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Economic Impact of The Panama Canal versus The Panama Canal Railroad Company on the Liner Shipping Industry

by

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Lianette Benítez

Abstract

Over the years, determinant factors as international economic growth, technology developments and political circumstances have influenced the production and consumption markets that conversely have shaped the liner shipping industry and the transport demand. This has led to solid trends in the container shipping industry, whereof ordering vessels of increased size have become the predominant one. This is mainly due to the robust findings in regards to the benefits that the principle of economies of scale means for shipping lines, in terms of the savings in operational and fuel costs per TEU-slot. However, even though this trend represents enormous advantages to shipping lines, for other actors in the liner shipping industry, namely ports, terminal operators, rail operators, intermodal operators and canals, among others, the effects are still uncertain. This last is the case of the Panama Canal (PC), which in 2006 decided to undertake a 5.25 billion dollars project to upgrade and expand its current locks, allowing the passage of containerships of 13200 TEU, instead of 4500TEU. Despite the fact that the potential effects that the Panama Canal expansion project will have in the liner shipping industry are still uncertain, what is indeed certain is that the project will open a new opportunity for the whole industry to expand their markets deploying bigger vessels and taking advantage of the benefits from economies of scale. Particularly for the container shipping lines, the Panama Canal expansion means a new alternative to re-design the current network configurations into ones more cost-effective. This research focused in Panama, the host-country of the Panama Canal expansion project and in its current land-bridge transhipment operations via the Panama Canal Railroad Company for the trade from FEA to ECSA. After the completion of the expansion project in Panama, shipping lines will have the possibility to deploy bigger vessels to cross the canal, instead of using the transhipment model through the PCRC. The main purpose of this study was to identify which of these two is the best alternative from a cost-perspective, assuming containerships with different capacities. The results of the research were gathered through the construction of a cost model, in which the operational, fuel, terminal handling and toll costs were calculated and compared in a cost per TEU-basis. The main findings of the study where that the transhipment operations through the rail are more expensive per TEU compared to the PC all-water route, regardless of the vessel size deployed, mainly due to the fact that the economics through the PC route allowed lower OC, FC and Tolls per TEU. Furthermore, results indicated that if the Panama Canal Authority builds an additional set of locks enabling the transit of 18000 TEU vessels, then shipping lines could reduce their total costs per TEU about 11% compared to the deployment of 13200 TEU vessels, even though the terminal handling fees for ECSA ports would have to be increased to cover the significant investments costs to upgrade their facilities. The research have several limitations, namely the capital, depreciation, inventory and the time cost were neglected. Also, the research does not consider a combined or intermediate scenario in which the PC and the PCRC can act as complements, which could potentially reduce the costs per TEU. Finally, these limitations constitute clear opportunities that could be considered to develop further research that could enhance, enrich and improve the accuracy of the current study.

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List of Abbreviations and Definitions

APL	American President Line
CAR	Caribbean Region
CCT	Colon Container Terminal
CWT	Canal Water Time
ECNA	East Coast North America
ECSA	East Coast South America
FEA	Far East Asia
IMF	International Monetary Fund
LOA	Length Over All
MIT	Manzanillo International Terminal
NCSA	North Coast South America
PCRC	Panama Canal Railroad Company
PCUMS	Panama Canal Universal Measurement System
PPC	Panama Ports Company
RT	Round-trip
TEU	Twenty-Foot Equivalent Unit
TTA	Total TEU Allowed
ULCV	Ultra Large Container Vessels
WCCA	West Coast Central America
WCSA	West Coast South America

Chapter 1 Introduction

Twenty-five years ago, the biggest containership prevailing in the market was known as the Panamax, a vessel with maximum length over all (LOA), beam and draught of 290, 32 and 12.5 meters respectively, due to the restrictions of the Panama Canal dimensions. After APL crossed the “Panamax barrier” by ordering the first post-Panamax vessels in 1986, the rest of the ship-owners promptly followed this practice, resulting in the trend nowadays known as increasing scale in vessels, with the aim of achieving economies of scale and lower operational costs. In 2011, Maersk Line ordered the biggest containerships worldwide, the triple-E vessels, which acronym stands for Economies of scale, Energy efficient and Environmentally improved. The continuous increase in the size of vessels registered in the order books, had led to debates with regards to this trend in which it is still uncertain how big will vessels become in the following years, since there are already expected orders for vessels with capacity up to 20000 and 22000 TEU. Although the benefits of bigger vessels are clear for shipping lines, for the rest of the main actors namely ports, terminal operators, inland operators and canals, these are still debatable. Port and terminal operators have had to significantly invest in upgrading their infrastructures and equipment in order to be capable of handling these big coming vessels without deterring the service time whilst protecting their competitiveness. Last year, 2013, Maersk Line announced the shifting from the Panama Canal to the Suez Canal for its Asia-U.S. East Coast services. Maersk Line CEO, Soren Skou, supported his decision based on the fact that through the Suez Canal, bigger ships of 9000 TEU could be deployed instead of ships of up to 4500 TEU, as it is today through the Panama Canal. This allowed the shipping line to take advantage of economies of scale, decreasing operational costs as well. However, it resulted in a decrease in the number of containerships transits through the Panama Canal, as a consequence of increasing scale in vessels and economies of scale. Obviously, this shift represented an attempt to the Panama Canal profitability and competitiveness. Nevertheless, to counterbalance these consequences and effects of bigger ships coming into the shipping business, the Panama Canal engaged in a USD 5.25 billion project for the expansion of the current canal, to enable the passage of ships from 4500 TEU up to 13200 TEU. It is estimated that the Panama Canal expansion project will be ready in 2015. The Panama Canal expansion basically means a new opportunity for the whole shipping industry to expand their businesses, improve the utilization of their assets and design more efficient routes and networks. By the time of its completion, shipping lines would have to consider the best option, whether to cross the Canal with bigger ships or remain with alternative routes as through the Cape Horn, Cape of Good Hope, Suez Canal, the U.S. intermodal system or transhipment operations as the one currently taking place through the Panama Canal Railroad. More specifically, focusing on one of the main nodes of shipping operations, Panama, the Panama Canal expansion will mean that shipping lines will face a trade-off, whether to deploy bigger ships and cross the Panama Canal or instead, continue discharging boxes in the Atlantic and loading these boxes again in the Pacific, and vice versa, after these have been transported through the Panamanian Isthmus by the Panama Canal Railroad Company, PCRC, and if this last option is preferred, how big should be the vessels calling the Atlantic and the Pacific in each side of the operation. As Soren Skou mentioned last year, this type of decisions will be determined by the economics.

1.1 Problem Statement

The trend of ordering large and ultra-large container vessels (ULCVs) has affected the shipping industry in general; from shipyards, ports, and canals to the shippers and final customers´ supply chains. As it is stated further in section 2.3, the deployment of bigger vessels lead to consolidation of trade routes and fewer port calls resulting in hub and spoke networks, where transhipment operations prevail. Furthermore, the so-called major "hub regions" emerged, namely Singapore, Middle East, the Mediterranean, North-West Europe and the Caribbean and Panama. Particularly in Panama, shipping lines have opted to establish different network models, in which they used mainly one port as a hub in the Pacific, namely Balboa and two ports as hubs in the Atlantic, namely Manzanillo International Terminal (MIT) and Cristobal. Currently, shipping lines deploy vessels between 1000 and 10000 TEU to call these ports in the Pacific and/or Atlantic, and then they use the Panama Canal Railroad Company (PCRC) to move containers from Pacific to Atlantic and vice versa via a "land-bridge transhipment". Maersk Line, APL, MSC, Hapag-Lloyd and MOL are some of the shipping lines that have established hub operations in these aforementioned Panamanian ports through PCRC, in which they consolidate cargo coming from Far East Asia (FEA), the West Coast Central America (WCCA) and/or the West Coast South America (WCSA), with destination the Caribbean (CAR), namely Caucedo, San Juan, Point Lisas, etc., the North Coast South America (NCSA), namely Cartagena, Barranquilla, Guanta, La Guaira, Puerto Cabello, etc., or to the East Coast of South America (ECSA), mostly Brazil. Same model applies from CAR/NCSA/ECSA to WCSA/WCCA/FEA.

Nevertheless, after 2015, with the completion of the Panama Canal expansion, shipping lines will have the possibility to cross the Canal with vessels up to 13200 TEU, which could probably reduce handling fees in ports due to the current ship-to rail-to ship model, as well as time and potential risks, while taking advantage of economies of scale. On the other hand, the final tolls for the passage through the new set of locks is still uncertain but it is expected that these will be higher than the current tolls, notwithstanding the fact that these have increased significantly in the past 5 years. Therefore, it is expected that shipping lines will be confronted with a dilemma regarding which is the option that from an economic perspective, makes sense the most, whether it is to continue the current land-bridge transhipment model, ship-to rail-to ship, with the possibility of deploying vessels with unlimited size or deploy bigger vessels of up to 13200 TEU to cross the new expanded Canal, avoiding extra handling fees and time.

