade.un.org/*

- **Indonesia**: total exports accounted USD$168 billion, while imports were USD$157 billion, thus a positive trade balance of USD$11 billion. Total exports (goods and services) represent 20.37 of total GDP, while imports account for 19.17%. Top five exports destinations receive 50.64% of total county exports, the United States represents 10.55% of total exports. Consumer goods is the largest export category with 39.39%, intermediate goods 26.27%, raw material 24.99% and capital goods 8.88%.

  In the year 2017, Indonesia exported 75.1% of its intra-APEC trade to Asian economies (42.7% to Asia and 32.4% Far East Asia), 22.0% to the Americas (21.8% to North America and 0.2% to South America), and 3.0% to Oceania. Individual economies of intra-APEC destination are the United States 20%, Japan 18%, China 15%; Malaysia 10% and the Philippines 8%.

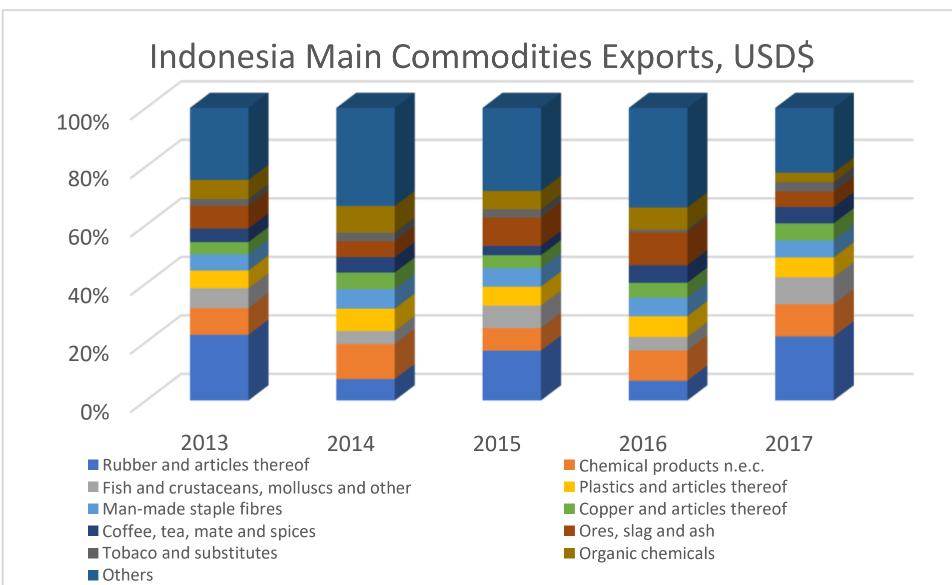
Figure A.18: Indonesia – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities shared 78% of total exports worldwide. Rubber and articles share 29%; chemical products 11%; fish and crustaceans, mollusk others 9%; plastic and articles 7%; and man-made staple fibers 6%; as shown in the following graph.

Figure A.19: Indonesia – Top 10 Exports Commodities Share, by Value USD$

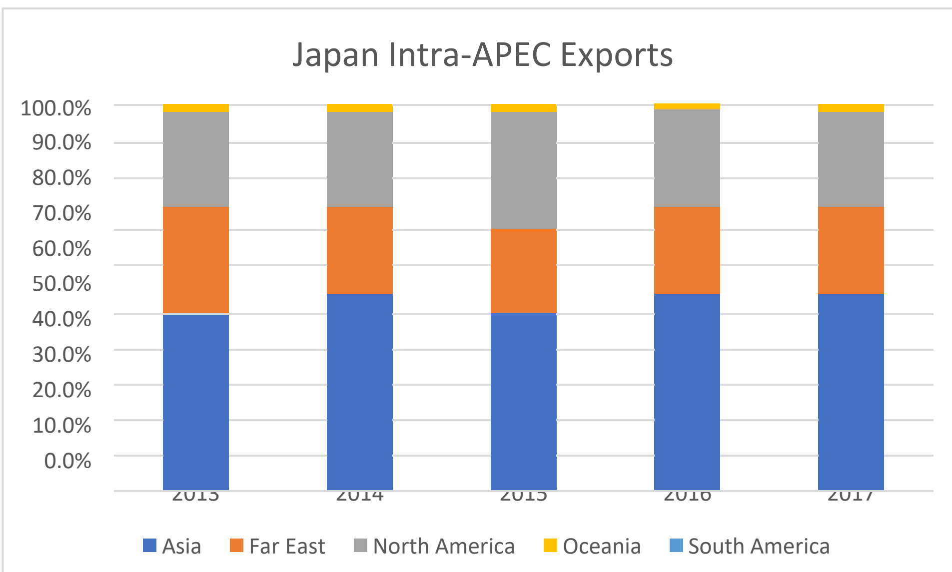


Source: *www.comtrade.un.org/*

- **Japan**: exports totaled USD$698 billion and imports were USD$671 billion, resulting a positive trade balance of USD$26 billion. In 2016, total exports, goods and services, represented 16% of total GDP, and imports 15%[10]. The top five destinations of Japan exports account for 56.91% of total exports, the United States is number one destination and represents 19.35% of total exports, the other four destinations are Asian economies. Out of the total exports, 47.56% are capital goods, 24.68% consumer goods, 19.91 intermediate goods, and 1.54% raw material.

  Japan intra-APEC exports within Asian economies share 76.4% (Asia 56.3% and Far East Asia 20.1%); the Americas 22.2% (North America 21.9% and South America 22.2%) and Oceania 1.4%. Individual economies of intra-APEC destination are China 26%, the United States 19%, Republic of Korea 14%; Hong Kong, China 8% and Thailand 8%.

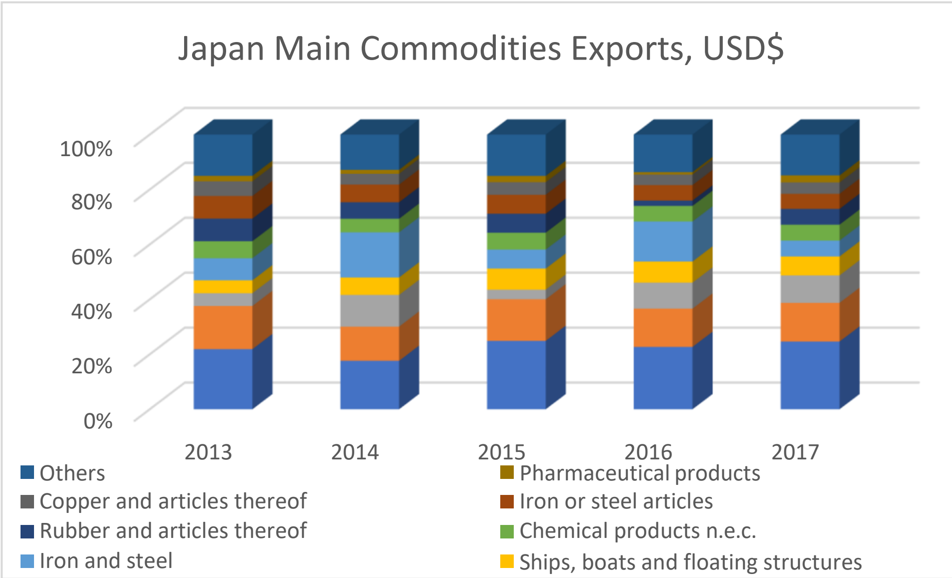
Figure A.20: Japan – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

Japan's top 10 commodities, in 2017, shared 85% of total exports worldwide. Plastics and articles 14%; organic chemicals 10%; ships, boats and floating structures 7%; iron and steel 6%; and chemical products 6%, as shown in the following graph.

Figure A.21: Japan – Top 10 Exports Commodities Share, by Value USD$

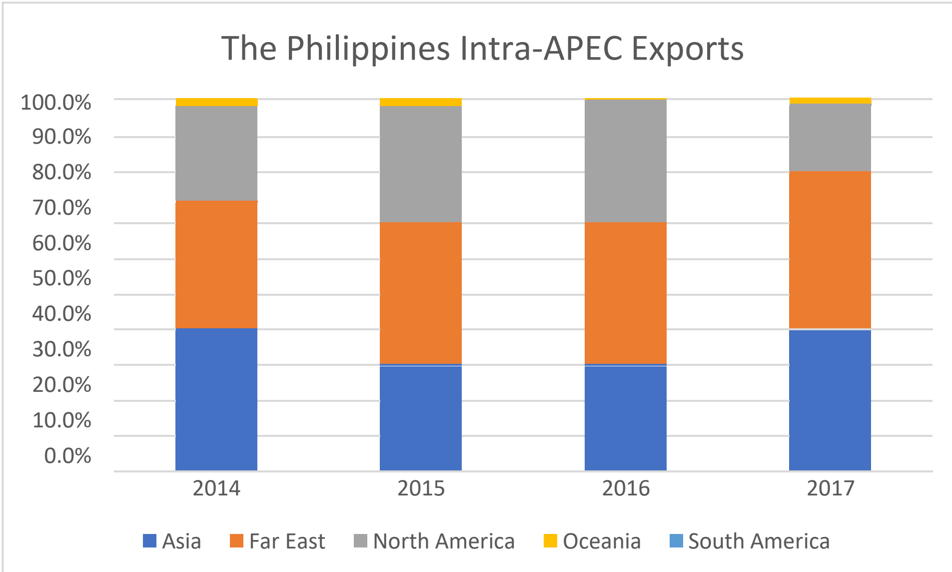


Source: *www.comtrade.un.org/*

- **The Philippines**: total exports reaches USD$68 billion and imports were USD$102 billion, thus a negative trade balance of USD$-33 billion. Total goods and services exports as a percentage of GDP represents 30.95% and imports 40.88%[11]. The top five destinations share 60.98% of the Philippines exports, four of these destinations are Asian economies, the United States ranks number two with a share of 14.07% of total exports. Capital goods share 62.88% of exports, consumer goods 17.61%, intermediate goods 12.76% and raw material 6.75%.

  In the year 2017, the Philippines exported 83.1% of its intra-APEC trade to Asian economies (40.2% to Asia and 42.9% Far East Asia), 15.8% to the Americas (15.7% to North America and 0.1% to South America), and 1.2% to Oceania. Individual economies of intra-APEC destination are Japan 32%, China 20%, the United States 15%; Thailand 8%, and Republic of Korea 8%.

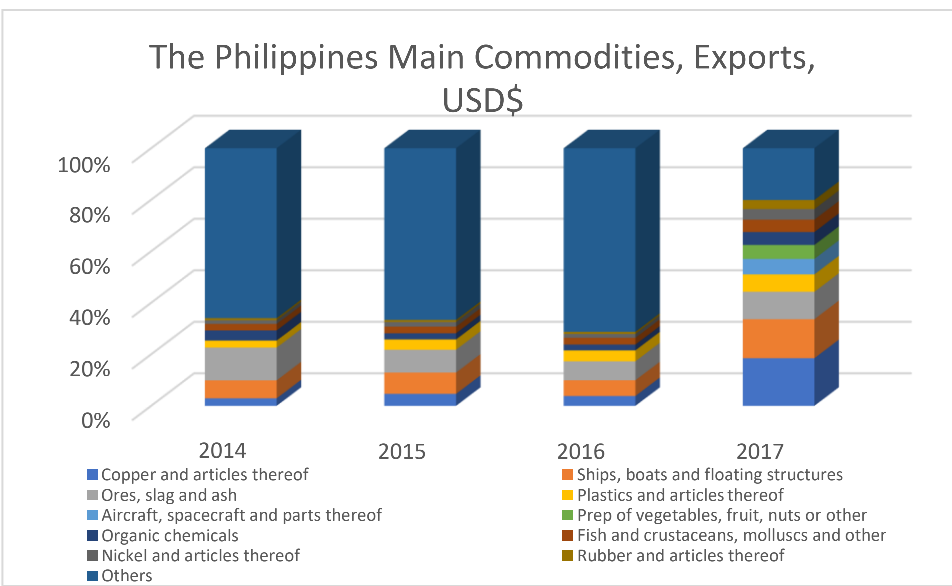
Figure A.22: The Philippines – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities shared 80% of total exports worldwide. Copper and articles share 18%; ships, boats and floating structures 15%; ores, slag and ash 11%; plastics and articles 7%; and aircraft, spacecraft and parts 6%; as shown in the following graph.

Figure A.23: The Philippines – Top 10 Exports Commodities Share, by Value USD$

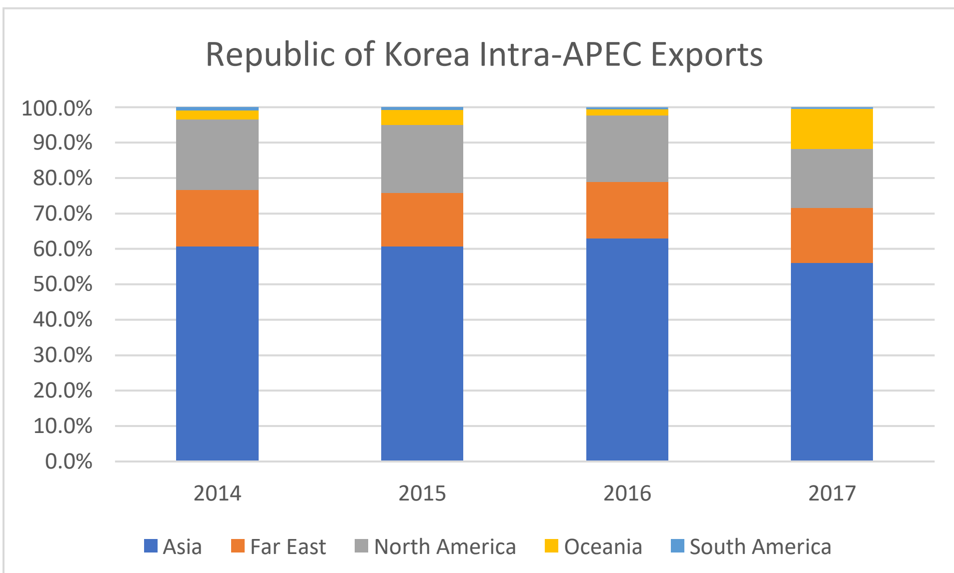


Source: *www.comtrade.un.org/*

- **Republic of Korea**: exports sum USD$573 billion and imports were USD$478 billion, for a positive trade balance of USD$95 billion. Total goods and service exports as a percentage of GDP 43.09% and imports 37.69%[12]. Four of the top five exports destination are Asian economies, except for the United States ranked number two with 12.00%, top five destination share of total exports 56.58%. Capital goods represents 54.91% of exports, intermediate goods 22.81%, consumer goods 21.67% and raw material 0.61%.

  In the year 2017, the Republic of Korea exported 71.6% of its intra-APEC trade to Asian economies (56.1% to Asia and 15.6% Far East Asia), 17.0% to the Americas (16.6% to North America and 0.4% to South America), and 11.3% to Oceania. Individual economies of intra-APEC destination are China 34%, the United States 13%, Australia 11%, Japan 10% and Viet Nam 8%.