1.2 Research Question and Objectives

In the previous subchapter, the problem statement, or research dilemma was presented. The trade-off that shipping lines would have to consider in Panama motivates this research with the aim of finding the best alternative from a shipping line perspective that would make most economic sense in terms of costs.

For the aforementioned, the main research question is: "What is the economic impact in terms of cost-performance of the Panama Canal versus the Panama Canal Railroad Company and what are the effects in the liner shipping operations in Panama?"

The main research question will be answered through the following research sub-questions:

- What is the cost for container shipping lines related to the transhipment operation with the Panama Canal Railroad Company?
- What is the cost for container shipping lines to transit through the Panama Canal?
- What is the best alternative post-Panama Canal expansion for shipping lines based on costs per TEU?
- How the difference between the Panama Canal versus the Railroad performance in terms of costs, influence the shipping lines?
- What is the cost for shipping lines related to the land-bridge transhipment operation when different ship sizes are deployed in the intercontinental and regional trade?

The objectives of this research are basically to identify the best alternative for the operations of shipping lines in Panama considering the costs involved for crossing the Panama Canal versus using the Panama Canal Railroad in a transhipment model. This will be achieved by pursuing the following individual objectives:

1) Determine the costs per TEU involved in the transhipment operation utilizing the Panama Canal Railroad Company versus the transit through the Panama Canal, for different ship sizes.
2) Compare the total costs per TEU for shipping lines of the transhipment model through the Railroad operation versus the transit through the Panama Canal.
3) Identify the best route alternative post-Panama Canal expansion in terms of costs per TEU from a shipping lines perspective.
4) Evaluate the possible effects of the cost-performance comparison in the liner shipping operations in Panama.

1.3 Research Design

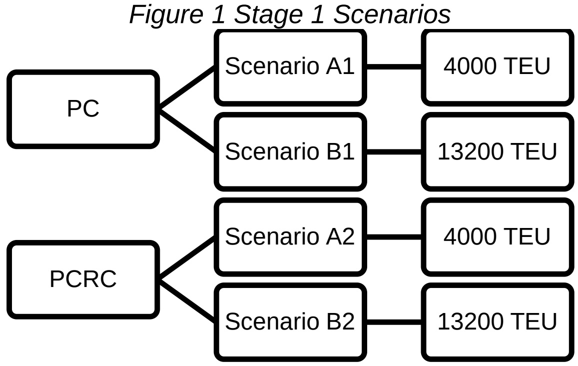
The research will be conducted through a theoretical and quantitative analysis. The theoretical part will include a brief review of the background literature and history of Panama, where it will be explained to the reader the origins of trade in Panama and how the railroad and the Panama Canal emerged. This is of special importance in order to understand where the current network designs in liner shipping in Panama came from. Then it will continue with the literature discussion on how the Panama Canal shaped the shipping industry and conversely, how the developments and trends in the liner industry shaped Panama, converting the country into one of the main hubs in America for transpacific and transatlantic services. Furthermore, the research will dedicate two chapters in which the Land-bridge transhipment model and the Panama Canal route will be described and explained respectively. Both chapters will include the main users of each transportation mode and the costs each of these routes represent for shipping lines. In the Panama Canal route chapter, the main highlights about the Panama Canal Expansion project will be discussed, including a brief citation of the main studies conducted about the potential effects that the expansion will have in the liner shipping industry. For the quantitative analysis, this research will evaluate some of the routing alternatives that shipping lines will face upon the completion of the Panama

Canal expansion project. For this analysis, the route from FEA to ECSA through Panama will be considered, since it is one of the routes currently used by most of the shipping lines, through PCRC.

The quantitative study will be divided in two stages, each conformed by different scenarios. The study will compare the best option between crossing the Panama Canal versus the land-bridge transhipment through PCRC, in terms of performance, particularly being the costs and times. In the first stage, scenario A1 will evaluate the total costs arising from deploying a 4000 TEU vessel to cross the Panama Canal. Scenario A2 will evaluate the costs from deploying a 4000 TEU vessel but through the land-bridge transhipment, PCRC. Similarly, Scenarios B1 and B2 will evaluate the best alternative between the Panama Canal and the PCRC in which it will be determined the total costs of both routes, but this time assuming a ship size of 13200 TEU as the maximum capacity that the expanded Panama Canal will be able to support. The trade-off in this stage will be whether to use the Panama Canal or the land-bridge transhipment, varying the ship size following the maximum capacity of the Panama Canal. This trade-off is considered to be the most likely in the short-run for shipping lines. The following diagram illustrates the scenarios that will be studied in stage 1.

Stage 1

Figure 1 Stage 1 Scenarios

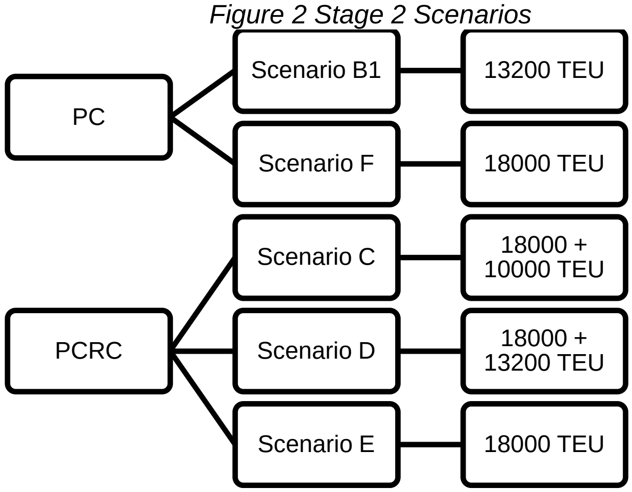


The second stage will evaluate different scenarios in the long-run post-Panama Canal expansion, where a combination of ship sizes will be deployed for each of the legs of the voyage, namely FEA-PCW and PCE-ECSA and vice versa, again evaluating the best route whether it is through the Panama Canal or through the PCRC. The stage will be conformed by five different scenarios namely Scenario B1, C, D, E and F. Scenario B1 will be the starting scenario in this second stage, which will evaluate the total costs arising from crossing the PC with a 13200 TEU vessel, as it will be calculated in Stage 1. Furthermore, following the trend of increasing scale in liner shipping and economies of scale, Scenario C will evaluate the PCRC option deploying an 18000 TEU vessel in the FEA-PCW leg and a 10000 TEU vessel in the PCE-ECSA leg, which is the current size of vessels calling at these ports. Scenario D will evaluate the PCRC option deploying an 18000 TEU vessel in the FEA-PCW leg but a 13200 TEU vessel in the PCE-ECSA leg. Scenario E will evaluate the PCRC option deploying an 18000 TEU vessel, maximizing the benefits arising from economies of scale, but also baring the effects in handling fees and port dues that may arise from the significant investments that ECSA ports would have to incur to be able to handle this ULCVs. And last, Scenario F will evaluate the PC option assuming a hypothetical scenario wherein the Panama Canal Authority decides to build a fourth set of locks in which UCLVs of 18000 TEU are able to cross the Panama Canal. The total costs of these five aforementioned scenarios will be calculated and compared. The scenario resulting in the lowest cost per TEU will be considered as the best alternative for shipping lines.

Figure 2 illustrates the different scenarios that will be studied in Stage 2. The trade-off in this stage is to determine the most convenient size to deploy in each of the legs FEA-PCW and PCE-ECSA, assuming that the land-bridge transhipment will be utilized and comparing the outcomes with the PC route.

Stage 2

Figure 2 Stage 2 Scenarios



These scenarios will be evaluated based on costs. For this, a cost model will be developed, in which the total costs for both stages will be calculated, from a shipping line perspective. The cost model will consider four main costs; operating costs, fuel costs, port handling fees and the tolls incurred when crossing the Panama Canal or when using the Railroad. The model as well as the relevant data gathered will be explained in detail in Chapter 5. The total costs of each of the four scenarios will be calculated, wherein the scenario resulting in the lowest total costs will be determined as the preferred one. Then, a sensitivity analysis will be conducted by varying the vessel utilization, the Panama Canal tolls and the THC in ECSA ports for Stage 2. The research will finalize with the conclusions, where the limitations of the study will be clearly presented as well as the recommendations for future research.

1.4 Relevance of the Study

There is a vast amount of literature available in regards to the potential impacts of the Panama Canal expansion project, especially in the Asia to North America trade, particularly the East Coast of North America. Others studies have focused on the comparison of alternatives as the U.S. Intermodal System and the Suez Canal, again for the Asia to North America trade (Knight, 2008; Prince, 2012; Metcalf, 2013; Johnson, 2012; Rodrigue D. JP., 2010; Rodrigue & Notteboom, 2012; Ungo &

Sabonge, 2012; Snyder, Doyle, & Toor, 2012; MARAD, 2013; among others), mainly due to the fact that from a trade-flows perspective, the trans-pacific trade is one of the biggest and most important trades worldwide. Nevertheless, there are few or none studies dedicated to the potential impacts of the Panama Canal expansion in Panama and Latin American trades, and in the operation networks that shipping lines have established there, as is the case of the transhipments through PCRC in Panama. Therefore, for this research, the relevance to study the Asia-Latin America trade, particularly through Panama, is inspired in the increasing importance and growth that Latin America has been registering during the past years, driving the attention of the liner shipping industry towards it. A major prove of the increasing development of Latin America is the fact that this year, 2014, Maersk Line announced the return of SeaLand, a shipping line under the APM-Maersk Group that will be dedicated to the Intra-Americas trade, as MCC-Transport is dedicated to the Intra-Asia trade and Seago Line to the Intra-Europe trade. Although the liner shipping operations from Asia to Latin America are not as massive as for instance an Asia-Europe or an Asia-North America trade, it is still important to study the small networks, since these are part of the overall liner shipping network designs, and even more important, achieving greater efficiencies in terms of costs in these smaller networks enable global carriers to offer better worldwide-customer service and competitiveness to their global shippers.

Chapter 2 Literature Review

2.1 History of Trade in Panama

The history of trade in Panama dates back to the conquest times, a period where the country faced vast and radical changes that resulted in the Panama Canal, which since its opening was considered one of the most influencing and determining infrastructures for the maritime industry and trade flows in the world.

It all started in the early 1500s when Rodrigo de Bastidas, a Spaniard explorer, reached for the first time the Isthmus of Panama, when sailing from the west coast of Venezuela. One year later, 1502, the Spanish explorer Christopher Columbus reached several locations of the Isthmus of Panama, being one a harbour in the Atlantic Ocean, which he named Puerto Bello. Today this harbour is known as "Portobelo" and is located in the Panamanian province Colón.

Nevertheless, it was not until the beginnings of 1513, when the advantageous geographical position of the Isthmus of Panama was acknowledged. In 1513, the rumours of a "new ocean" with plenty of gold caught the attention of the Spanish Vasco Nuñez de Balboa. He settled a voyage from "La Española", today known as Dominican Republic and Haiti, to Panama, where he crossed the Isthmus and reached the "new ocean" which he named "The South Ocean", present-day called Pacific Ocean. This event marked Panama´s significant value as a transportation route, to carry gold and treasures from the Pacific Ocean, mostly collected from Peru, to the Atlantic Ocean and later on transported to Spain. This route, called the "Camino Real" or Royal Trail linked a village in the Pacific named "Panama" to the Spanish colony in the Atlantic named "Nombre de Dios". Years later, due to the harsh weather conditions, diseases as well as the pirate attacks, the most famous being Sir Francis Drake who destroyed "Nombre de Dios", the Royal Trail was modified resulting in a new path from "Panama" in the Pacific to "Portobelo" in the Atlantic, known as the "Camino de Cruces" (Meditz, 1987).
In the 1530s, these two intercontinental and trans-isthmian paths inspired the Spanish crown to evaluate the possibility of the construction of a canal, in order to avoid the risks and dangers of the transportation of gold by land. Charles I, the King of Spain, ordered by decree to the then-governor of Panama, Pedro Arias de Avila, to survey a route to make possible the passage by ships through the Panamanian Isthmus. The survey suggested that a canal project was too dangerous due to many mountains, flooding rivers, jungles and swamps. Several years later, the Spaniard idea of building a canal through the Panamanian Isthmus ended with the Spanish king Philip II, when his catholic advisors reminded him of the Bible passage "What God has joined together, let no man put asunder". King Philip II issued a decree ordering the death of anyone who tried to build a canal through Panama (DuTemple, 2003).

2.1.1 The Panama Canal Railroad

Centuries after a series of geopolitical events in Panama, many attempts to construct a Railroad through the Isthmus of Panama took place, motivated by the benefits that a shorter and faster route connecting both oceans, Atlantic and Pacific, generated. England and later France were some of the countries that tried to build a railroad, however, due to the high costs and obstacles to undertake the construction of the Railroad, the project was lost by default (Otis, 1862).

The United States interest in the Railroad initiated with the settlement of the new North American boundaries incorporating Oregon, and the Mexico war, which incorporated California (Otis, 1862). There were three routes capable to connect the East with the West of the USA. The first one was crossing by land the USA from East to West. The second one was through Cape Horn, the most southern tip of America, which was considered a dangerous and tedious route. The third one was by ship from New York and New Orleans in the East, to Chagres in Panama Atlantic Coast, all the way to the Pacific Coast through the Isthmus of Panama, to connect with Oregon and California in the West again by ship (The Panama Railroad). In 1848, steam-ships were granted to the Pacific Mail Steamship Company to establish two mail lines, from New York in the East of the USA to California and Oregon in the West of the USA, crossing through Panama. The investors for the mail delivery were William H. Aspinwall, Gardiner Green Howland, Henry Chauncey and Edwin Bartlett. Everything changed at the end of 1848 with the discovery of gold in California, known as the California Gold Rush. The traffic from the East to the West of the USA increased enormously, which awakened Mr Aspinwall´s interest to develop a railroad through the Panamanian Isthmus that would improve the time and connectivity through this route, especially for the gold-seekers. In 1850 Mr Aspinwall together with a group of New York investors, got permission for the construction of a railroad that would link the two oceans across the Isthmus (The Panama Railroad). In 1855, despite all the tropical diseases as malaria and yellow fever that caused the death to many workers, the railroad was completed, running between Panama City in the Pacific and Colón in the Atlantic, in an estimate time of 4 hours (DuTemple, 2003). The following 3 years after its completion were “golden” years for the railroad. Estimates of USD 700 million in gold were carried through the Panamanian Isthmus by railroad without registrations of loss or robbery. Nevertheless, in 1869 the U.S. transcontinental railroad construction was completed, which meant that there was no longer a necessity to travel to Panama to go from the East to the West Coast of the United States, or vice versa. This last event marked the end of the Panama Canal Railroad, leading the company into bankruptcy (Panama Canal Railway Company, 1999).

When the French attempt to construct the Panama Canal started, explained in detail in section 2.1.2, they bought the railroad and conditioned it back into operations. In 1886, 799,264 passengers were transported with the railroad. After the bankruptcy of the French canal company, in 1902 the United States bought the railroad for USD 40 million. When the U.S canal constructions started, the railroad had to be relocated due to the fact that the canal was going to be dug mostly where the railroad laid. The relocation of the railroad was finished in 1912 and in 1913 the railroad was abandoned. With the completion of the Panama Canal in 1914, and years later with the construction of a highway through the Isthmus, the railroad lost all its importance and value. In 1977, the railroad came to form part of the Panamanian government due to the conditions under the Torrijos-Carter Treaty, a treaty that would grant to Panama control over the Panama Canal after December 31, 1999. In 1998 the Panamanian government privatized the railroad and granted a concession to the Panama Canal Railroad Company (PCRC), a joint venture between Kansas City Southern and MI-Jack

Products, which entitled them with all the rights over the railroad. Since then, the railroad is supporting the daily transhipment operations as well as the local cargo, carrying containers from one ocean to the other. Additionally the railroad continues to provide passenger service through the Isthmus from Panama City to Colón and vice versa (Panama Canal Railway Company, 1999).

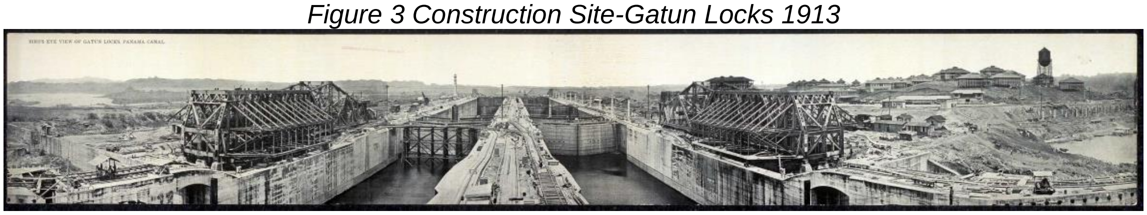
2.1.2 The Panama Canal

In 1869 the French, leaded by Ferdinand de Lesseps, completed the Suez Canal, connecting the Mediterranean Sea with the Red Sea, which shortened tremendously the route from Asia to Europe. In the late 1870s, due to the Suez Canal success, the French were enthusiastic about the construction of the Panama Canal. By that time, Panama was part of Colombia, thus on 1879 approval from Colombia was granted to form a company that would have the exclusive rights to build a canal along the railroad route (Meditz, 1987). The idea of Ferdinand de Lesseps was to build a canal similar to the one previously built in Egypt, a sea-level canal with a desert terrain and dry sand. Nonetheless, the circumstances in Panama were completely different, terrain surrounded by mountains, tropical weather, humid conditions, 250 days of rain in a year, and the most determinant factor, seas were at different levels (DuTemple, 2003). These circumstances, added to financial issues, lack of engineering and technical background to construct a lock canal instead of a sea-level canal, lead to the failure of the French attempt to build the Panama Canal. In 1889, all French works stopped and shareholders decided to dissolve the company (The Panama Canal Authority, 1998).