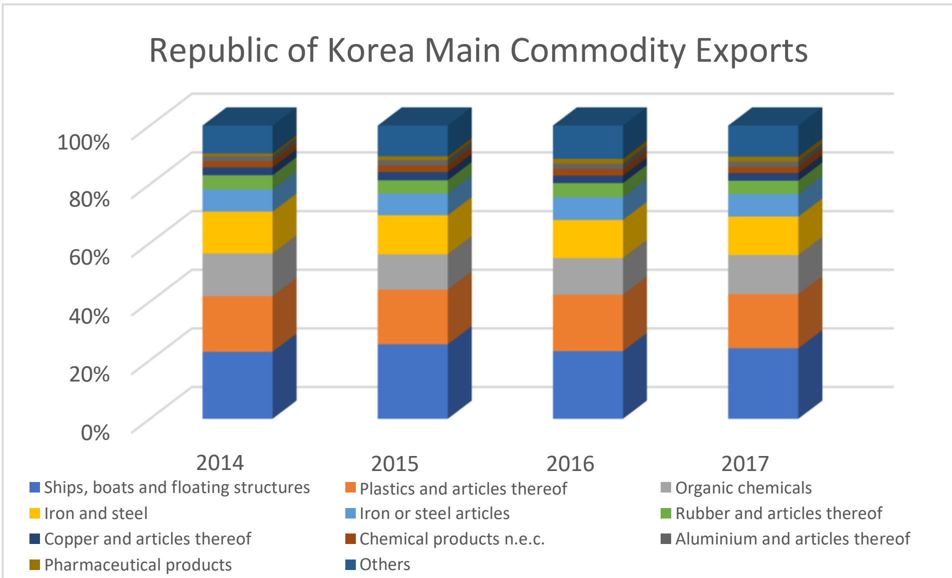
Figure A.24: Republic of Korea – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities shared 89% of total exports worldwide. Ships, boats and floating structures share 24%; plastics and articles 18%; organic chemicals 13%; iron and steel 13%; and iron or steel articles 8%; as shown in the following graph.

Figure A.25: Republic of Korea – Top 10 Exports Commodities Share, by Value USD$



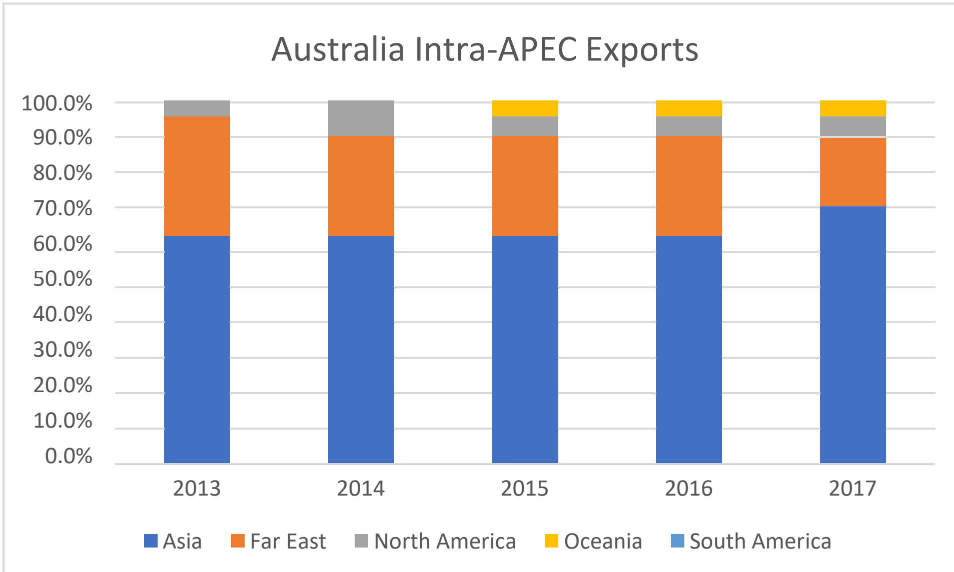
Source: *www.comtrade.un.org/*

Oceania

- **Australia**: total exports account USD$230 billion, and imports USD$228 billion for a positive trade balance of USD$1.7 billion. Goods and services total exports as a percentage of economy's GDP represents 21.27%, while imports 20.62%[13]. Top five destinations of Australian exports are Asian economies, sharing 65.44%, China is the largest economy of destination, ranked number one with 29.59% of Australia Exports. Raw material is the economy main export category with 58.61% share, intermediate goods 16.76%, consumer goods 16.28% and capital goods 4.71%.

  According to data extracted from UN Comtrade webpage, in the year 2017, 90.1% of total Australia's intra-APEC regional trade destined to Asian economies (67.8% Asia and 22.3% Far East Asia), while 3.3% was commerce with Oceania economies and 6.6% with North and South America economies. Individual economies as main destinations for Australia intra-APEC trade are China 59%, Japan 11%, Republic of Korea 8% and the United States 6%.

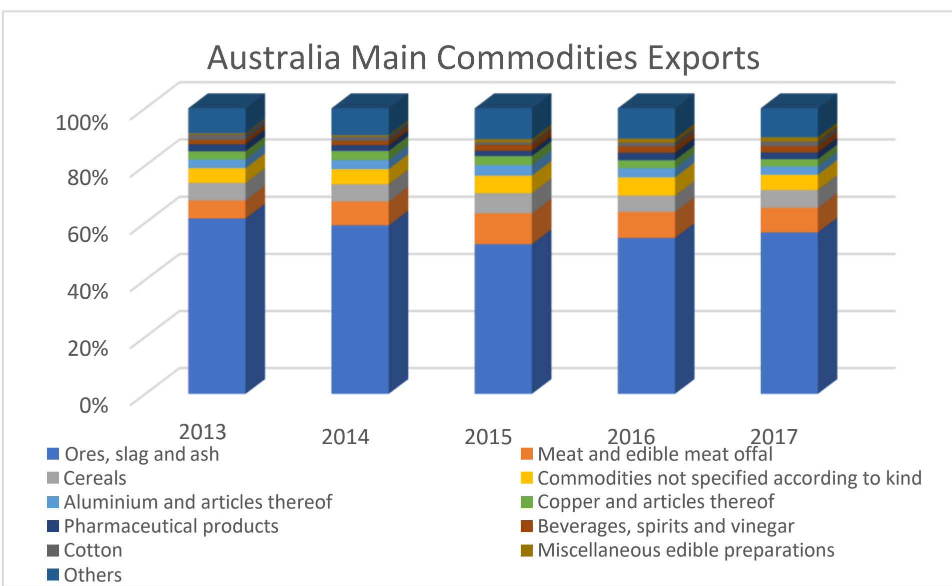
Figure A.26: Australia – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

Australia's top 10 exports commodities represents 90% of total economy exports, ores, slag and ash shared 57% of 2017 exports, followed by meat and edible meat offal with 9%, and Cereals with 6%. The graph shows Australia's top 10 commodity exports.

Figure A.27: Australia – Top 10 Exports Commodities Share, by Value USD$

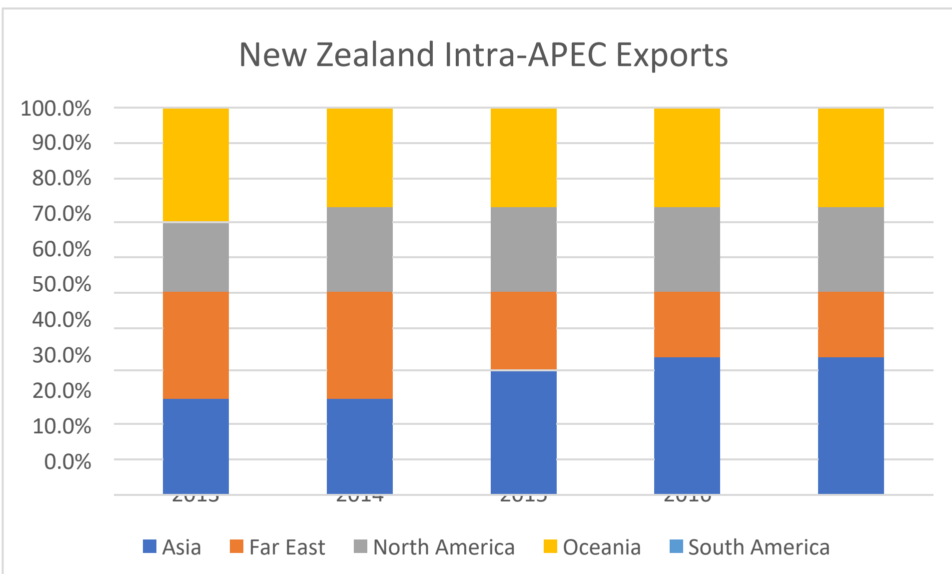


Source: *www.comtrade.un.org/*

- **New Zealand**: exports reached USD$38 billion, and imports were USD$40 billion, thus generating a negative trade balance of USD$-2 billion. Total exports, as a percentage of 2016 PIB represent 25.00%, while imports 25.00%[14]. Top five economies of destination share 57.43% of New Zealand exports; China with 22.29%, Australia 16.43%, the United States 9.94%, Japan 5.98% and the Republic of Korea 2.79%. Raw material shares 32.91% of total exports, intermediate goods 29.37%, consumer goods 27.10% and capital goods 7.29%.

  New Zealand intra-APEC exports, in the year 2017, main block destination was Asian economies with 49.7% (34.1% Asia and 15.6% Far East Asia), 25.4% with the Americas (North America 25.3% and South America 0.1%); Oceania 24.9%. Individual economies as main destinations for New Zealand intra-APEC trade are China 24%, Australia 24%, the United States 22%, Japan 10% and Hong Kong, China 4%.

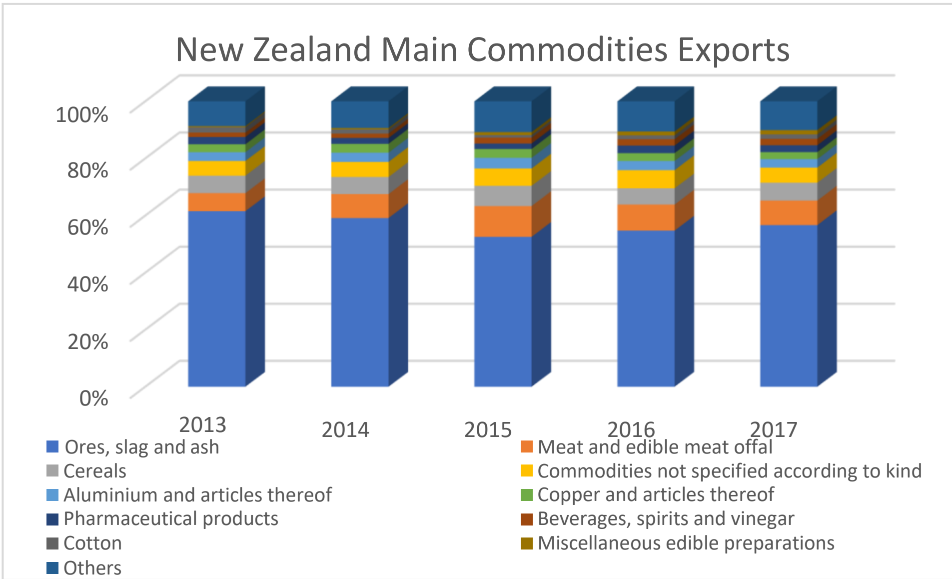
Figure A.28: New Zealand – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

New Zealand's top 10 exports commodities represents 88% of total economy exports; meat and edible meat offal share 57% of 2017 exports, followed by beverages, spirits and vinegar 11%; fish and crustaceans, mollusks and others 9%; and miscellaneous edible preparations 6%. Next graph shows New Zealand's top 10 commodity exports.

Figure A.29: New Zealand – Top 10 Exports Commodities Share, by Value USD$



Source: *www.comtrade.un.org/*

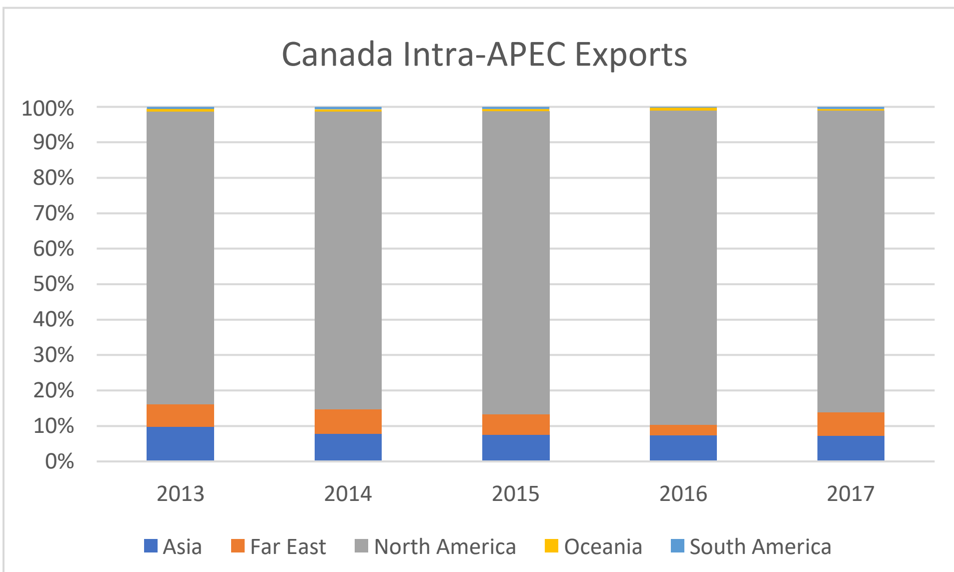
- **Papua New Guinea**: total exports account for USD$4.6 billion, and imports USD$8.3 billion, thus a negative trade balance of USD$-3.8 billion[15]. The top five destination economies account 66.82% of total exports, there are three Asian economies, one European and one Oceania economy; Australia with 35.88% share, Japan 11.69%, Germany 7.04%, China 6.69% and Singapore 5.52%.

North America

- **Canada:** total exports account for USD$420 billion, and imports for USD$432 billion, thus a negative trade balance of USD$-11.7 billion. Goods and services exports as percentage of GDP is 30.89% and imports 33.17%[16]. The top five Canadian destinations represent 87.02% of total county exports. North American trading partners share 77.29%; the United States 75.85% and Mexico 1.44%; China 4.32%, United Kingdom 3.24%, and Japan 2.17%. Consumer goods is the largest export category with 28.63%, raw material 24.36%, intermediate goods 22.86% and capital goods 17.46%.

  Of all intra-APEC trade, the Americas share 85.6% (North America 85.1% and South America 0.5%), Asia share 13.9% (Asia 7.1% and Far East Asia 6.7%) and Oceania 0.5%. Main intra-APEC economies of Canadian destinations are the United States with 83%, China 5%, Japan 4%, Mexico 2% and Republic of Korea 2%. These five economies represent 96% of total Canadian intra-APEC exports.

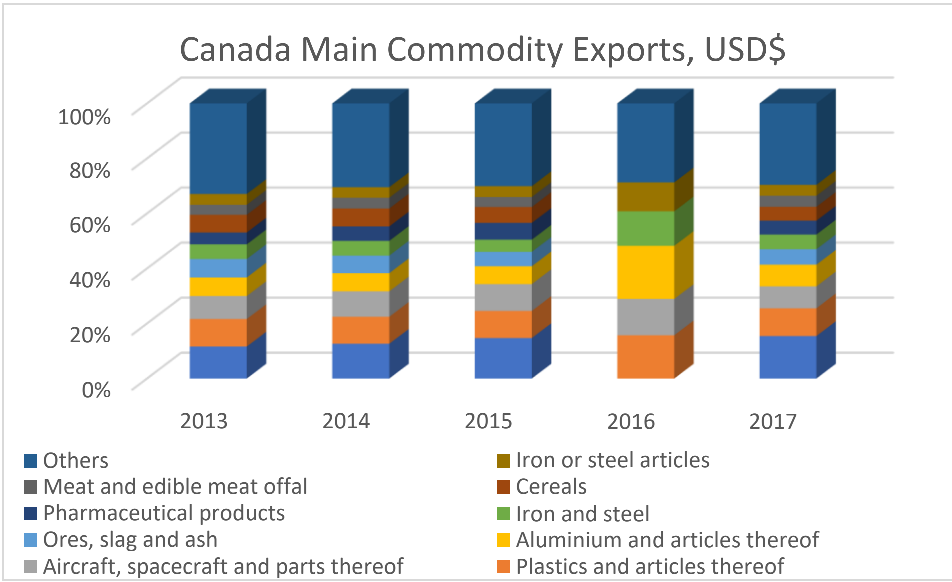
Figure A.30: Canada – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 export commodities worldwide account for 70% of Canadian exports. Plastics and articles share 10%, aircraft, spacecraft and parts 8%, aluminum and articles 8%, ores, slag and ash 6% and Iron and steel 5%.

Figure A.31: Canada – Top 10 Exports Commodities Share, by Value USD$

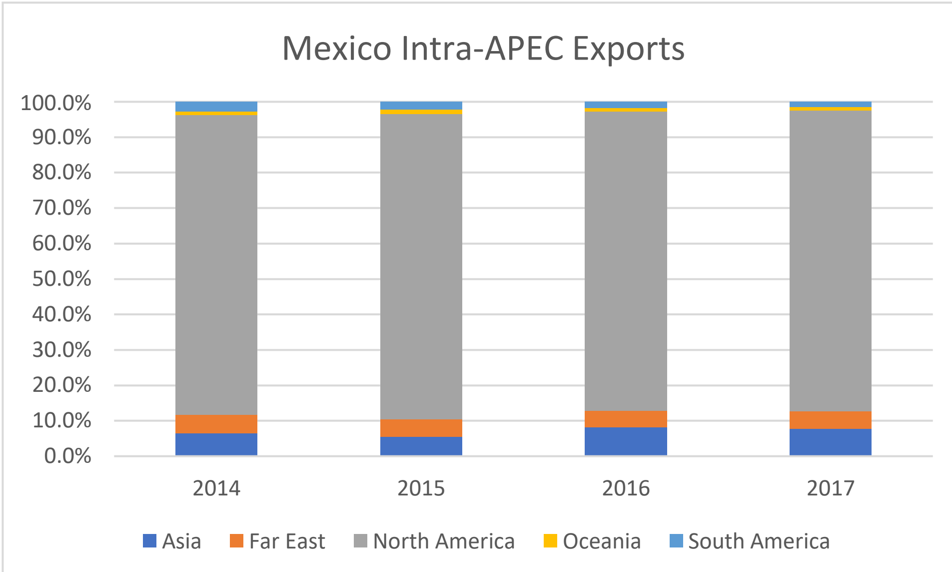


Source: *www.comtrade.un.org/*

- **Mexico**: exports reached USD$409 billion, imports USD$420 billion for a negative trade balance of USD$-11 billion. Goods and services exports as a percentage of GDP is 37.87%, while imports 39.67%[17]. The top five economies of Mexico exports destinations share 87.11%, neighbors' economies share 82.73%, the United States with 79.95% and Canada with 2.78%; Germany 1.70%, China 1.64% and Spain 1.04%. Capital goods accounts for 48.14% of total exports, consumer goods 30.50%, raw material 10.98% and intermediate goods 9.08.

  Mexico exported 86.3% of its intra-APEC trade to American economies (84.8% to North America and 1.5% South America), 12.8% to Asian economies (7.7% to Asia and 5.0% to Far East Asia), and 1.0% to Oceania. Individual economies of intra-APEC destination are the United States 81%, China 6%, Canada 4%; Republic of Korea 2% and Japan 2%.

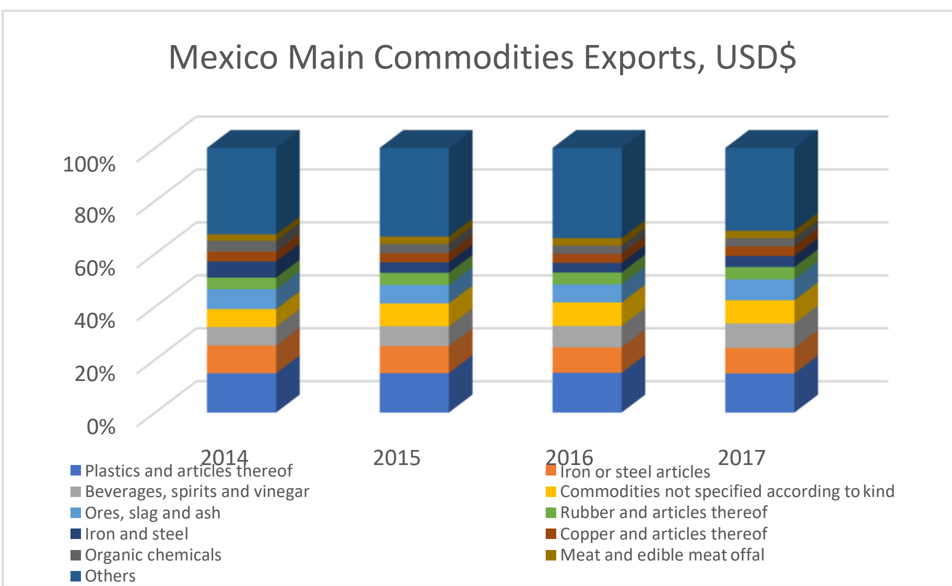
Figure A.32: Mexico – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities shared 69% of total exports worldwide. Plastics and articles share 15%; iron or steel articles 10%; beverage, spirits and vinegar 9%; ores, slag and ash 8%; and rubber and articles 5%; as shown in the following graph.

Figure A.33: Mexico – Top 10 Exports Commodities Share, by Value USD$

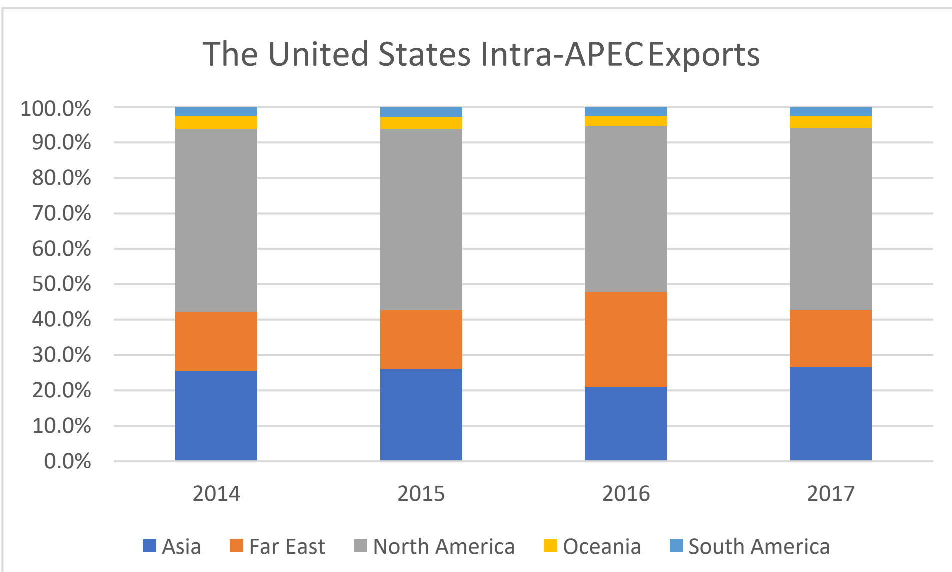


Source: *www.comtrade.un.org/*

- **The United States**: total exports reached USD$1.5 trillion, and imports were USD$2.4 trillion, thus a negative trade balance of USD$-862 billion[18]. Total exports, as a percentage of GDP, for 2016, represent 11%, while imports 14%. The top five destination economies represent 50.41% of total exports, neighbors' economies share 34.00%, Canada 18.26%, Mexico 15.74%; then China 8.4%, Japan 4.37% and United Kingdom 3.64%. Capital goods share 33.54% of total exports, consumer goods 25.91%, intermediate goods 19.53% and raw material 10.24%.

  Of all intra-APEC trade, the American economies share 53.8% (North America 51.4% and South America 2.4%), Asian economies share 42.8% (Asia 26.6% and Far East Asia 16.2%) and Oceania 3.4%. The main intra-APEC economies of the United States destinations are Canada with 27%, Mexico 24%, China 15%, Japan 10% and Republic of Korea 6%. These five economies represent 82% of total the United States intra-APEC exports.

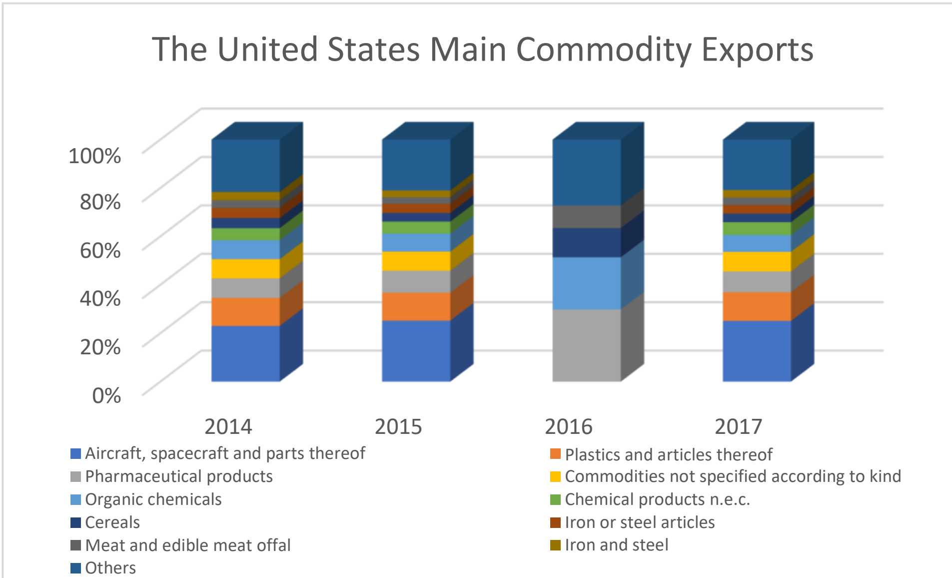
Figure A.34: The United States – Intra-APEC Exports Share, by Regional Blocks, as a percentage of USD$



Source: www.comtrade.un.org/

The top 10 export commodities worldwide account for 79% of the United States exports, aircraft, spacecraft and parts share 25%, plastics and articles 12%, pharmaceutical products 9%, organic chemicals 7% and chemical products 5%.

Figure A.35: The United States – Top 10 Exports Commodities Share, by Value USD$



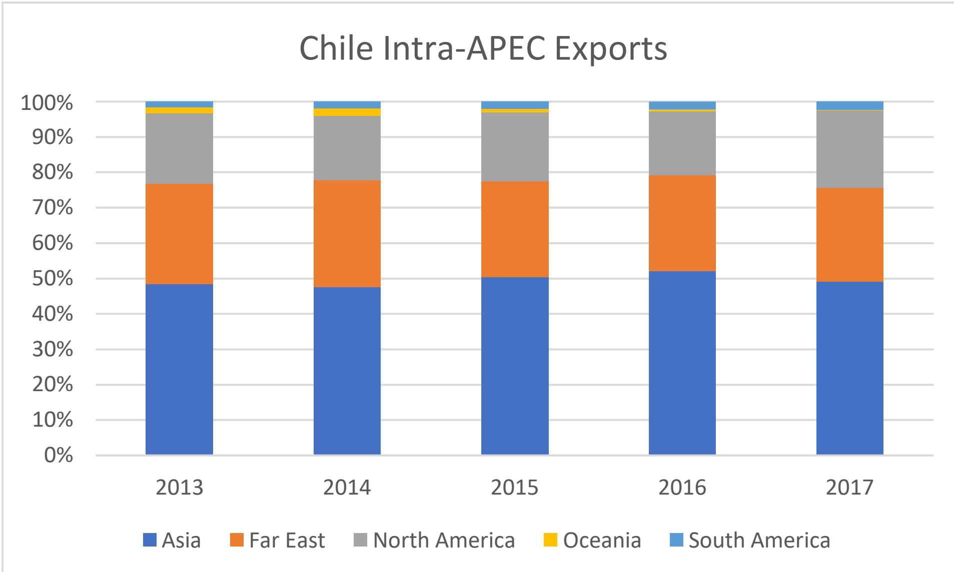
Source: *www.comtrade.un.org/*

South America

- **Chile**: exported USD$69 billion and imported USD$65 billion for a positive trade balance of USD$4 billion. Total goods and services exports as a percentage of GDP is 28.70%, while imports 26.99%[19]. Top five destination economies for Chile exports represent 62.49%, out of them, three Asian economies share 43.08%; China 27.58%, Japan 9.31%, Republic of Korea 6.19%; the United States rank number two with 14.44% and Brazil is the fifth destination with 4.97%. Raw materials lead exports with 46.69% of the total, intermediate goods with 40.25%, consumer goods 10.53% and capital goods 2.53%.

  Chile exported, in the year 2017, 75.6% of its intra-APEC trade to Asia (49.1% Asia and 26.6% Far East Asia), 24.1% to the Americas (21.7% North America and 2.4% South America), and 0.2% to Oceania. The top intra-APEC economies of destination are China 46%, the United States 17%, Japan 16%, Republic of Korea 10% and Canada 3%.

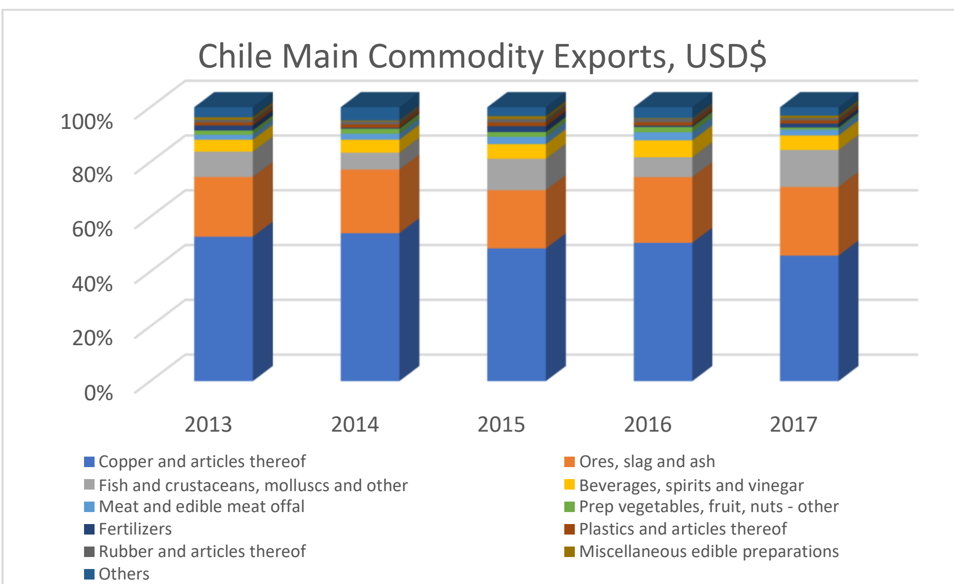
Figure A.36: Chile – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities represent 97% of Chilean total exports worldwide; copper and articles share 46% of total value in 2017; ores, slang and ash 25%; fish and crustaceans, mollusks and others 14%; beverage, spirits and vinegar 5%; and meat and edible meat offal 2%.