After Panama´s separation from Colombia in 1903, separation achieved due to United States support since they were deeply interested in building and owing a canal, a treaty known as the Hay-Bunau-Varilla was signed, granting the United States a “canal zone” of 5 miles wide in each side of the Isthmus. In May 4, 1904 the United States started to construct the lock canal. During the years of construction, it is estimated that the workforce grew until an approximate of 33,000 people from all around the world. It took four years to build all the set of locks, Gatun with three pairs of chambers, Pedro Miguel with one pair of chambers and Miraflores with two pairs of chambers, all named after geographical names already used locally. Figure 3 presents a panoramic view from the construction site of the Gatun Locks in 1913.

The project successfully ended on January 1914 when the first oceangoing vessel completed its voyage through the Panama Canal. The official inauguration ceremony of the Panama Canal took place on August 15, 1914, one hundred years ago (The Panama Canal Authority, 1998).

Figure 3 Construction Site-Gatun Locks 1913



Source: US Library of Congress

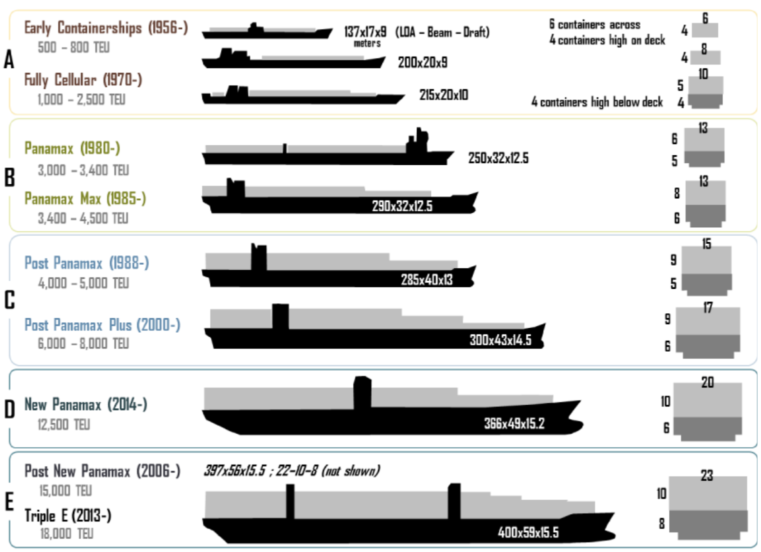
2.2 Developments and Trends in Liner Shipping

The opening of the Panama Canal in 1914 shaped the maritime industry, mainly because it shortened considerably the distance between US east cost and US west coast, as well as from South America to the United States, avoiding the sailing around the Cape Horn. Since then, trade between the Atlantic and the Pacific has been mainly determined by the economic development and organic growth in the region, as well as driven by consumption patterns. After the World War II, with the Bretton Woods Conference and the establishment of the International Monetary Fund (IMF), Japan´s economy emerged increasing substantially the traffic through the Panama Canal, positioning the country as the second user of the Canal for many years (ECLAC, 2013).

Furthermore, in the nineteen sixties, the maritime industry experienced dramatic changes with the introduction of the container by Malcolm Mc Lean. Before the containerization, as it is commonly referred to this event, general cargo was transported in small ships called general cargo ships. Shipping at that time was very costly and labour-intensive. Ships spent excessive amount of time in ports that resulted in a series of difficulties as port congestion, delays and uncertainty in times and unreliability, which conversely lead to higher inventories throughout the supply chain, increasing the cost and final price of goods to customers. Things changed quickly with containerization, mainly because of the facility with which cargo could be handled and organized, not just inside the port, but also outside by truck to the warehouse, in what is called today door-to-door logistics (Haralambides H. , 2007). Studies as Levinson, 2006 and Rodrigue and Notteboom, 2009 acknowledged the advantages especially in time and cost savings that the containerization brought to the industry and the world. The invention of the container marked a new era in the maritime and shipping industry. Immediately after that, ships became more specialized, for instance ships for the carriage of chemicals, refrigerated vessels, and the early containerships, later called fully cellular container vessels (ECLAC, 2013). By the end of the 1970s, these fully cellular container vessels were the most popular for the transportation of general goods. Ports as well became more specialized, incorporating terminal operators for the specific handling of containers.

Taking into account that around these same years, 1967-1975, the Suez Canal remained closed several times due to political conflicts between Egypt and Israel, the route through the Panama Canal was often used, driving the shipbuilding industry to build the first so-called Panamax vessel, named after the Panama Canal dimension restrictions (Ham & Rijsenbrij, 2012). Approximately a decade after the Panamax, due to the rapid growth in the number of containers used for trade and the low profitability per container slot, the industry started to build larger ships to achieve economies of scale. In 1986, American President Lines (APL) was the first to order three container ships post-Panamax, a ship that due to its dimensions was no longer capable to transit through the Panama Canal. APL was followed by other shipping lines, namely CGM, MISC, HMM and Nedlloyd who ordered post-Panamax ships in the early nineteen nineties (Wijnolst & Wegeland, 2009). Innumerable studies about economies of scale have been conducted, (for instance Cullinane and Khanna, 1999 and Cullinane and Khanna, 2000) demonstrating the benefits that bigger vessels represent for the cost per container unit or per slot. Shipyards as Hyundai Heavy Industries affirmed that operating big vessels of about 13,000 TEU can be 29% cheaper than operating a vessel of 7,500 TEU, these savings being enhanced when fuel prices increase (Saanen & Rijsenbrij, 2014). Thus, after the Panamax size barrier was broken, it was just a matter of time for the industry to start ordering bigger and bigger vessels looking after economies of scale. Figure 4 illustrates the evolution of the containerships, starting in 1956 with the early containerships of about 500 TEU. After the vast acceptance of the container in international trade, the Panamax was built with an estimate capacity of 3000 TEU. The Panamax was followed by the construction of the Panamax Max in the range of 3,400 – 4,500 TEU, which are the vessels with an optimized design that are still able to cross the Panama Canal, notwithstanding its size restrictions by the Panama Canal dimensions. From the figure, it can be depicted that in a matter of 25 years or less, the size in containerships has increased dramatically, from 4,500 up to 18,000 TEU.

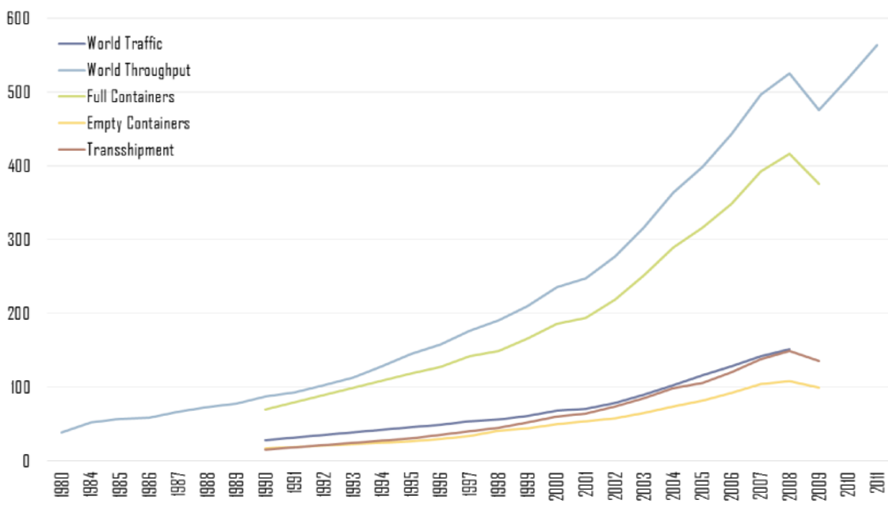
Figure 4 The evolution of Containerships



Source: Ashar and Rodrigue, 2012.
Note: Dimensions in meters. LOA: Length overall

The trend of increasing the size of containerships also meant that these bigger vessels had geographical restrictions as well as the challenge that economies of scale only make sense if the utilization of the vessel is high, in other words if there is enough cargo to fill the ships. As a result, the liner industry has opted to redesign its operating networks in such a way that they benefit from economies of scale whilst reaching an optimum level of utilization in their vessels (Ducruet & Notteboom, 2012). As a consequence, operating networks in which containers are transhipped have been developed; this is discharging containers from a big vessel, also called mother vessel, and loading them in another vessel, typically of smaller size also called a feeder. These networks are also referred as “hub and spoke” networks. Hub and Spoke models have lead to an increase in the amount of times a container has been handled. According to Ducruet and Notteboom, in 1990 the world containerized traffic accounted for 28.7 million TEU. This traffic increased to 152 million TEU in 2008. Conversely, the global port throughput in 1990 was around 88 million TEU. This number increased to 535 million TEU in 2008. These figures indicate that in the 1990s each container in terms of TEU was handled 3 times between its first port of loading and the last port where these containers were discharged. By 2008, containers were handled around 3.5 times (Ducruet & Notteboom, 2012). Nowadays, it is estimated that the global port throughput is around 600 million TEU and the worldwide container traffic around 160 million TEU, resulting in a ratio of almost 4:1, which means that each container is handled almost four times. In order words, it has been estimated that a container is transhipped twice from its place of loading until its final place of discharge (Haralambides, 2014). Graph 1 illustrates this phenomenon, where container port throughput has soared since the 1990s, compared to the container worldwide traffic that has also increased but much less. This also suggests that shipping networks have become more complex if compared to shipping networks 20 years ago. Obviously transhipment costs, not just represented by the handling charges and port fees but also in respect of time consumed, cannot be neglected.