Figure A.37: Chile – Top 10 Exports Commodities Share, by Value USD$

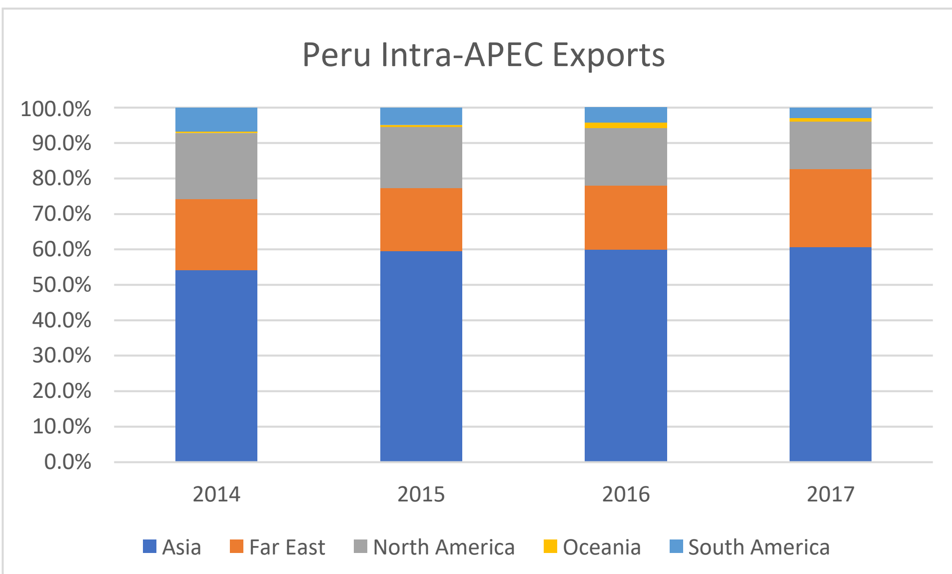


Source: *www.comtrade.un.org/*

- **Peru**: total exports for 2017 were USD$44 billion, and imports were USD$39 billion for a positive trade balance of USD$4 billion. Exports of goods and services as a percentage of GDP accounted for 24.26%, while imports 22.6%[20]. The top five exporting destinations share 56.55%, Asian economies are the main destinations with 35.55%, China ranked number one share 26.28%, the United States 15.69%, Switzerland 5.31%, Republic of Korea 4.83% and India 4.44%. Raw material is the main export category with 49.20%, intermediate goods 33.39%, consumer goods 16.38% and capital goods 1.03%.

  Peru exported, in the year 2017, 82.7% of its intra-APEC trade to Asian economies (60.5% Asia and 22.2% Far East Asia), 16.2% to the American economies (13.3% North America and 2.9% South America), and 1.1% to Oceania. The top intra-APEC economies of destination are China 58%, Republic of Korea 11%, the United States 10%, Japan 9%, and Chile 3%.

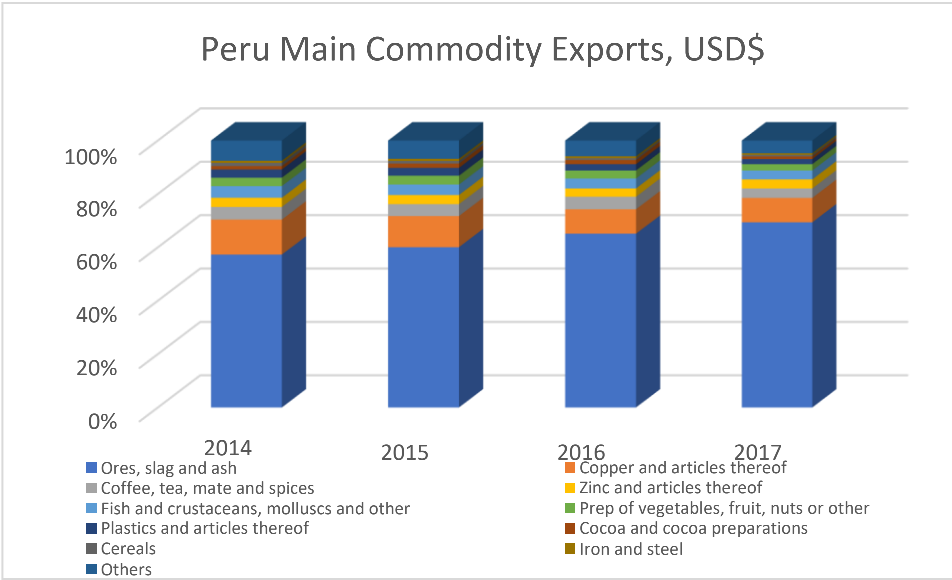
Figure A.38: Peru – Intra-APEC Exports Share, by Regional Blocks, as a Percentage of USD$



Source: *www.comtrade.un.org/*

The top 10 commodities represent 95% of Peruvian total exports worldwide; ores, slag and ash share 69% of the total value in 2017; copper and articles 9%; coffee, tea, mate and spices 4%; zinc and articles 3%; and fish and crustaceans, mollusks and others 3%.

Figure A.39: Peru – Top 10 Exports Commodities Share, by Value USD$



Source: *www.comtrade.un.org/*

List of Endnotes

[1] Source: *www.apec.org/Publications/2018/11/APEC-in-Charts-2018*
[2] World Bank Integrated Trade Solution *www.wits.worldbank.org/CountryProfile/es/CHN*
[3] Source: *www.mof.gov.tw/Eng/Detail/Index?nodeid=259&pid=57876; www.trade.gov.tw/english/Pages/Detail.aspx?nodeID=94&pid=651989&dl_DateRange=all&txt_SD=&txt_ED=&txt_Keyword=&Pageid=0*
[4] World Integrated Trade Solution *www.wits.worldbank.org/CountryProfile/es/HKG*
[5] World Integrated Trade Solution *www.wits.worldbank.org/CountryProfile/es/RUS*
[6] World Integrated Trade Solutions *www.wits.worldbank.org/CountryProfile/es/SGP*
[7] World Integrated Trade Solutions *www.wits.worldbank.org/CountryProfile/es/THA*
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[9] World Bank Integrated Trade Solution *www.wits.worldbank.org/CountryProfile/es/BRN*
[10] World Integrated Trade Solution *www.wits.worldbank.org/countrysnapshot/es/JPN*
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[20] World Integrated Trade Solutions *www.wits.worldbank.org/CountryProfile/es/PER*

APPENDIX B
Slow Steaming Analysis Model's Estimating Methods and Inputs

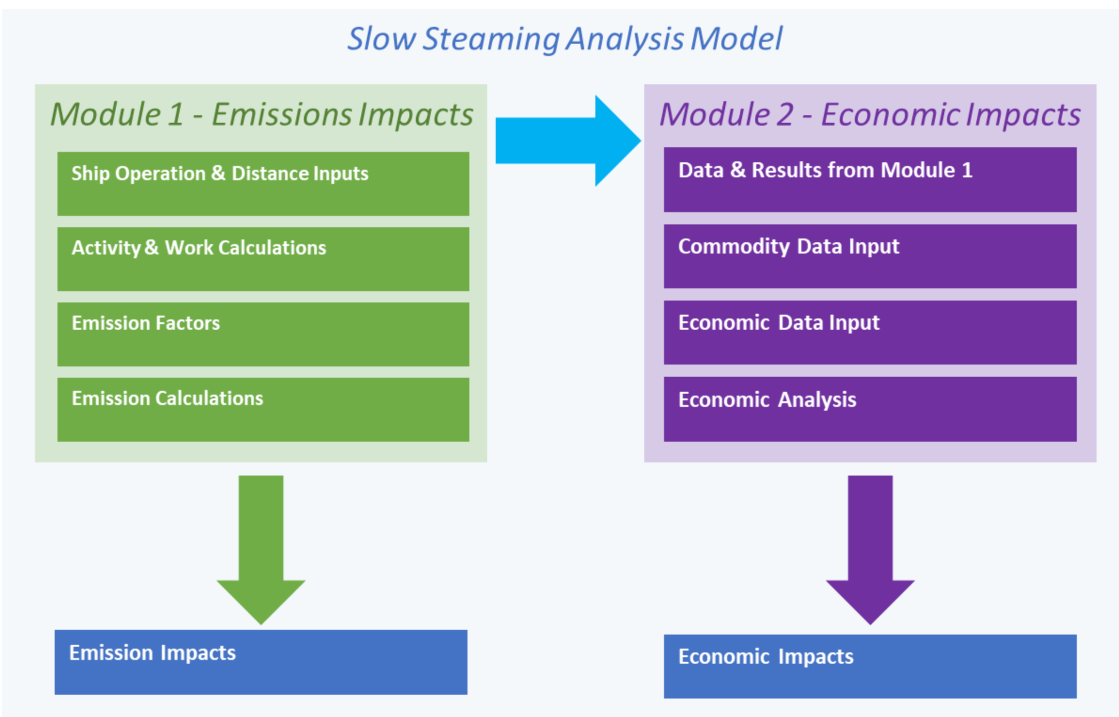
B.1 Overview Slow Steaming Analysis Model

The Slow Steaming Analysis (SSA) Model was developed as an analysis tool that APEC economies and other stakeholders could conduct their own analysis of specific scenarios relating to slow steaming. The findings then serve to inform delegations to the IMO MEPC and ISWG-GHG meetings and assist in the ongoing discussion focused on slow steaming as a short-term measure.

The SSA Model consists of two modules: Module 1 – GHG Impacts (Module 1) and Module 2 – Economic Impacts (Module 2). The two modules allow users to enter specific data related to ships, distances, operational parameter, and economic parameters to evaluate specific scenarios. The user enters ship operational data, distances, and other related parameters (detailed in Section B.1 below) into Module 1. The output of Module 1 is then copied by the user and pasted into Module 2 to conduct further economic analysis. The inputs to Module 2 are detailed in Section 2.0 of the report. The outputs include emission impacts, additional ships needed, delay durations for at-sea transits, and economic impacts.

The model was developed using Microsoft Excel so it could be easily used by a wide range of users. An illustration of the SSA Model and its two modules is presented in the figure below.

Figure B.1: SSA Model Illustration



A detailed explanation for Module 1 is provided in Section B.2 and Module 2 is described in Section B.3.

B.2 SSA Model, Module 1 – GHG Impacts

There are three worksheet tabs to the emissions model:

1. **Information:** provides general information about the model
2. **Ship and Emission Factor (EF) Parameters:** user input on container and bulk ship size, average maximum rated speed, average propulsion power rating, engine type, operational parameters for auxiliary engines and boilers, emission factors for greenhouse gases (GHGs), and global warming potential factors
3. **Analysis Matrices:** user input related to number of ships, distances, baseline speeds, incremental speed reduction, and lowest reduced speed

User inputs are numbers and text in blue font. Each worksheet is further described in the following sections.

Ship and Emission Factor Parameters Worksheet

The ship parameters that are needed in analysing slow steaming and the input table for ship parameters is provided in the table below.

Table B.1: Ship Parameter Inputs

Ship Types	Ship Sizes	Average Maximum Rated Speeds knots	Percent of Maximum Draft	Hull Fowling Variable	Route Option: Coastal At-Sea	Weather Impact Variable	Average Propulsion Ratings kW	Engine Type MSD/SSD	At-Sea Avg Aux Loads kW	At-Sea Avg Boiler Loads kW	At-Sea GSA Speeds knots	At-Sea Published Speeds knots
Container	1,000 teu	18.94	100%	9%	At-Sea	15%	11,974	MSD	750	300	13.9	18.0
Container	3,000 teu	21.97	100%	9%	At-Sea	15%	27,617	SSD	750	400	16.1	20.0
Container	6,000 teu	24.80	100%	9%	At-Sea	15%	57,343	SSD	1,000	650	16.3	20.0
Container	9,000 teu	23.43	100%	9%	At-Sea	15%	53,261	SSD	1,100	675	16.3	20.0
Container	14,000 teu	22.65	100%	9%	At-Sea	15%	55,327	SSD	1,200	800	16.1	20.0
Container	17,000 teu	22.56	100%	9%	At-Sea	15%	69,937	SSD	1,400	500	14.8	20.0
Bulk	Handymax	14.13	100%	9%	At-Sea	15%	7,496	MSD	250	65	11.8	12.0
Bulk	Panamax	14.43	100%	9%	At-Sea	15%	9,387	SSD	350	65	11.8	12.0
Bulk	Capesize	14.55	100%	9%	At-Sea	15%	18,149	SSD	400	65	11.7	12.0

A description of the ship parameter inputs is provided below:

1. **Ship types:** for the APEC study, container and dry bulk (bulk) were specified. Other ship types can be entered along with their corresponding parameters.
2. **Ship sizes:** for the APEC study, container 1,000 twenty-foot equivalent units (teu), 3,000 teu, 6,000 teu, 9,000 teu, 14,000 teu, and 17,000 teu sizes were selected to cover a broad range of container ship. For bulk, Handymax, Panamax, and Capesize were selected.
3. **Average maximum rated speeds, in knots:** these are the average maximum rated speed for the ship type-size combination. For the APEC study, these values are based on IHS Markit Data[1] (formerly Lloyd's Register data) for all "in service/commission" ships for the specific ship types and size ranges. For container ships, X,000 teu size range equals ship capacities of X,000 to X,999 teu. For bulk ships the following parameters were used to derive the average values:
    a. Statcode3 = Bulk Dry

b. Statcode5 = Bulk Carrier and Ore Carrier
c. ShipTypeGrouping = Bulk Carrier-Handymax, Bulk Carrier-Panamax, and Bulk Carrier-Capesize

4. **Percent of maximum draft:** this value represents the percent of maximum draft the ship is operating at for the scenario. For the APEC study, ships were assumed to be fully laden or 100%.
5. **Hull fowling factor:** this factor represents the extra work the propulsion engine based on the condition of the hull. For the APEC study, the same valued was used as in the International Maritime Organization Third Greenhouse Gas Study 2014[2] (IMO 2014) was used. The user can set this value based on the particular scenario being assessed.
6. **Route type:** the user can pick between “At-Sea” or “Coastal” – the selection is used by the Weather impact factor. Coastal routes are assumed to be sheltered from the weather compared to at-sea routes, consistent with IMO 2014.
7. **Weather impact factor:** the value of this field is driven by the selection made in the Route type field. At-Sea selection sets the value to 15% and Coastal sets the value to 10%. These values are the same values used in IMO 2014 and take into account averaged weather impacts on propulsion engine loads.
8. **Average propulsion power ratings, in kilowatts (kW):** using the same ship categorization approach as average maximum rated speed, averages of propulsion power were determined for each ship and size combination. Note that these values can be changed to match specific route scenarios, as needed.
9. **Engine type:** the two primary engine types used in the APEC study for propulsion power are slow speed diesel (SSD) engines and medium speed diesel (MSD) engines. SSD engines, by IMO definition,[3] are those engines that are rated less than 130 revolutions per minute (rpm), and MSD engines are those engines rated at 130 to less than 2,000 rpm. Engine type is important as SSD and MSD have different emission factors. Note that the model can be configured for any ship/fuel/engine configuration.
10. **At-sea average auxiliary loads, in kW:** these are the average load of the auxiliary engine system during at-sea transits. It assumes that the ship does not utilize a shaft generator which can be used instead of auxiliary engines. The loads used in the APEC study and provided in the table are from the same data sources[4] used in the IMO 2014, however updated with data collected since the publication of the study. Note that these values can be changed to match specific route scenarios, as needed.
11. **At-sea average boiler loads, in kW:** these are the average load of the boiler system during at-sea transits. The boiler load averages are for ships that do not cover all boiler functions with waste heat recovery plants. The data source is the same as 6, above. Note that these values can be changed to match specific route scenarios, as needed.
12. **At-sea global speed averages (GSA), in knots:** these are the baseline speeds ships are traveling prior to the implementation of any slow steaming strategy. These speeds can be established in many different ways. One option is to use the latest published information on the global fleet by applicable ship type and size categories as determined in IMO 2014[5] for 2012. These speeds can be used as a

starting point for the baseline GSA speed, however, there are indications that ships maybe traveling faster than the 2012 speeds. At this time there are no new publications that have investigated ship speeds and published their findings to the extent of IMO 2014.