Graph 1 Global Container Traffic vs. Global Container Port Throughputs



Source: Hofstra University, New York, USA
Adapted from Drewry Shipping Consultants

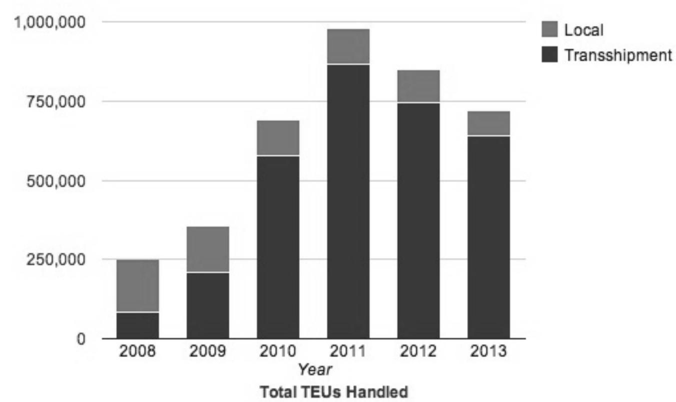
Several studies regarding the advantages and disadvantages of operating in hub and spoke networks vs. direct port calls have been discussed. For example: Notteboom T., 2010; Guy, 2003; McCalla et al., 2005. The main advantages of implementing a hub and spoke model falls in the fact that fewer port calls are needed leading to a reduced round-trip voyage time, which increases frequency of calls and thus less vessels are required in the specific network. Additionally, cargo consolidation provides a higher vessel utilization, which leads to higher benefits from economies of scale. However, the higher handling charges, the longer overall transportation times and distances for the customers as well as the reduced accessibility could counterbalance the benefits arising from these hub and spoke networks. Therefore, it results that shipping lines often face a trade-off with regards of higher accessibility and frequency in greater number of ports vs. higher load factor and economies of scale achieved through larger vessels (Ducruet & Notteboom, 2012).

2.2.1 Developments of Liner Shipping in Panama: A Transhipment Hub

Hub and Spoke networks have been developed mainly in four regions, namely Singapore, Middle East, the Mediterranean and the Caribbean including Panama. In Panama, in spite of the existence of ports more than 150 years ago, container terminals were fully developed in the 1990s, starting in the Atlantic with Manzanillo International Terminal (MIT) in 1993, and later in the port of Cristobal also in the Atlantic and the port of Balboa in the Pacific, the last two operated by Panama Ports Company (PPC).

Currently, there are other terminals operating in Panama, for instance Colon Container Terminal (CCT), which forms part of the Evergreen Group and PSA Panama International Terminal, owned by the Singaporean government, in addition to two more terminals that will be build in the coming years in preparation for the Panama Canal Expansion. Nonetheless, MIT, PPC and Cristobal are considered the main terminals in Panama, mainly due to the volume each of these terminals handle, being transhipments the greatest share of its operations.

Graph 2 Port of Cristobal - Local vs. Transhipment (TEU throughput)

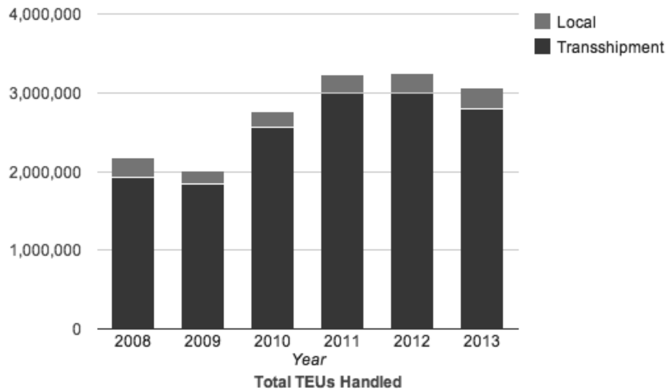


Source: Georgia Tech, Logistics Innovation and Research Centre Panama

Graph 2 represents the percentages of local cargo vs. transhipment cargo that PPC handles in the Port of Cristobal. In 2013, Cristobal handled around 721,000 TEUs, where 89% of the handlings were transhipments.

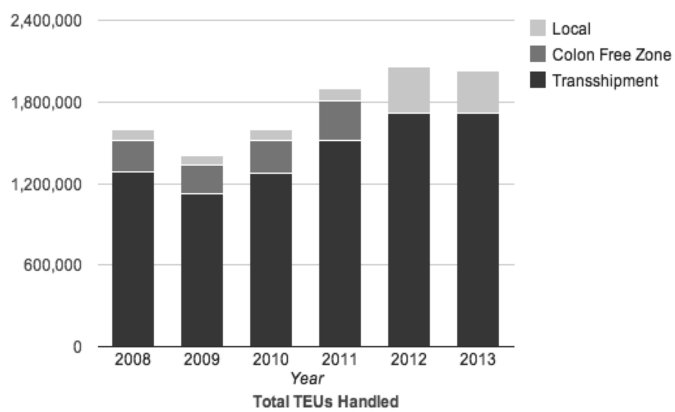
Graph 3 and Graph 4 also represent the percentages of local cargo vs. transhipment cargo that PPC handled in the Port of Balboa and that MIT handled in 2013, respectively. Balboa registered a throughput of 3 million TEU, being transhipments 91% of the total TEU, and MIT registered a throughput of 2 million TEU, being transhipments 85% of the total throughput.

Graph 3 Port of Balboa - Local vs. Transhipment (TEU throughput)



Source: Georgia Tech, Logistics Innovation and Research Centre Panama

Graph 4 Manzanillo - Local vs. Transhipment (TEU throughput)



Source: Georgia Tech, Logistics Innovation and Research Centre Panama

The ratio between transhipments and local cargo has been similar since these terminals started operations. This means that clearly, Panama is mainly used as a transhipment hub. In 1992, when Maersk Line opened operations in Panama, it started to carry containers from U.S. East Coast to WCSA and vice versa. Since PPC opened as a container terminal in 1999, this shipping line has utilized Panama Ports Company in Balboa as a hub for most of its cargo coming from FEA, WCCA, WCSA and Australia. Similarly, the shipping line utilizes Manzanillo as a hub for its cargo coming from the East Coast North America (ECNA), the Mediterranean, Europe, CAR, NCSA and ECSA. Shipping lines as Mediterranean Shipping Company (MSC), APL, MOL, Hapag-Lloyd, among others, have implemented similar hub systems in both oceans through Panama. Figure 5 represents the main routes that shipping lines serve through Panama as a transhipment hub.

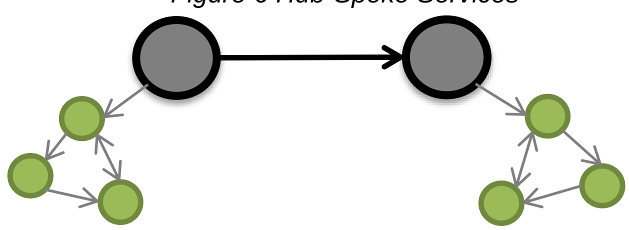
Figure 5 Panama Hub-Transhipment Networks

Source: City of Knowledge Panama, 2013

Depending on the network design, shipping lines for certain services choose to cross the canal, taking advantage of "double dipping" in Panama, which are services that combine inter-continental routes with inter-regional routes, where the mother vessel calls the hub port in both ways, usually in the middle of a round-trip voyage, allowing to discharge cargo as well as to load cargo which have also arrived from other feeder networks and take it to the final port (Zuesongdham, 2013). For some other services, they choose to operate with the "land-bridge transhipment" model, via PCRC and serve the destinations by feeders. These two operational models will be explained in detail in the following chapters 3 and 4.

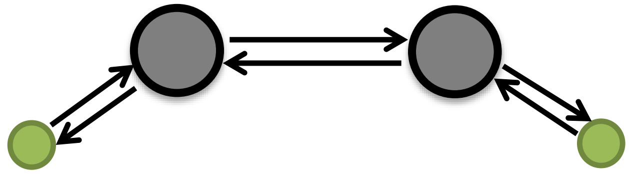
Figure 6 and Figure 7 illustrates the design of the hub-spoke services and the double-dipping services mentioned previously, currently taking place in Panama.