13. **At-sea published speeds, in knots:** these speeds are from various published strings or routes by ship lines. They were derived from taking the mileage of the sea transits, the schedule, and average port stays to calculate the average sea transit speed needed to make the route viable, as published. For the APEC study, the published speeds were used because they gave the greatest range of speeds regimes for analysis. Note that these values can be changed to match specific route scenarios, as needed.

The emission factor input grid is where the user can input emission factors for propulsion engines, auxiliary engines, and boilers. Emissions are estimated for carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). For the APEC study, MSD and SSD propulsion emission factors from IMO 2014 were used and Global Warming Potential (GWP) applied. The GWP values used were one for CO_2, 298 for N_2O, and 25 for CH_4. The normalized emission estimates are in units of carbon dioxide equivalents (CO_2e) that these values can be changed to match specific scenarios, as needed. The EF inputs are presented in the table below.

Table B.2: Emission Factor Inputs

EF Type	Prop EF CO_2 g/kWh	Prop EF N_2O g/kWh	Prop EF CH_4 g/kWh	Aux EF CO_2 g/kWh	Aux EF N_2O g/kWh	Aux EF CH_4 g/kWh	Boiler EF CO_2 g/kWh	Boiler EF N_2O g/kWh	Boiler EF CH_4 g/kWh
MSD Prop/MSD Aux	670	0.034	0.010	707	0.036	0.008	950	0.049	0.002
SSD Prop/MSD Aux	607	0.031	0.012	707	0.036	0.008	950	0.049	0.002

Analysis Matrices Worksheet

This worksheet has both model inputs, stepwise estimates, and results. The first parameter that user can set is the minimum slow steaming speed, in knots. For the APEC Study, this value was set to 10.0 knots. This was selected because it is the VSR speed limit for ships without an Alternative Compliance Plan in the PANYNJ CVI Program. It should be noted that this speed is most likely unrealistic at a global level because of the issues associated with steering and navigating in rough seas, however it gives the broadest range of speeds and helps illustrates that the effects of slow steaming can vary across speeds.

There are 13 matrices that step through the analysis such that the user can see the impacts in various steps needed to perform the analysis. At the bottom of the worksheet there is a series of figures that provide a graphical representation of the percent change in CO_2e emissions and the required number of additional ships for each scenario. Note that the vertical axis has been set such that the figures provide a common magnitude illustration for each scenario.

Matrix 1 – Ship & Route Operational Data

In this matrix the user can enter key ship and route operational data for each scenario. These inputs are for each ship type and size combination. The first set of inputs are provided in the table below.

Table B.3: Ship Fleet and Distance Inputs

Ship Type	Ship Size	Number of Ships	Shortest Distance 1 (nm)	Ocean Transit Distance Distance 2 (nm)	Distance 3 (nm)	Distance 4 (nm)	Longest Distance 5 (nm)
Container	1,000 teu	12	200	1,650	3,100	4,550	6,000
	3,000 teu	12	200	1,650	3,100	4,550	6,000
	6,000 teu	12	600	2,200	3,800	5,400	7,000
	9,000 teu	12	800	2,600	4,400	6,200	8,000
	14,000 teu	15	1,000	3,000	5,000	7,000	9,000
	17,000 teu	15	1,200	4,650	8,100	11,550	15,000
Bulk	Handymax	12	600	2,700	4,800	6,900	9,000
	Panamax	12	600	3,450	6,300	9,150	12,000
	Capesize	12	600	3,950	7,300	10,650	14,000

A description of the ship fleet and ocean transit distance inputs is provided below:

1. **Number of Ships:** This is the number of ships or the size of the fleet operating on a string or route across the distances entered. For the APEC study, 12 ships were input for all ship type and size combinations, with the exception of the two largest container ship sizes, which was 15. Note that these values can be changed to match specific route scenarios, as needed.
2. **Distance 1 (Shortest Distance), nm**: Distance 1 is the shortest distance the user can input for a given scenario. For the APEC study, 200 to 1,200 miles were selected, as shown above, to illustrate a range of potential short travel distances.
3. **Distance 5 (Longest Distance), nm:** Distance 5 is the longest distance the user can input for a given scenario. For the APEC study, 6000 to 15,000 miles were selected, as shown above, to illustrate a wide range of potential long travel distances.
4. **Distances 2-4, in nm:** These are equidistance segments between Distances 1 and 5, this allows the user to observe how the fleet is impacted over a broad range of intermediate distances for comparisons or use for mapping out a complex route.

The next portion of Matrix 1 that has user inputs is provided in the table below. This table presents the high baseline speed scenario inputs.

Table B.4: Baseline Speed and Operational Inputs

Ocean Transit Speed Range												Arrival
GSA (knots)	GSA -1 (knots)	GSA -2 (knots)	GSA -3 (knots)	GSA -4 (knots)	GSA -5 (knots)	GSA -6 (knots)	GSA -7 (knots)	GSA -8 (knots)	GSA -9 (knots)	GSA -10 (knots)	Slow Down Increment (knots/step)	Delay Tolerance (hours)
18.0	17.2	16.4	15.6	14.8	14.0	13.2	12.4	11.6	10.8	10.0	0.80	48.0
20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0
12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0
12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0

A description of the baseline speed and operational inputs is provided below:

1. **Global Speed Average (GSA), in knots:** the GSA sets the scenario's baseline speed from which slow steaming benefits are calculated. For the APEC study, there were two scenarios used:

   a) High baseline speed scenario, with speeds ranging from 20.0 to 10.0 knots, file name: *FINAL APEC SSA Model Module 1 – GHG Impacts – High Baseline Speed Scenario V2 (Aug 19) scg.xlsx*
   b) 2012 annual average speeds from IMO 2014 scenario (2012 average speed IMO 2014 scenario), with speeds ranging from 16.3 to 10.0 knots, file name: *FINAL APEC SSA Model Module 1 – GHG Impacts – 2012 Avg Speed IMO 2014 Scenario V2 (Aug 19) scg.xlsx*

   The user can enter any desired speeds for any scenario for any ship type and size combination.
2. **GSA-X, in knots:** these values are calculated incremental reductions in speed from the GSA speed. There are 10 incremental speeds (GSA-1 through GSA-10).
3. **Slow Down Increment, in knots per step:** the slow down increment can be set for each ship type and size combination and for the APEC study they were set to values above to have each ship type-size combination end with the lowest slow steaming value (10 knots). Note that these inputs can be set to any desired increment depending on the scenario being analysed.
4. **Arrival Delay Tolerance, in hours:** these factors allow the user to set a time delay tolerance level associated with the arrival of a ship, in hours. For the APEC study, 48 hours was used meaning that a delay that's less than 48 hours does not warrant an extra ship to be added to the fleet. Setting this value to zero means that any slowdown results in an extra ship being added to the scenario fleet, which is not practicable. Note that the tolerances these inputs can be set to any desired increment depending on the scenario being analysed.
5. **Notes:** the notes column is provided for the user to insert any notes as needed.

Matrix 2 – At-Sea Ship Transit Times

This matrix calculates the at-sea ship transit times based on the user's inputs. It should be noted that times in modes outside of at-sea speeds (transition from at-sea to maneuvering, maneuvering, at-anchorage, at-berth, etc.) are not included as slow steaming would not generally impact these modes and the distances in those modes are generally insignificant compared to the at-sea transit. Therefore, the model assumes that there is no significant impact during these modes from a global speed reduction measure and the times associated with these modes are not impacted.

The transits times are calculated using the following equation:

Equation 2

$$\text{Transit Times}_{\text{GSA-X}} = \text{Distance \#} / \text{Speed}_{\text{GSA-X}}$$

Where,

Transit $\text{Times}_{\text{GSA-X}}$ – at-sea transit times for baseline GSA speeds and incremental reduced speeds GSA-1 through GSA-10 over the specific distance, in hours

Distance # – Distances 1-5, in nm

$\text{Speed}_{\text{GSA-X}}$ – at-sea transit baseline GSA speeds and incremental reduced speeds GSA-1 through GSA-10, in knots

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.5: Matrix 2 – Illustrative Results for Distance 5

Ship Type	Ship Size	At-Sea Transit Times per Ship Distance 5										
		GSA (hours)	GSA -1 (hours)	GSA -2 (hours)	GSA -3 (hours)	GSA -4 (hours)	GSA -5 (hours)	GSA -6 (hours)	GSA -7 (hours)	GSA -8 (hours)	GSA -9 (hours)	GSA -10 (hours)
Container	1,000 teu	431.7	444.4	458.0	472.4	487.8	504.2	521.7	540.5	560.7	582.5	600.0
	3,000 teu	372.7	388.3	405.4	424.0	444.4	466.9	491.8	519.5	550.5	585.4	600.0
	6,000 teu	429.4	447.3	466.7	487.8	510.9	536.4	564.5	595.7	630.6	669.9	700.0
	9,000 teu	490.8	511.2	533.3	557.5	583.9	613.0	645.2	680.9	720.7	765.6	800.0
	14,000 teu	559.0	582.5	608.1	636.0	666.7	700.4	737.7	779.2	825.7	878.0	900.0
	17,000 teu	1,013.5	1,049.0	1,087.0	1,127.8	1,171.9	1,219.5	1,271.2	1,327.4	1,388.9	1,456.3	1,500.0
Bulk	Handymax	762.7	774.5	786.7	799.3	812.3	825.7	839.6	853.9	868.7	884.1	900.0
	Panamax	1,016.9	1,032.7	1,049.0	1,065.7	1,083.0	1,100.9	1,119.4	1,138.5	1,158.3	1,178.8	1,200.0
	Capesize	1,196.6	1,215.3	1,234.6	1,254.5	1,275.0	1,296.3	1,318.3	1,341.0	1,364.5	1,388.9	1,400.0

Matrix 3 – Ship Time Deltas

This matrix calculates the delay in times or time deltas between the baseline GSA speed and the slow steaming reduced speed increments (GSA-1 through GSA-10) for the at-sea transit for each ship type and size combination for each distance (Distances 1-5).

The time deltas are calculated using the following equation:

Equation 3

$$\text{Time Delta}_{GSA\text{-}X} = [\text{Time}_{GSA\text{-}X} - \text{Time}_{GSA}]$$

Where,

$\text{Time Delta}_{GSA\text{-}X}$ – the change in time between baseline speed and the specific reduced speed increment over the specific distance, in hours

$\text{Time}_{GSA\text{-}X}$ – at-sea transit time at speed increment GSA-1 through GSA-10 over the specific distance, in hours

Time_{GSA} – at-sea transit time at baseline GSA speeds over the specific distance, in hours

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.6: Matrix 3 – Illustrative results for ship time deltas

Ship Type	Ship Size	Time Delta per Ship Distance 5										
		GSA (hours)	GSA -1 (hours)	GSA -2 (hours)	GSA -3 (hours)	GSA -4 (hours)	GSA -5 (hours)	GSA -6 (hours)	GSA -7 (hours)	GSA -8 (hours)	GSA -9 (hours)	GSA -10 (hours)
Container	1,000 teu	0.0	12.8	26.4	40.8	56.2	72.5	90.1	108.9	129.1	150.9	168.3
	3,000 teu	0.0	15.7	32.7	51.4	71.8	94.3	119.1	146.8	177.8	212.7	227.3
	6,000 teu	0.0	17.8	37.2	58.4	81.5	107.0	135.1	166.3	201.2	240.4	270.6
	9,000 teu	0.0	20.4	42.5	66.7	93.1	122.2	154.4	190.1	229.9	274.8	309.2
	14,000 teu	0.0	23.5	49.1	77.0	107.7	141.4	178.7	220.2	266.7	319.0	341.0
	17,000 teu	0.0	35.4	73.4	114.3	158.4	206.0	257.7	313.9	375.4	442.8	486.5
Bulk	Handymax	0.0	11.8	24.0	36.6	49.6	63.0	76.8	91.2	106.0	121.4	137.3
	Panamax	0.0	15.8	32.0	48.8	66.1	84.0	102.5	121.6	141.4	161.8	183.1
	Capesize	0.0	18.7	38.0	57.9	78.5	99.7	121.7	144.4	167.9	192.3	203.4

Matrix 4 – Ship Delay Impact Ratios

This matrix calculates the ship delay impact ratio between the baseline GSA speed conditions and the slow steaming reduced speed increments (GSA-1 through GSA-10) for the at-sea transit for each ship type and size combination for each distance (Distances 1-5).

The ship delay impact ratio is based on the following equation:

Equation 4

$$\text{Ship Delay Impact Ratio}_{GSA\text{-}X} = \text{Time}_{GSA\text{-}X} / [\text{Time}_{GSA} + \text{Arrival Delay Tolerance}]$$

Where,

Ship Delay Impact $\text{Ratio}_{GSA\text{-}X}$ – the delay impacts related to the reduced speed increments over the specific distance, taking into account the Arrival Delay Tolerance factor, in hours

Arrival Delay Tolerance – the arrival delay that is tolerable, as detailed in Matrix 1 above, in the scenario being evaluated, in hours

Equation terms not listed have been defined above.

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.7: Matrix 4 – Illustrative Results for Ship Delay Impact Ratios

Ship Type	Ship Size	Ship Delay Impact Ratio Distance 5										
		GSA (ratio)	GSA -1 (ratio)	GSA -2 (ratio)	GSA -3 (ratio)	GSA -4 (ratio)	GSA -5 (ratio)	GSA -6 (ratio)	GSA -7 (ratio)	GSA -8 (ratio)	GSA -9 (ratio)	GSA -10 (ratio)
Container	1,000 teu	1.00	1.00	1.00	1.00	1.02	1.05	1.09	1.13	1.17	1.21	1.25
	3,000 teu	1.00	1.00	1.00	1.01	1.06	1.11	1.17	1.23	1.31	1.39	1.43
	6,000 teu	1.00	1.00	1.00	1.02	1.07	1.12	1.18	1.25	1.32	1.40	1.47
	9,000 teu	1.00	1.00	1.00	1.03	1.08	1.14	1.20	1.26	1.34	1.42	1.48
	14,000 teu	1.00	1.00	1.00	1.05	1.10	1.15	1.22	1.28	1.36	1.45	1.48
	17,000 teu	1.00	1.00	1.02	1.06	1.10	1.15	1.20	1.25	1.31	1.37	1.41
Bulk	Handymax	1.00	1.00	1.00	1.00	1.00	1.02	1.04	1.05	1.07	1.09	1.11
	Panamax	1.00	1.00	1.00	1.00	1.02	1.03	1.05	1.07	1.09	1.11	1.13
	Capesize	1.00	1.00	1.00	1.01	1.02	1.04	1.06	1.08	1.10	1.12	1.12

Matrix 5 – Ship Fleet Impacts

This matrix calculates the ship fleet impact to determine the number of additional ships needed between the baseline GSA speed conditions and the slow steaming reduced speed increments (GSA-1 through GSA-10) for the at-sea transit for each ship type and size combination for each distance (Distances 1-5).