Figure 6 Hub-Spoke Services



Source: Modified from Hamburg Port Authority, 2013

Figure 7 Double-Dipping Network



Source: Modified Hamburg Port Authority, 2013

Chapter 3 Transhipment Model with the Panama Canal Railroad

3.1 Description of the Transhipment Operations

When shipping lines started to deploy larger containerships in their intercontinental trade routes, vessels that came from FEA, especially to Central America, South America and The Caribbean were already big enough to be able to cross the canal. In response to this, they started to operate with the Panama Canal Railroad Company, PCRC, which basically serves as a "land-bridge" link for transhipment cargo, together with a smaller share of local cargo moving to the Colon Free Trade Zone. This transhipment model consists of big vessels from FEA to the PCW calling Balboa Terminal in the Pacific side, where containers are unloaded and loaded in the PCRC. Then, the PCRC transports these boxes to the Atlantic side, where they are unloaded in Cristobal or Manzanillo Terminal, depending on the carrier´s request. Later on, these boxes are loaded again, usually in a smaller vessel or feeder vessel to be transported to different destinations in Latin America and The Caribbean. The PCRC is an attractive alternative for those shipping lines that have established hub operations in Panama, in both sides of the Isthmus. The new ships that have been delivered have created a cascading effect in the deployment of vessels globally, as presented in Table 1. Currently, shipping lines are deploying vessels in the range of 7000-9200 TEU in intercontinental services as the one concerning this research, from FEA to PCW. For the Intra-Americas Trade, current vessels are in the range of 2000-4000 TEU.

Table 1 Vessels Cascading-Global Effect

Trade Route	Vessel Size TEU
Asia-North Europe	18270
Asia-Mediterranean	14000
Asia-USWC	13800
Asia-ECSA	9700
EU-ECSA	8800
Asia-WCSA	9200
Asia-Middle East	14000
EU-South Africa-Asia	12500

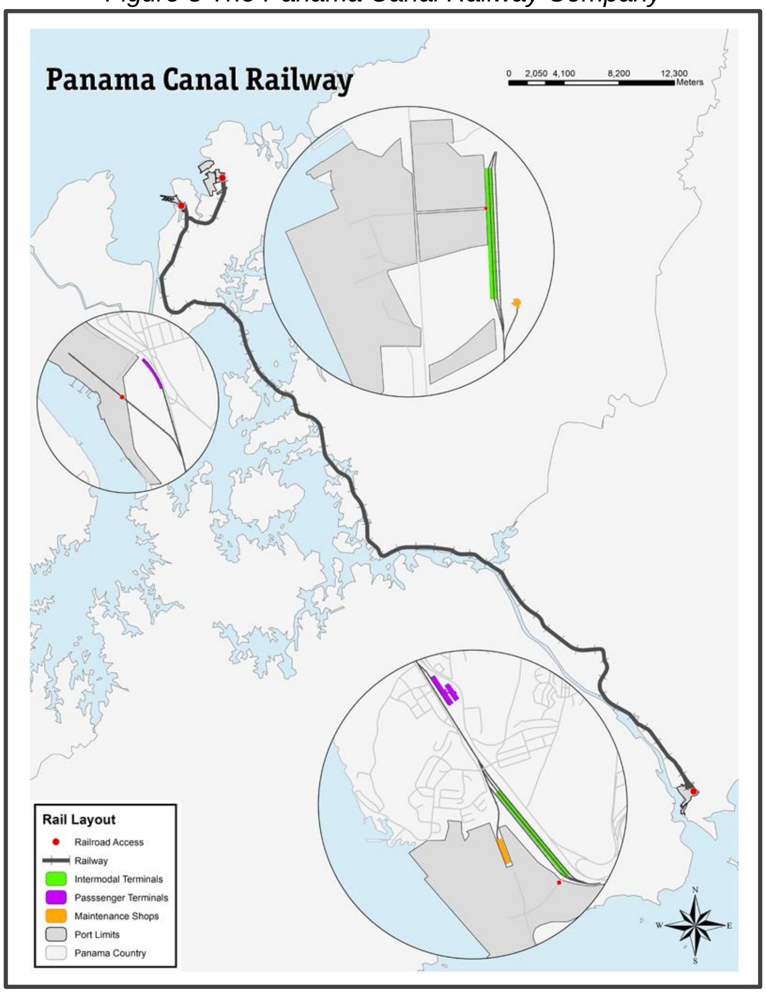
Source: Davidson, 2014 from Drewry

Appendix B presents some examples of the networks configurations that shipping lines, designed in which they call Balboa Terminal in the Pacific, consolidating cargo that comes mainly from Asia and moving it to the Atlantic via the PCRC. Appendix B also presents some other examples of the liner services that call Manzanillo, after cargo have been consolidated there and transport these to South America East Coast and The Caribbean.

3.2 Performance of the PCRC for Shipping Lines: Cost and Times

In order to understand why the shipping lines that have established hub operations in Panama, opted to use the PCRC instead of the Panama Canal, it is important to acknowledge that Panama is the only country where freight cargo can be transported in customs zone from the Pacific to the Atlantic in a matter of few hours. PCRC has two intermodal facilities, one in the Pacific adjacent to Balboa Terminal, and the other one in the Atlantic adjacent to Cristobal and Manzanillo International Terminal. Currently, the PCRC capacity allows for ten trains in each direction, north/south, with an approximate travel time of 1 hour and 15 minutes. It is estimated that the loading and unloading in each port takes around 2 hours, thus the total time that takes to move a container from the Pacific to the Atlantic is around 5 hours. The freight cars are double-stack and equipped with reefer plugs (Georgia Tech, 2014). Figure 8 illustrates the PCRC route and each of the terminals connected to it in the Pacific and the Atlantic (red dots).

Figure 8 The Panama Canal Railway Company



Source: Georgia Tech: Logistics Innovations and Research Centre, 2014

The price that the PCRC negotiates with shipping lines is considered to be “all-in” rates; these are rates that include the complete journey from the Pacific to the Atlantic or vice versa, including the terminal handling charges to load and unload these containers. The price varies just depending on the type of container, regardless of the size; in other words, tariffs apply for dry containers, reefer containers, full containers and empty containers. Based on the shares of full dry/reefer and empties (MTs), it is estimated that this all-in tariff is in the range of USD 175 – 194 per TEU, according to estimations from professionals in the field. Chapter 5 will evaluate the PCRC transhipment operation through a cost model, to identify if this alternative will remain the preferred one for shipping lines for the trade to the East Coast of South America, as it is today.

Chapter 4 The Panama Canal Route

Since the opening of the Panama Canal in 1914 until today, the Canal has served for more than 1 million transits of vessels, with an estimate of 9.5 billion long tons. Traditionally, the Panama Canal route served mostly for the transit of bulk carriers, containing lumber and wheat. However, after the introduction of the container and its vast acceptance worldwide, the transits of containerships increased tremendously, ending as the main customer segment for the Panama Canal. This is due to the fact that containerships represent half of the total revenues that the Panama Canal receives from transit tolls. In 2013, the containerships segment had an average of 3,103 transits that accounted for 951.4 million dollars in toll revenues, 51.5 % of the overall Panama Canal toll revenues. In terms of performance in the provision of its services, the Panama Canal has been continuously working on its reliability and customer service experience. The Panama Canal service performance is measured in Canal Water Time (CWT), which is the time transpired from the moment a vessel arrives to Canal waters plus the transit time. According to the Annual Report of the Panama Canal for 2013, the CWT decreased from 25.7 to 24.5 hours, meaning an improvement of 4.53% when compared to the fiscal year 2012 (Canal de Panama, 2013).

4.1 Main Routes and Users of the Panama Canal

In the full container vessels segment, the main five trade routes are Asia and USEC, USEC and WCSA, Europe and WCSA, WCSA and ECSA (Intercostal) and USEC and WCCA, as presented in the table below. Table 2 also presents each trade route with its respective cargo ton totals measured in PC/UMS tons (the Panama Canal Universal Measurement System) and long tons, according to the Panama Canal statistics for the Fiscal Year 2013.

Table 2 Main Trade Routes of the Panama Canal - Top 5

Trade Route	PCUMS Net Tons	Long Tons
East Coast U.S. - Asia	112,722	77,027
East Coast U.S. - W.C. South America	29,950	28,156
Europe - West Coast South America	22,885	14,209
South America Intercostal	16,668	11,556
East Coast U.S. - W.C. Central America	11,617	9,560

Source: Panama Canal Transit Statistics, 2013

The main shipping line users of the Panama Canal services are Maersk Line, MSC, Hapag-Lloyd, Evergreen and CMA-CGM. Table 3 presents the total number of transits for each of these carriers for the fiscal year 2012. Despite that during 2013 and the first half of 2014 the shipping networks and services have been constantly changing seeking for efficiencies, these 5 shipping lines are still considered as the top 5 users of the Panama Canal in the full container vessel segment. Appendix A and Appendix B present the name of some of the services, the network maps and the port calls that these mentioned shipping lines designed to cross the Panama Canal.

Table 3 Main Users of the Panama Canal per No. Of Transits - Top 5 Shipping Lines

Shipping Line	No. Transits 2012
Maersk Line	572
Mediterranean Shipping Company	387
Hapag-Lloyd	301
Evergreen	301
CMA-CGM	199

Source: Panama Canal Authority Database, 2012

Mainly these shipping lines employ Balboa Terminal and Manzanillo/Cristobal Terminal as hubs, operating in the aforesaid “double-dipping” networks, which they complement with their feeder services in the north-south trade.

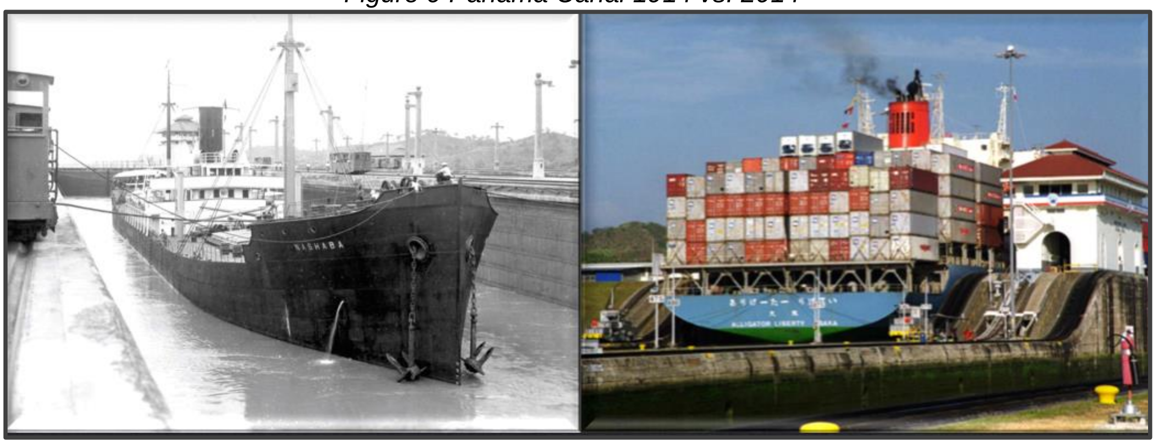
4.2 Current Tolls and Costs for Shipping Lines

Tolls have always been a part of the requirements for vessels to transit through the Panama Canal. In 1994, tolls were charged based on tonnage measurement, according to the PC/UMS. The PC/UMS or Panama Canal Universal Measurement System consists of a mathematical formula based on net tonnage as stated in the International Convention on Tonnage Measurement System of 1969, in which one net PC/UMS ton is equivalent to 100 cubic feet of capacity. In 1999, when the Panama Canal was turned over to the Panamanian Government, the Panama Canal Authority restructured the business model of the Canal, from a “break-even” model into a system where reliability, customer satisfaction and profitability became the business drivers. In 2005, following the profitability model, the Panama Canal Authority started to price-differentiate in the full container vessels segment, changing the tolls assessment from the PC/UMS tonnage to a system based on TEU, or twenty-foot equivalent unit, capacity. In 2007, the tariff was dependent on the ship carrying laden or ballast TEUs. For laden TEUs, the toll was $54 and for ballast $43.20. This structure prevailed until 2009, when the toll for a laden TEU was $72 and for ballast $57.60, an increase of approximately 33% in 3 years. In 2011, a new tolls system was approved, where in addition to the fee charged per TEU capacity of the ship either laden or ballast, a fee for each full TEU also applied. This system is still effective and consists of $74 per TEU according to the vessel capacity plus $8 per each loaded TEU, according to the amount of TEUs with cargo by the time the vessel is transiting through the canal. For ballast TEU capacity the fee is $65.60 per TEU. An important remark in the current tolls assessment system is that tolls are charged per TTA (Total TEU Allowed). This means that, despite the container vessel capacity being for instance 5000 TEU, if the TTA is 4500 due to visibility restrictions to cross the canal, then the tolls are applied to the 4500 TEU capacity. (Canal de Panamá, 2012)

4.3 The Panama Canal Expansion Project

On December 31st, 1999 when the Panamanian Government took control over the Panama Canal, the developments and trends in shipping previously discussed in section 2.2 and 2.3, were noticed. Figure 9 depicts a ship transiting through the Panama Canal in 1914 versus today, 2014, wherein the ships have a slack of just few inches in each side, being prominent the need to expand the canal. This triggered the beginning of “The Master Plan” in 2005, constituted by a series of studies with the purpose of expanding the Panama Canal to be able to serve the new coming vessels, impacting directly economies of scale and at the same time protect its value and competitiveness. In 2006, the expansion project officially started with the approval of Panamanians via a national Referendum established by national law, in which 77.80% of the country agreed to execute the plan.

Figure 9 Panama Canal 1914 vs. 2014

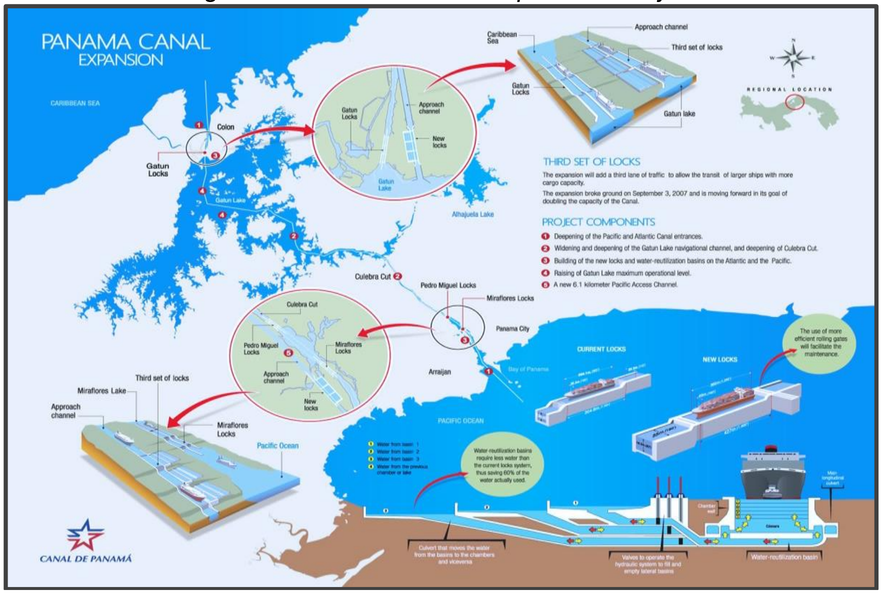


Source: Panama Canal Expansion: Potential Impact on World Trade, 2013

The Panama Canal expansion consists mainly on the construction of a third set of locks, which structures the project in five different components. First, deepening of the entrances in both oceans, Pacific and Atlantic. Second, deepening and widening the Gatun Lake, and deepening of the Culebra Cut. Third, the building of the new locks in the Atlantic and the Pacific, each of them with three chambers and three water-reutilization basins. Fourth, elevating the Gatun Lake maximum operational level and fifth, the construction of a 6.1 kilometres navigation access channel in the Pacific (Canal de Panama, 2014).

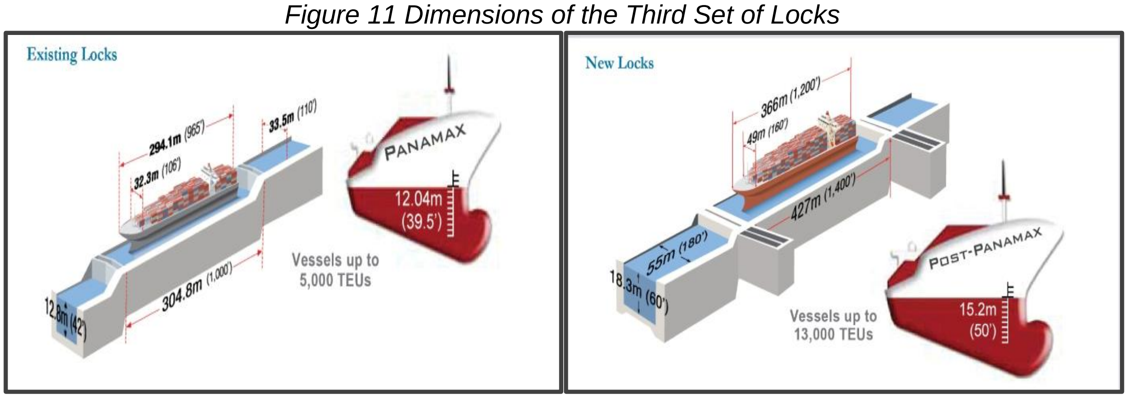
Figure 10 illustrates these five main components of the expansion project. The dimensions of the new locks will be 427 meters of length, 55 meters of width and a maximum depth of 28.3, which will allow the passage of bigger ships of up to 13,200 TEU, as presented in Figure 11.