The ship fleet impact is based on the following equation:

Equation 5

$$\text{Ship Fleet Impact}_{GSA\text{-}X} = \text{Ship Delay Impact Ration}_{GSA\text{-}X} \times \text{Number of Ships}_{GSA\text{-}X}$$

(rounded up to nearest integer)

Where,

Ship Fleet Impact$_{GSA\text{-}X}$ – the number of ships needed to maintain the baseline frequency of calls within the allowable tolerance factor for each ship size, GSA, and distance combination, number of ships

Equation terms not listed have been defined above.

Note that the ship fleet impact is rounded up to the nearest integer as partial ships cannot be deployed.

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.8: Matrix 5 – Illustrative Results for Ship Fleet Impacts

Ship Type	Ship Size	Ship Fleet Impact to Keep Acceptable Call Frequency Distance 5										
		GSA (# of ships)	GSA -1 (# of ships)	GSA -2 (# of ships)	GSA -3 (# of ships)	GSA -4 (# of ships)	GSA -5 (# of ships)	GSA -6 (# of ships)	GSA -7 (# of ships)	GSA -8 (# of ships)	GSA -9 (# of ships)	GSA -10 (# of ships)
Container	1,000 teu	12	12	12	12	13	13	14	14	15	15	16
	3,000 teu	12	12	12	13	13	14	15	15	16	17	18
	6,000 teu	12	12	12	13	13	14	15	15	16	17	18
	9,000 teu	12	12	12	13	14	14	15	16	17	18	18
	14,000 teu	15	15	16	16	17	18	19	20	21	22	23
	17,000 teu	15	15	16	16	17	18	18	19	20	21	22
Bulk	Handymax	12	12	12	12	13	13	13	13	13	14	14
	Panamax	12	12	12	13	13	13	13	13	14	14	14
	Capesize	12	12	12	13	13	13	13	13	14	14	14

Matrix 6 – Propulsion Engine Load Factors

This matrix calculates the propulsion engine load factors (LF) for baseline GSA speed conditions and the slow steaming reduced speed increments (GSA-1 through GSA-10) for the at-sea transit for each ship type and size combination. Note that these values are the same for each distance.

The propulsion LF is based on the percent draft of the ship, the propeller curve, weather conditions, and hull conditions, which is consistent with IMO 2014, and the equation is as follows:

Equation 6

$$\text{Propulsion Engine } LF_{GSA\text{-}X} = [(\text{Percent of Draft})^{0.66} \times (\text{GSA-X} / \text{Avg Max Rated Speed})^{3}] \\ / [(1 - \text{Weather Impact Variable}) \times (1 - \text{Hull Fouling Variable})]$$

Where,

Propulsion Engine $LF_{GSA\text{-}X}$ – propulsion engine loads, dimensionless
Percent of Draft – this is the percent of draft that the ship is running
GSA-X – baseline GSA speeds and speed reduction increments GSA-1 through GSA-10 speeds, knots
Avg Max Rated Speed – average maximum rated speed for propulsion engine by ship type and size combination, knots
Weather Impact Factor – accounts for at-sea or coastal weather conditions that impacts propulsion power required
Hull Fouling Factor – accounts for hull fouling which effects propulsion power required

Equation terms not listed have been defined above.

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.9: Matrix 6 – Illustrative Results for Propulsion Engine Load Factors

Ship Type	Ship Size	Propulsion Load Factor Distance 5										
		GSA	GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	0.51	0.47	0.43	0.39	0.35	0.32	0.29	0.26	0.23	0.21	0.19
	3,000 teu	0.51	0.45	0.40	0.35	0.30	0.26	0.22	0.19	0.16	0.13	0.12
	6,000 teu	0.37	0.32	0.29	0.25	0.22	0.19	0.16	0.14	0.12	0.10	0.08
	9,000 teu	0.44	0.39	0.34	0.30	0.26	0.22	0.19	0.16	0.14	0.11	0.10
	14,000 teu	0.46	0.41	0.36	0.32	0.27	0.24	0.20	0.17	0.14	0.12	0.11
	17,000 teu	0.37	0.33	0.30	0.26	0.24	0.21	0.18	0.16	0.14	0.12	0.11
Bulk	Handymax	0.75	0.72	0.69	0.65	0.62	0.59	0.56	0.54	0.51	0.48	0.46
	Panamax	0.71	0.68	0.64	0.61	0.59	0.56	0.53	0.50	0.48	0.45	0.43
	Capesize	0.67	0.64	0.61	0.58	0.56	0.53	0.50	0.48	0.45	0.43	0.42

Matrix 7 – Fleet Propulsion Engine Work

This matrix calculates the propulsion engine energy consumption or work for baseline GSA speed conditions and the slow steaming reduced speed increments (GSA-1 through GSA-10) during at-sea transit for each ship type and size combination for each distance (Distances 1-5).

The fleet propulsion engine work is based on the following equation, similar to that used in IMO 2014:

Equation 7

$$\text{Fleet Propulsion Engine Work}_{GSA\text{-}X} = [\ \text{Ship Fleet Impact}_{GSA\text{-}X} \times \text{Transit Time}_{GSA\text{-}X} \times \text{Avg Prop Power Rating} \times \text{Propulsion LF}_{GSA\text{-}X}\ ]$$

Where,

Fleet Propulsion Engine Work$_{GSA\text{-}X}$ – propulsion engine work for baseline GSA speeds and speed reduction increments GSA-1 through GSA-10, over the specific distance (Distances 1-5), in kilowatt-hours (kWh)

Equation terms not listed have been defined above.

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.10: Matrix 7 – Illustrative Results for Fleet Propulsion Engine Work

Ship Type	Ship Size	Fleet Propulsion Work Distance 5										
		GSA (kWh)	GSA -1 (kWh)	GSA -2 (kWh)	GSA -3 (kWh)	GSA -4 (kWh)	GSA -5 (kWh)	GSA -6 (kWh)	GSA -7 (kWh)	GSA -8 (kWh)	GSA -9 (kWh)	GSA -10 (kWh)
Container	1,000 teu	31,695,756	29,897,787	28,152,314	26,459,337	26,887,092	25,166,773	25,311,272	23,581,111	23,477,350	21,754,844	21,873,095
	3,000 teu	62,836,250	57,864,936	53,098,462	52,581,563	47,861,703	46,699,427	45,101,209	40,423,367	38,401,681	36,080,614	36,362,168
	6,000 teu	108,472,474	99,993,788	91,860,087	91,077,320	83,013,280	81,117,050	78,468,928	70,457,963	67,070,112	63,160,359	61,240,058
	9,000 teu	136,545,872	125,872,845	115,634,089	114,648,737	112,535,952	102,110,682	98,777,209	94,605,816	89,705,072	84,183,544	77,089,393
	14,000 teu	215,405,955	198,364,029	194,159,260	177,479,239	171,644,998	164,662,026	156,670,762	147,811,648	138,225,123	128,051,629	127,421,446
	17,000 teu	388,092,584	362,313,059	359,914,057	334,305,806	328,995,164	321,664,684	296,044,620	286,570,276	275,548,569	263,156,680	259,862,334
Bulk	Handymax	51,657,162	50,093,201	48,553,281	47,037,400	49,341,024	47,750,908	46,186,835	44,648,807	43,136,822	44,854,795	43,282,598
	Panamax	80,983,028	78,531,204	76,117,067	79,885,671	77,352,014	74,859,186	72,407,187	69,996,017	72,827,650	70,318,945	67,854,208
	Capesize	175,179,954	169,831,264	164,565,500	172,664,549	167,139,643	161,704,573	156,359,338	151,103,940	157,164,406	151,698,239	149,299,885

Matrix 8 – Fleet Auxiliary Engine Work

This matrix calculates the auxiliary engine energy consumption or work for baseline GSA speed conditions and the slow steaming reduced speed increments (GSA-1 through GSA-10) for the at-sea transit for each ship type and size combination for each distance (Distances 1-5).

The fleet propulsion work estimate is consistent with IMO 2014 and is based on the following equation:

Equation 8

$$\text{Fleet Auxiliary Engine Work}_{GSA\text{-}X} = \text{Ship Fleet Impact}_{GSA\text{-}X} \times \text{Transit Time}_{GSA\text{-}X} \times \text{At-Sea Avg Auxiliary Load}$$

Where,

Fleet Auxiliary Engine Work$_{GSA\text{-}X}$ – auxiliary engine work for baseline GSA speeds and speed reduction increments GSA-1 through GSA-10, over the specific distance (Distances 1-5), in kWh

At-Sea Avg Auxiliary Load – average power load that the auxiliary engine system uses during at-sea transits, in kW

Equation terms not listed have been defined above.

Note that the SSA Model does not take into account ships that use shaft generators during at-sea transits. The difference is that ships with shaft generators do not generally use auxiliary engine power at-sea; instead a generator driven from the propulsion shaft is used to power auxiliary load demands for the ship. This system requires the propulsion engine(s) to work incrementally higher as they need to power the shaft generator. Slow steam could render the shaft generator not functional and trigger the auxiliary engines to turn on instead. The result is the house load would be shifted from the propulsion emissions to the auxiliary engine emissions, which typically have an incrementally higher fuel consumption rate than large two-stroke diesel engines.

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.11: Matrix 8 – Illustrative Results for Fleet Auxiliary engine Work

Ship Type	Ship Size	Fleet Auxiliary Work Distance 5										
		GSA (kWh)	GSA -1 (kWh)	GSA -2 (kWh)	GSA -3 (kWh)	GSA -4 (kWh)	GSA -5 (kWh)	GSA -6 (kWh)	GSA -7 (kWh)	GSA -8 (kWh)	GSA -9 (kWh)	GSA -10 (kWh)
Container	1,000 teu	3,884,892	4,000,000	4,122,137	4,251,969	4,756,098	4,915,966	5,478,261	5,675,676	6,308,411	6,553,398	7,200,000
	3,000 teu	3,354,037	3,495,146	3,648,649	4,134,276	4,333,333	4,902,724	5,532,787	5,844,156	6,605,505	7,463,415	8,100,000
	6,000 teu	5,153,374	5,367,412	5,600,000	6,341,463	6,642,336	7,509,579	8,467,742	8,936,170	10,090,090	11,387,560	12,600,000
	9,000 teu	6,478,528	6,747,604	7,040,000	7,972,125	8,992,701	9,440,613	10,645,161	11,982,979	13,477,477	15,157,895	15,840,000
	14,000 teu	10,062,112	10,485,437	11,675,676	12,212,014	13,600,000	15,128,405	16,819,672	18,701,299	20,807,339	23,180,488	24,840,000
	17,000 teu	21,283,784	22,027,972	24,347,826	25,263,158	27,890,625	30,731,707	32,033,898	35,309,735	38,888,889	42,815,534	46,200,000
Bulk	Handymax	2,288,136	2,323,580	2,360,140	2,397,869	2,639,892	2,683,486	2,728,545	2,775,142	2,823,359	3,094,303	3,150,000
	Panamax	4,271,186	4,337,349	4,405,594	4,849,023	4,927,798	5,009,174	5,093,284	5,180,266	5,675,676	5,776,031	5,880,000
	Capesize	5,743,590	5,833,333	5,925,926	6,523,297	6,630,237	6,740,741	6,854,991	6,973,180	7,641,326	7,777,778	7,840,000

Matrix 9 – Fleet Boiler Work

This matrix calculates the boiler energy consumption or work for baseline GSA speed conditions and the slow steaming reduced speed increments (GSA-1 through GSA-10) for the at-sea transit for each ship type and size combination for each distance (Distances 1-5).

There is an input related to boiler operations (cells G151 and G152), which is the LF at which waste heat recovery no longer works and the boilers turn on. There is a switch for each ship type. Based on discussions during the Vessel Boarding Program, this value is typically between main engine load of 20% to 25%. The value is set in decimal form. For the APEC study this value is set for 0.25 for both ship types (container and bulk). To turn this function off (ships without waste heat recovery) and have the boilers operate during the entire transit, set this value to one.

The fleet boiler work is consistent with IMO 2014 and is based on the following equation:

Equation 9

$$\text{Fleet Boiler Work}_{GSA\text{-}X} = \text{Ship Fleet Impact}_{GSA\text{-}X} \times \text{Transit Time}_{GSA\text{-}X} \times \text{At-Sea Avg Boiler Load}$$

Where,

$\text{Fleet Boiler Work}_{GSA\text{-}X}$ – boiler work for baseline GSA speeds and speed reduction increments GSA-1 through GSA-10, over the specific distance (Distances 1-5), in kWh

At-Sea Avg Boiler Load – average load that the boiler system uses during at-sea transits, in kW

Equation terms not listed have been defined above.

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below. Blank columns imply that the boilers were not turned on for those speeds.

Table B.12: Matrix 9 – Illustrative Results for Fleet Boiler Work

Ship Type	Ship Size	Fleet Boiler Work Distance 5										
		GSA (kWh)	GSA -1 (kWh)	GSA -2 (kWh)	GSA -3 (kWh)	GSA -4 (kWh)	GSA -5 (kWh)	GSA -6 (kWh)	GSA -7 (kWh)	GSA -8 (kWh)	GSA -9 (kWh)	GSA -10 (kWh)
Container	1,000 teu									2,523,364	2,621,359	2,880,000
	3,000 teu							2,950,820	3,116,883	3,522,936	3,980,488	4,320,000
	6,000 teu					4,317,518	4,881,226	5,504,032	5,808,511	6,558,559	7,401,914	8,190,000
	9,000 teu						5,793,103	6,532,258	7,353,191	8,270,270	9,301,435	9,720,000
	14,000 teu						10,085,603	11,213,115	12,467,532	13,871,560	15,453,659	16,560,000
	17,000 teu					9,960,938	10,975,610	11,440,678	12,610,619	13,888,889	15,291,262	16,500,000
Bulk	Handymax											
	Panamax											
	Capesize											

Matrix 10 - Fleet Propulsion Engine CO_2e Emissions

This matrix calculates the fleet propulsion engine CO_2e emissions for baseline GSA speed conditions and the slow steaming reduced speed increments (GSA-1 through GSA-10) for the at-sea transit for each ship type and size combination for each distance (Distances 1-5). CO_2e emissions are the sum of CO_2 equivalent emissions of CO_2, N_2O, and CH_4 which each GHG emission factor is multiplied by a global warming potential to normalize GHGs. For the APEC study, the values used were consistent with IMO 2014.

The propulsion emission estimate is based on the following equation:

Equation 10

$$\text{Fleet Propulsion Engine } CO_2\text{e Emissions}_{GSA\text{-}X} = \sum \left(\text{Fleet Propulsion Work}_{GSA\text{-}X} \times EF_i \times GWP_i \times LAF_{GSA\text{-}X} \right) / 1{,}000{,}000$$

Where,

Fleet Propulsion Engine CO_2e Emissions$_{GSA\text{-}X}$ – CO_2e emissions are the summation of emission each GHG_i for baseline GSA speeds and speed reduction increments GSA-1 through GSA-10, over the specific distance (Distances 1-5), in metric tons (tonnes)

EF_i – emission factors for either MSD or SSD propulsion engines and for each GHG_i (CO_2, N_2O and CH_4), in g GHG_i/kWh

Load Adjustment Factor – the LAF curve used in IMO 2014 was used to adjust the emissions based on engine load factor

GWP_i – global warming potential, in CO_2e/GHG_i

1,000,000 – conversion of grams to tonnes

Equation terms not listed have been defined above.

The LAF is applied for both SSD and MSD propulsion engines, even though the emissions test data used to estimate LAF was only for SSD propulsion engines. MSD propulsion engine emissions will change with load, however using these factors would be considered more likely to be representative than not applying a LAF to MSD propulsion engines as was done in IMO 2014.

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.13: Matrix 10 – Illustrative Results for Fleet Propulsion Engine Emissions

Ship Type	Ship Size	Fleet Propulsion CO_2e Emissions Distance 5 GSA (tonnes)	GSA -1 (tonnes)	GSA -2 (tonnes)	GSA -3 (tonnes)	GSA -4 (tonnes)	GSA -5 (tonnes)	GSA -6 (tonnes)	GSA -7 (tonnes)	GSA -8 (tonnes)	GSA -9 (tonnes)	GSA -10 (tonnes)
Container	1,000 teu	22,347	21,294	20,281	19,304	19,889	18,825	19,156	18,068	18,222	17,036	17,286
	3,000 teu	40,145	37,554	34,990	35,247	32,694	32,424	31,861	28,948	27,892	26,592	26,933
	6,000 teu	72,200	67,777	62,999	63,505	58,644	58,090	56,993	51,673	49,677	47,257	46,294
	9,000 teu	88,874	83,217	77,795	78,316	78,136	72,135	70,737	68,713	65,788	62,667	57,678
	14,000 teu	139,403	130,296	129,686	120,298	118,680	115,308	111,681	106,847	101,372	94,845	94,854
	17,000 teu	258,318	244,657	245,855	232,115	230,385	228,258	212,993	208,139	202,083	194,915	193,444
Bulk	Handymax	35,267	34,242	33,257	32,347	34,064	33,122	32,213	31,268	30,413	31,862	30,912
	Panamax	50,192	48,785	47,491	50,051	48,620	47,311	46,048	44,827	46,878	45,636	44,296
	Capesize	108,928	105,961	103,105	108,718	105,633	102,838	100,137	97,263	101,998	99,030	97,762

Matrix 11 - Fleet Auxiliary Engine CO_2e Emissions

This matrix calculates the fleet auxiliary CO_2e emissions for baseline GSA speed conditions and the slow steaming reduced speed increments (GSA-1 through GSA-10) for the at-sea transit for each ship type and size combination for each distance (Distances 1-5). CO_2e emissions are estimated in the same method as fleet propulsion emissions.

The auxiliary emission estimate is based on the following equation:

Equation 11

$$\text{Fleet Auxiliary Engine } CO_2e \text{ Emissions}_{GSA\text{-}X} = \sum [\text{ Fleet Auxiliary Work}_{GSA\text{-}X} \text{ x } EF_i \text{ x } GWP_i \,] \,/\, 1{,}000{,}000$$

Where,

Fleet Auxiliary Engine CO_2e Emissions$_{GSA\text{-}X}$ – CO_2e emissions are the summation of emissions of each GHG_i for baseline GSA speeds and speed reduction increments GSA-1 through GSA-10, over the specific distance (Distances 1-5), in metric tons (tonnes)

EF_i – emission factors for MSD auxiliary engines and for each GHG_i (CO_2, N_2O and CH_4), in GHG_i/kWh

Equation terms not listed have been defined above.

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.14: Matrix 11 – Illustrative Results for Fleet Auxiliary Engine Emissions

Ship Type	Ship Size	Fleet Auxiliary CO_2e Emissions, Distance 5										
		GSA (tonnes)	GSA -1 (tonnes)	GSA -2 (tonnes)	GSA -3 (tonnes)	GSA -4 (tonnes)	GSA -5 (tonnes)	GSA -6 (tonnes)	GSA -7 (tonnes)	GSA -8 (tonnes)	GSA -9 (tonnes)	GSA -10 (tonnes)
Container	1,000 teu	2,789	2,872	2,959	3,053	3,415	3,529	3,933	4,075	4,529	4,705	5,169
	3,000 teu	2,408	2,509	2,619	2,968	3,111	3,520	3,972	4,196	4,742	5,358	5,815
	6,000 teu	3,700	3,853	4,020	4,553	4,769	5,391	6,079	6,416	7,244	8,175	9,046
	9,000 teu	4,651	4,844	5,054	5,723	6,456	6,778	7,642	8,603	9,676	10,882	11,372
	14,000 teu	7,224	7,528	8,382	8,767	9,764	10,861	12,075	13,426	14,938	16,642	17,833
	17,000 teu	15,280	15,814	17,480	18,137	20,023	22,063	22,998	25,350	27,919	30,738	33,168
Bulk	Handymax	1,643	1,668	1,694	1,721	1,895	1,927	1,959	1,992	2,027	2,221	2,261
	Panamax	3,066	3,114	3,163	3,481	3,538	3,596	3,657	3,719	4,075	4,147	4,221
	Capesize	4,123	4,188	4,254	4,683	4,760	4,839	4,921	5,006	5,486	5,584	5,629

Matrix 12 - Fleet Boiler CO_2e Emissions

This matrix calculates the fleet boiler CO_2e emissions for baseline GSA speed conditions and the slow steaming reduced speed increments (GSA-1 through GSA-10) for the at-sea transit for each ship type and size combination for each distance (Distances 1-5). CO_2e emissions are estimated in the same method as fleet propulsion emissions.

The boiler emission estimate is based on the following equation:

Equation 12

$$\text{Fleet Boiler } CO_2e \text{ Emissions}_{GSA\text{-}X} = \sum[\text{ Fleet Boiler Work}_{GSA\text{-}X} \times EF_i \times GWP_i\,] \;/\; 1{,}000{,}000$$

Where,

Fleet Boiler CO_2e Emissions$_{GSA\text{-}X}$ – CO_2e emissions are the summation of emission each GHG_i for baseline GSA speeds and speed reduction increments GSA-1 through GSA-10, over the specific distance (Distances 1-5), in metric tons (tonnes)

EF_i – emission factors for boilers and for each GHG_i (CO_2, N_2O and CH_4), g GHG_i/kWh

Equation terms not listed have been defined above.

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.15: Matrix 12 – Illustrative Results for Fleet Boiler Emissions

Ship Type	Ship Size	Fleet Boiler CO_2e Emissions Distance 5										
		GSA (tonnes)	GSA -1 (tonnes)	GSA -2 (tonnes)	GSA -3 (tonnes)	GSA -4 (tonnes)	GSA -5 (tonnes)	GSA -6 (tonnes)	GSA -7 (tonnes)	GSA -8 (tonnes)	GSA -9 (tonnes)	GSA -10 (tonnes)
Container	1,000 teu									2,434	2,529	2,778
	3,000 teu							2,847	3,007	3,398	3,840	4,167
	6,000 teu					4,165	4,709	5,309	5,603	6,327	7,140	7,900
	9,000 teu						5,588	6,301	7,093	7,978	8,973	9,376
	14,000 teu						9,729	10,817	12,027	13,381	14,907	15,975
	17,000 teu					9,609	10,588	11,036	12,165	13,398	14,751	15,917
Bulk	Handymax											
	Panamax											
	Capesize											

Matrix 13 – Net Fleet CO_2e Emissions Changes

This matrix calculates the net fleet CO_2e emission changes from the comparison of the baseline GSA speed conditions and each of the reduced speed increments (GSA-1 through GSA-10) for the at-sea transits for each ship type and size combination for each distance (Distances 1-5).

The net emission change estimate is based on the following equation:

Equation 13

$$\text{Net Fleet } CO_2e \text{ Emissions}_{GSA\text{-}X} = \\ [\ (\text{Fleet Propulsion } CO_2e \text{ Emissions}_{GSA\text{-}X} + \text{Fleet Auxiliary } CO_2e \text{ Emissions}_{GSA\text{-}X} + \text{Fleet Boiler } CO_2e \text{ Emissions}_{GSA\text{-}X}) - (\text{Fleet Propulsion } CO_2e \text{ Emissions}_{GSA} + \text{Fleet Auxiliary } CO_2e \text{ Emissions}_{GSA} + \text{Fleet Boiler } CO_2e \text{ Emissions}_{GSA})\ ]\ / \\ [\ \text{Fleet Propulsion } CO_2e \text{ Emissions}_{GSA} + \text{Fleet Auxiliary } CO_2e \text{ Emissions}_{GSA} + \text{Fleet Boiler } CO_2e \text{ Emissions}_{GSA}\ ]$$

Where,

Net Fleet CO_2e Emissions$_{GSA\text{-}X}$ – net CO_2e emissions each speed reduction increment (GSA-1 through GSA-10) compared to the baseline GSA speeds, over the specific distance (Distances 1- 5, in metric tons (tonnes)

Note that negative results imply a reduction and positive results implies an increase in emissions. Equation terms not listed have been defined above.

This calculation is conducted for each ship type and size combination and for each distance (Distances 1-5) and for each speed (GSA through GSA-10). An example of the results from the SSA model setup for the high baseline speed scenario is provided in the table below.

Table B.16: Matrix 13 – Illustrative Results for Net Fleet Emissions Changes

Ship Type	Ship Size	Net Fleet CO_2e Emission Change Distance 5 GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10
Container	1,000 teu	-3.9%	-7.5%	-11.1%	-7.3%	-11.1%	-8.1%	-11.9%	0.2%	-3.4%	0.4%
	3,000 teu	-5.9%	-11.6%	-10.2%	-15.9%	-15.5%	-9.1%	-15.0%	-15.3%	-15.9%	-13.2%
	6,000 teu	-5.6%	-11.7%	-10.3%	-11.0%	-10.2%	-9.9%	-16.1%	-16.7%	-17.6%	-16.7%
	9,000 teu	-5.8%	-11.4%	-10.1%	-9.6%	-9.6%	-9.5%	-9.7%	-10.8%	-11.8%	-16.1%
	14,000 teu	-6.0%	-5.8%	-12.0%	-12.4%	-7.3%	-8.2%	-9.8%	-11.6%	-13.8%	-12.3%
	17,000 teu	-4.8%	-3.8%	-8.5%	-5.0%	-4.6%	-9.7%	-10.2%	-11.0%	-12.1%	-11.4%
Bulk	Handymax	-2.7%	-5.3%	-7.7%	-2.6%	-5.0%	-7.4%	-9.9%	-12.1%	-7.7%	-10.1%
	Panamax	-2.6%	-4.9%	0.5%	-2.1%	-4.4%	-6.7%	-8.8%	-4.3%	-6.5%	-8.9%
	Capesize	-2.6%	-5.0%	0.3%	-2.4%	-4.8%	-7.1%	-9.5%	-4.9%	-7.5%	-8.5%

B.3 SSA Model, Module 2 – Economic Impacts

There are five worksheet tabs to the economic impact model:

1. **Economic Impact Approach:** provides general information about the model
2. **Environmental Inputs:** This contains the table from Module 1 for vessel speeds (GSA to GSA-10), and the ship size categories used in Module 2.
3. **Selected Routes Liners:** user inputs for container vessel routes, including economies and ports of origin, economies and ports of destination, commodity or product under analysis and its category, FOB value, weight, value/kg, services and vessels' characteristics, for existing services; as well as sources of information.
4. **Selected Routes Bulk:** user inputs for dry bulk vessel routes, including economies and ports of origin, economies and ports of destination, commodities or products under analysis and its category, FOB value, weight, value/kg, vessels characteristics, as well as sources of information.
5. **Economic Impact Matrix:** user inputs related to economies GDP, yearly export volume in kilos, export yearly value in USD$, economies and ports of origin, economies and ports of destination, commodities at level 4 harmonized code (HS), interest cost, depreciation cost, insurance cost and impact (cost) of additional day of delay. Distance, speed range and time are also presented in this tab.

The model user can change the numbers and text in blue font. Each worksheet is further described in the following sections.

Economic Impact Approach Worksheet
The schematic representation of the SSA Model, and sub Module 1 – GHG Impacts and Module 2 – Economic Impacts, including inputs, interactions and outputs.

Environmental Inputs to the Economic Impact Model (Module 2) Worksheet
Ship size categories for container and dry bulk cargo vessels, as well as speed (Global Speed Average – GSA) are used as inputs to run the SSA Model, Module 2 – Economic Impacts. Lines 15 to 23, and columns A to Z, of the SSA Model, Module 1 – GHG Impacts are copied and pasted as "values" into rows 13 to 21, columns A to Z, of Module 2 – Economic Impacts. Data needs to be pasted in the specific cells. The needed parameters are provided in the table below. The description of the parameters was explained in Module 1. Table B.17 presents the Environmental Input data required to run the Economic Impact Model, Module 2.

Table B.17: Environmental model Inputs

Ship Type	Ship Size	Number of Ships	Shortest Distance 1 (nm)	Ocean Transit Distance Distance 2 (nm)	Distance 3 (nm)	Distance 4 (nm)	Longest Distance 5 (nm)	At-Sea Transit Speed Range GSA (knots)	GSA -1 (knots)	GSA -2 (knots)	GSA -3 (knots)	GSA -4 (knots)	GSA -5 (knots)	GSA -6 (knots)	GSA -7 (knots)	GSA -8 (knots)	GSA -9 (knots)	GSA -10 (knots)	Reduction Increment (knots/GSA-X)	Delay Tolerance (hours)
Container	1,000 teu	12	200	1,650	3,100	4,550	6,000	18.0	17.2	16.4	15.6	14.8	14.0	13.2	12.4	11.6	10.8	10.0	0.80	48.0
	3,000 teu	12	200	1,650	3,100	4,550	6,000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
	6,000 teu	12	600	2,200	3,800	5,400	7,000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
	9,000 teu	12	800	2,600	4,400	6,200	8,000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
	14,000 teu	15	1,000	3,000	5,000	7,000	9,000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
	17,000 teu	15	1,200	4,650	8,100	11,550	15,000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
Bulk	Handymax	12	600	2,700	4,800	6,900	9,000	12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0
	Panamax	12	600	3,450	6,300	9,150	12,000	12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0
	Capesize	12	600	3,950	7,300	10,650	14,000	12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0

Selected Routes Liners Worksheet

This worksheet lists the six different trade flows selected to analyze their economic impact. Information provided in this tab comes from existing services, from the shipping lines web pages; links are in column "U", row 12 to 17, in that spreadsheet. Selected economies and ports of origin and destination are listed in rows 12 to 17, columns A to E. The methodology to select intra-APEC long distance economies trade flows, as well as the selected commodities or products (column F), is explained in Appendix A. The sources to obtain data for different origins and destinations are also described in Appendix A. in order to get real information on the selected commodities, FOB value (column H) and weight (column I) were obtained from Datamyne. Column J is a formula calculating value per kilo for selected commodities (Value Kg = FOB Value/Weight).

The information of service name, as explained in the paragraph before, is obtained from the shipping line web page. Input in column K the selected vessel nominal capacity in teu; Column L indicates the actual name of the vessel in that service, followed by its IMO number (column M), Dead Weight Tonnage (column N), vessel LOA (column O), vessel beam (column P), draft (column Q) and vessel design speed (column R). As these are real vessels in current liner services, the page is protected so that no changes are allowed in these inputs. Table B.18 illustrate the data input explained in this section.

Table B.18: Container ship selected service routes, vessel, cargo, distance

Economy of origin	Port of origin	Economy of destination	Port of destination	Product	Category	FOB Value	Weight	Value Kg	Vessel Nominal Capacity TEU	Vessel	IMO	DWT	LOA	BEAM	Draft	Design Speed	Service name	Distance
Australia	Melburne	China	Shanghai	Fresh or chilled boneless bovine meat	Perishable	$8,716	1,254	$6.95	5,090	ITAL Liberia	9322475	68,100	294	32	10.5	22	CA3	6,660
Chile	San Antonio	China	Shanghai	Cherries	Perishable	$26,414	11,760	$2.25	9,572	CSCL Long Beach	9314258	111,737	337	46	13.8	25	CFCX	10,531
Japan	Tokyo	United States	Los Angeles	Machines for Man. Semiconductor Devices/elec	High value	$695,456	18,000	$38.64	8,212	ONE Hannover	9302138	99,214	336	45.8	12.9	21.3	Fuji Service	4,854
China	Shanghai	United States	Los Angeles	Memories, Electronic integrated circuits	Consumer goods	$117,724	8,187	$14.38	8,452	Ever Logic	9604081	104,366	334.98	45.8	11.9	25	Hangzhou Bay Bridge	5,781
Vietnam	Ho Chi Minh Cit	United States	Long Beach	Furniture nesoi and parts	Consumer goods	$144,127	8,791	$16.39	8,888	OOCL Beijing	9477878	101,544	334.95	42.85	11.2	24	South China Sea	9,257
United States	Los Angeles	China	Shanghai	Waste and Scrap paper	Low value	$560	18,662	$0.03	13,386	Cosco Spain	9516442	156,572	365.9	51.2	11.7	24	Bohai	6,668

Row 19 presents the formula used to calculate transit time ($\text{Transit Times}_{GSA\text{-}X} = \text{Distance \#} / \text{Speed}_{GSA\text{-}X}$).

The analysis for each liner service, economies and ports of origin and destination are presented in rows 21 to 81. Column B lists the port rotation from the exporter economy to the economy port of destination, as listed in current liner services web pages. The same is true for column C, where the published days in the service rotation are listed. Column D is the vessel itinerary transit time in days from port of origin to port of destination selected for the analysis. Column E is the distance in nautical miles (nm) from port to port which, once reaching the final port of destination, totals the voyage distance from the selected port and economy of origin to the selected port and economy of destination. As validation or calibration, column F reflects the calculation of voyage time at the vessel design speed to each distance. For each service, the total voyage time, including intermediate ports, and the total time in port (Total time in port = average time in port * numbers of ports) is added to calculate the total time (Total time = transit time + total time in port). Total time is calculated for each speed range (GSA to GSA-10), column T to AD. Table B.19 and Table B.20 provides an example of the inputs and transit time calculation.

The source of information for liner vessel speed is “Environmental Inputs” tab.

Table B.19: Service rotation, distance and model calibration (validation)

Shipping Line Itinerary - Australian meat to China - CA3 Service				Voyage time validation including time in port
Melbourne-Shanghai	Published days	Transit time - days	nm	
1 Melbourne	23			
2 Sydney	26	3	582	1.10
3 Brisbane	29	6	515	0.98
4 Yokohama	41	18	3,930	7.44
5 Osaka	42	19	360	0.68
6 Busan	44	21	372	0.70
7 Qingdao	46	23	502	0.95
8 Shanghai	49	26	399	0.76
	26 Total transit days		**6,660**	12.61
http://www.apl.com/products-services/line-services/flyer/CA3APL			**Time in port (days)**	10.96
			Total time (days)	**23.57**
			Addditional delay time (days)	

Table B.20: Service time calculation at different speed ranges

	Shipping Line Itinerary - Australian meat to China CA3 Service				GSA	GSA -1	GSA -2	GSA -3	GSA -4	GSA -5	GSA -6	GSA -7	GSA -8	GSA -9	GSA -10	Transit time in days @ different vessel speed										
	Melbourne - Shanghai	days	Published Transit time - days	nm	(knots)	(knots)	(knots)	(knots)	(knots)	(knots)	(knots)	(knots)	(knots)	(knots)	(knots)	Time 0	Time 1	Time 2	Time 3	Time 4	Time 5	Time 6	Time 7	Time 8	Time 9	Time 10
1	Melbourne	23			20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0											
2	Sydney	26	3	582	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.21	1.28	1.35	1.43	1.52	1.62	1.73	1.87	2.02	2.20	2.43
3	Brisbane	29	6	515	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.07	1.13	1.19	1.26	1.34	1.43	1.53	1.65	1.79	1.95	2.15
4	Yokohama	41	18	3,930	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	8.19	8.62	9.10	9.63	10.23	10.92	11.70	12.60	13.65	14.89	16.38
5	Osaka	42	19	360	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	0.75	0.79	0.83	0.88	0.94	1.00	1.07	1.15	1.25	1.36	1.50
6	Busan	44	21	372	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	0.78	0.82	0.86	0.91	0.97	1.03	1.11	1.19	1.29	1.41	1.55
7	Qingdao	46	23	502	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.05	1.10	1.16	1.23	1.31	1.39	1.49	1.61	1.74	1.90	2.09
8	Shanghai	49	26	399	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	0.83	0.88	0.92	0.98	1.04	1.11	1.19	1.28	1.39	1.51	1.66
	26	Total transit days		**6,660**												**13.88**	**14.61**	**15.42**	**16.32**	**17.34**	**18.50**	**19.82**	**21.35**	**23.13**	**25.23**	**27.75**
	http://www.apl.com/products-services/		**Time in port (days)**													**10.96**	**10.96**	**10.96**	**10.96**	**10.96**	**10.96**	**10.96**	**10.96**	**10.96**	**10.96**	**10.96**
			Total time (days)													**24.84**	**25.57**	**26.38**	**27.28**	**28.30**	**29.46**	**30.78**	**32.31**	**34.09**	**36.19**	**38.71**
			Addditional delay time (days)														**0.73**	**1.54**	**2.45**	**3.47**	**4.63**	**5.95**	**7.47**	**9.25**	**11.35**	**13.88**

Average time in port was obtained from UNCTAD Review of Maritime Transport report, assuming 1.37 days for liner services, information listed in row 84. Changes in average time at port modifies the vessel time. This input is locked; thus, the user cannot change it.

Selected Routes Bulk Worksheet

This worksheet lists the three dry bulk trade flows. Several sources of information were used to develop this section; all of them listed in this worksheet. The vessel information source link for each trade flow is presented in column AQ. The methodology to select intra-APEC long distance economies trade flows, as well as the selected commodities or products, is explained in Appendix A. Product information, parcel size, rates and prices are real information from sources listed in this tab. Distance was obtained from the Marine Traffic webpage. Speed range (GSA to GSA-10) comes from “Environmental Inputs” tab. Time calculation formula (Transit Times$_{GSA\text{-}X}$ = Distance # / Speed$_{GSA\text{-}X}$) was used to calculate delays at different speeds, in days. The source of information for dry bulk vessel speed is the “Environmental Inputs” tab. Each trade route distance was calculated based on the ports of origin and destination.

Economic Impact Worksheet

This worksheet has both model inputs, stepwise estimates, and results. A total of 9 matrices were developed in this worksheet; six for liner and three for dry bulk. The matrices were built in similar structure for container and bulk vessels and developed for each specific trade flow and commodity.

The first row includes ship type and size information, number of vessels, total distance, as well as average vessel speed; information, as well as time delay at different speeds row is obtained from “Selected Routes Liners” and “Selected Routes Bulk” tabs. Each matrix contains exports and import economies information, 2017 GDP data, Harmonized Code (HS) at the 4-digit level, description of the commodity under analysis, name of the service in the case of containerized cargo, total volume and value of export for each HS4 category, for selected economy of origin and destination. The economic impact of each commodity category trade flow is calculated as a percentage of the export economy GDP. Additional information in the matrix includes value per kilo and export value per container. in the case of liner, is inputted.

Economic impact, or shippers’ additional expenses, due to extra travel days is based in three variables, interest cost, depreciation cost and insurance cost. Variables used to measure the economic impact of slow steaming are:

- **Time delay:** number of hours or days that slow steaming will delay the cargo arrival at the destination port compared with total voyage days under current vessel speed (Transit $Times_{GSA\text{-}X}$ = Distance # / $Speed_{GSA\text{-}X}$). Time delay is dependent on vessel speed assumptions; any changes in GSA will automatically modify the voyage time. Changes in speed are to be made in Module 1 – GHG Impacts, tab “Analysis Matrices”, column D”, rows 15 to 23.
- **GDP impact**: the reduction of product exports is measured as an impact on total economy Gross Domestic Product (GDP) (GDP Impact = Commodity Total Export Value / Economy GDP). An economy’s GDP is labelled blue; thus, the user can update and modify it.
- **Interest cost**: the financial cost of capital invested in inventory over time. This measures the impact of each hour or day of delay in the cost of the product due to cost of money or interest rate. (here assumed to be 5%) (Interest Cost = (Export Value x Interest Rate) * (Time Delay/365.25)). Interest rate is labelled in blue font; thus, the user can modify it.
- **Depreciation cost**: is defined as the cost allocation of a product over its useful life. (for this economic analysis, it is assumed as 10% for containerized cargo, 30% for fresh perishable products, and 5% for dry bulk cargo) (Depreciation Cost = (Export Value x Depreciation Rate) x (Time Delay/365.25)). The depreciation rate is labelled in blue font; thus, the user can modify it.
- **Insurance cost**: a cost paid by the shippers to protect their goods while in transit. (the percentage used in the economic analysis is 2%) (Insurance Cost = (Export Value x Insurance Rate) x (Time Delay/365.25)). The insurance rate is labelled in blue font; thus, the user can modify it.

The output of the model is the daily cost of waiting, based on the annual trade flow value, in this case, year 2017, from the specific export economy to the specific import economy and specific commodity, in terms of additional cost due to extra travel day in USD$ and as a percentage of the yearly transaction volume. The model is set to calculate 10 different vessel speed ranges, as it was developed in Module 2 – GHG Impacts. The model also includes the economies exports to the world and their main trade partners. This is the same for the nine matrices developed (6 for containerized cargo, and 3 for dry bulk cargo). Table B.21 presents an example of Economic Impact Module worksheet, Matrix 1 inputs and outputs.

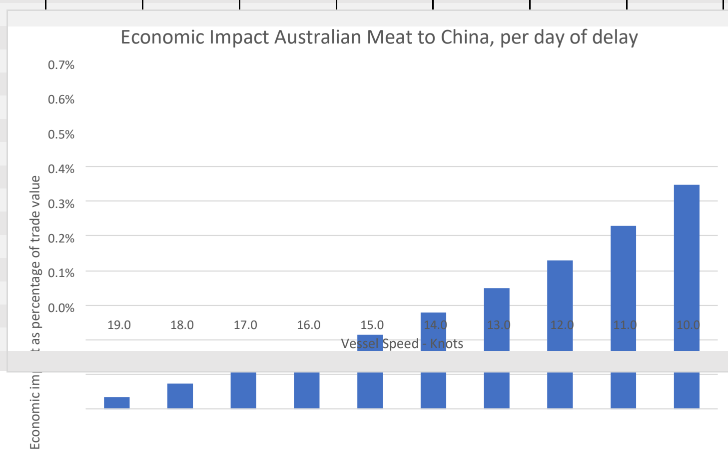
The model has been developed for specific trades from selected exporting economies and ports to selected importing economies and ports. Services used in the model are existing ones, as well as vessels and their characteristics. The model is locked to maintain these parameters.

Table B.21: Economic Impact Module Matrix inputs and outputs

Matrix 1 - Containerized cargo vessels - Australian meat to China

Ship Type	Ship Size TEU	Number of Ships	Total Distance (nm)	GSA (knots)	GSA -1 (knots)	GSA -2 (knots)	GSA -3 (knots)	GSA -4 (knots)	GSA -5 (knots)	GSA -6 (knots)	GSA -7 (knots)	GSA -8 (knots)	GSA -9 (knots)	GSA -10 (knots)	Slow Down Increment (knots/step)
				Ocean Transit Speed Range											
Container	5,090	6	6,660	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	0.60
Time delay @ different speed		Days			0.73	1.54	2.45	3.47	4.63	5.95	7.47	9.25	11.35	13.88	
Export economy		Australia													
GDP (USD$)	2017	$1,323,421,072,479													
Port of origin		Melburne													
Economy of destination		China													
Port of destination		Shanghai													
HS		0201													
Commodity		Fresh or chilled boneless bovine meat													
Service name		CA3													
Export Quantity (Kg)	2017	6,035,359													
Export Value (USD$)	2017	$59,903,965													
Meat export as percentage ofGDP		0.0045%													
Value per kg (USD$/Kg)		$9.93													
Export value per container ($)		$8,716													
Shippers' additional expenses					**Economic impact of delay at different speeds**										
Interest cost	5%	IC=(EV*IR)*(TD/365.25)			$5,988	$12,642	$20,079	$28,445	$37,927	$48,763	$61,266	$75,854	$93,093	$113,781	
Depreciation cost	10%	DC=(EV*DR)*(TD/365.25)			$11,977	$25,285	$40,158	$56,890	$75,854	$97,526	$122,533	$151,708	$186,186	$227,561	
Insurance cost	2%	InC=(EV*InR)*(TD/365.25)			$2,395	$5,057	$8,032	$11,378	$15,171	$19,505	$24,507	$30,342	$37,237	$45,512	
Total cost of waiting USD$	**Annual**				**$20,361**	**$42,984**	**$68,268**	**$96,714**	**$128,951**	**$165,795**	**$208,306**	**$257,903**	**$316,517**	**$386,854**	
Percentage impact per extra travel days					0.03%	0.07%	0.11%	0.16%	0.22%	0.28%	0.35%	0.43%	0.53%	0.65%	

Australian meat exports HS0201 - year 2017	**USD$**	
World	2,267,345,153	
Japan	849,831,001	37.48%
USA	461,393,833	20.35%
Rep. of Korea	292,732,660	12.91%
Netherlands	77,764,637	3.43%
United Kingdom	60,311,956	2.66%
China	59,903,965	2.64%
https://comtrade.un.org/data/	**Total Share**	**79.47%**



List of Endnotes

[1] IHS Markit Data, *www.ihsmarkit.com/industry/maritime.html*, 2019

[2] Third IMO GHG Study 2014; IMO London, UK, April 2015; Smith, T. W. P.; Jalkanen, J. P.; B. Anderson, et. al. [IMO 2014] *www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf* [IMO 2014]

[3] IMO MARPOL Annex VI, Regulation 13 Nitrogen Oxides

[4] Starcrest Vessel Boarding Program, 2019

[5] IMO 2014, Table 14, pages 43-45