Figure 10 Panama Canal Expansion Project



Source: Canal de Panama Expansion Program, 2013

Figure 11 Dimensions of the Third Set of Locks



Source: *Panama Canal Expansion Study Phase 1: Developments in Trade and National and Global Economies, 2013*

4.3.1 Effects of the Panama Canal Expansion

It is expected that the Panama Canal expansion project will be completed by the end of 2015. This means that from 2016 onwards, bigger ships will be able to cross the canal resulting in more efficiencies and lower costs for shipping lines. However, the expansion will also have ripple effects on the main infrastructure providers, namely ports, terminal operators and rail/inland connections, as well as in the network designs, trade flows and in the overall logistics and transportation chain. Several studies have been dedicated to the analysis of the possible effects that the new Panama Canal will have in the shipping industry and economy. Most of these studies are dedicated to the effects that the Panama Canal expansion project will have in the United States, (for instance Knight, 2008; Prince, 2012; Metcalf, 2013; Johnson, 2012). The U.S.

Department of Transportation realized an extensive study in regards to the potential effects of this project. In their study they mentioned four determinant factors that will shape the impact that the expansion will have in the United States. First, the increased concentration in port calls, due to the deployment of larger ships. It is likely that the deployment of larger vessels will lead to consolidation of the port calls, especially for the trade between FEA and USEC. This will directly impact U.S. ports, since fewer calls with larger ships will lead to higher peak loads and call size, which in turn will favour those ports that have enough handling and storage capacity as well as inland connections, enabling a fast service time for these calls. Second, the state of readiness of the U.S. ports and its related infrastructures; This is related to the previous factor, wherein just the ports that are ready in terms of depth, height, available berths, handling capacity, storage capacity and high connectivity, will be the ones receiving these larger vessel calls, benefiting from the expansion. Third, the use of foreign transhipment ports since depending on how shipping lines design their networks and cost structures, as well as the extent in which U.S. ports invest in preparing its capacity to receive bigger vessels, transhipment ports in Panama and The Caribbean are likely to be developed. Last, the development of marine highways between smaller and larger ports in the United States, since it is likely to be a suitable solution to avoid extra costs and risks that could result from foreign transhipment ports (U.S. Department of Transportation , 2013). These factors are also applicable to other countries or regions that will be receiving the traffic generated from the Panama Canal expansion, as for instance the case of ECSA.

Other studies have focused on analysing if there will be a shift of cargo and trade flows, or if there will be no impact in the global freight distribution networks at all. This is also commonly referred as the “game-change” in the shipping industry that could arise after the completion of the expansion project. Some of the studies that favour the view that there will be no change in the freight distribution networks are mainly due to the fact that trade between the Atlantic and the Pacific is mostly driven by organic growth in the region and conversely, growth in this segment has been driven by containerization, as well as technology, trade liberalization and international economical and political conditions, as the North American Free Trade Agreement (NAFTA). However, actually it is believed that the majority of products that could be containerized have been containerized already, ceasing the potential organic growth in the transportation of containers. Hence, it is most likely that the Panama Canal expansion will not impact significantly the trade patterns as it did in 1914, when it started operations for the first time (ECLAC, 2013). Dr. Jean-Paul Rodrigue in his study about the factors impacting North America freight distribution in view of the Panama Canal expansion listed several determinants that could impact North America, concluding that there is some evidence supporting the view that the Panama Canal expansion will have small impact in freight distribution, however it is still difficult to assess the exact impact of the project, mostly because the main actors themselves are still uncertain. Nevertheless, what is certain is that these main actors, namely terminal operators, freight forwarders, logistics service providers, etc., will try to anticipate the possible effects and prepare themselves accordingly (Rodrigue D. J.-P., 2010). In another study by Dr. Rodrigue and Notteboom in regards the Panama Canal as a game changer or business as usual, they mentioned that an important determinant in the comparative advantage of the Panama Canal routing option depends on how the transport cost structure would change as well as the new tolls that the canal will charge. They also underlined the fact that the Panama Canal expansion serves as a value proposition especially for the emergence of a transhipment market in what is called the "Caribbean Transhipment Triangle", between Panama and the Caribbean, due to the advantageous position in the crossroads of transatlantic and transpacific trade as well as north-south trade. The expansion comes at a time of many uncertainties and rapid developments and changes, thus this project will not result in a "business as usual", but the effects of the "trade game" are still unclear (Rodrigue & Notteboom, 2012). Further studies have been focused on the evidence that the Panama Canal expansion and the increased traffic that it will carry will also have a game-changer and multiplier effect in Latin America and the Caribbean economy, including Panama, particularly for the development of transhipments. The expansion has been a driver for change in this region, stimulating investments in infrastructure, improving processes and coordination, and reducing logistics costs, in order to counterbalance the comparative disadvantage that Latin America and The Caribbean still has when compared to transhipment centres as Singapore (Inter-American Development Bank, 2013).

Additionally, extensive literature compares the Panama Canal with its main competitors namely the Suez Canal and the U.S. Intermodal System. Studies as Sabonge et all 2012 analysed the competitiveness of the Panama Canal with the Suez Canal, the Cape Horn and the U.S. Intermodal System. Their main findings were that the comparative competitiveness of the Panama Canal increases when economic activities and fuel prices are high. In their results, they also found that the Panama Canal competitiveness was higher for the USEC destinations than for the destinations located in the mid-western U.S. (Ungo & Sabonge, 2012). Other studies as Snyder et al, 2013 concluded that there would be shifts in trade flows from the Panama Canal to the Suez Canal, especially for the FEA-USEC trade route (Snyder, Doyle, & Toor, 2012).

It has to be taken into account that currently, the Panama Canal route for containerships is no longer the preferred for the FEA-USEC corridor, mainly due to the economies of scale. According to Drewry, the share for the Suez Canal in this trade route is 52%, while for the Panama Canal is 48%, positioning the Suez Canal ahead the Panamanian. Moreover, the opening of the Panama Canal expanded has been postponed almost two years from its original completion date, threatening the competitiveness of the Panama Canal since the more delayed the project, it is more likely that shipping lines will shift to alternative routes as Suez. An additional potential threat is the Nicaraguan Canal, that according to the projected plan, it will allow the passage of vessels of 18000 TEU, which enhance economies of scale benefits, as well as reducing the sailing times and fuel consumption for this aforementioned trade route (London, 2014).

4.3.2 Expected Tolls and Costs for Shipping Lines

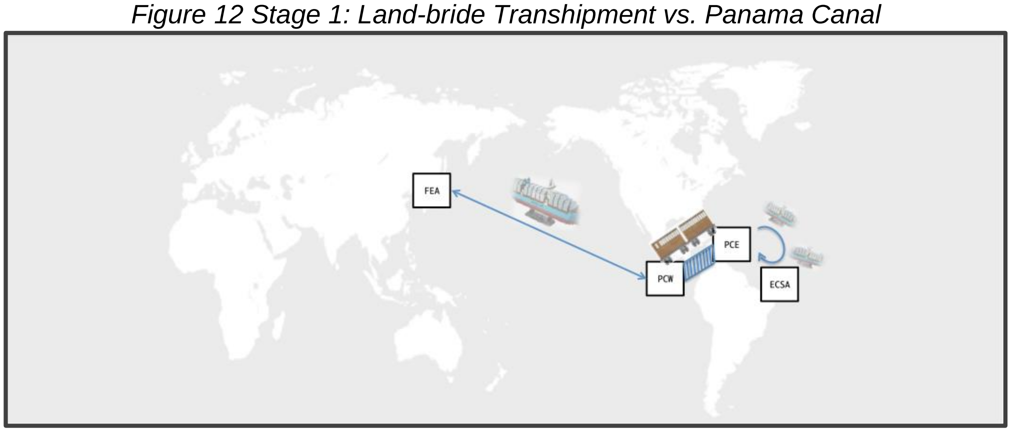
According to the Panama Canal Authority, new tolls for the widened Panama Canal will be officially announced by the end of this year, 2014. As mentioned before, the business model of the Panama Canal changed from a "break-even" model, to a business focused on profitability. Therefore it is expected that the new tolls will be settled in a level where the expansion investment is covered, generating profits as well. However, several factors have to be acknowledged when referring to the new tolls, for instance the fact that the postponement of the completion date has affected the market share and competitiveness through the Panama Canal route, especially in the container segment, and that higher tolls could magnify this result, instead of attracting those services that they have lost in the past two years. Nevertheless, what is certain is that the new tolls structure should be able to differentiate those ships that will remain using the current set of locks from those bigger ships that will be using the new wider locks. Re-calling the sub-chapter 4.2, the tolls for the container segment have been recently revised and settled in USD 74 per TEU-ship capacity and USD 8 per Full TEU. Thus, we could assume three possibilities being first, a percentage increase overall of the current tolls, second an increase in the amount charged per TEU-ship capacity and third, an increase in the amount charged per each full TEU. Since the beginning of the Master Plan, it was estimated that the Panama Canal Authority intended to increase the tolls in a rate of approximately 3.5% per year from 2009 until 2025 (Leach, 2006). The last revision of the Panama Canal tolls for the container segment was done on 2011, this means that for 2015, it can be expected an increase of 15% in the current tolls. For this research, the cost model presented in the next chapter, will consider the current tolls, however these aforementioned three scenarios will be evaluated through a sensitivity analysis, which will be discussed in detail in Chapter 6.

Chapter 5 The Cost Model

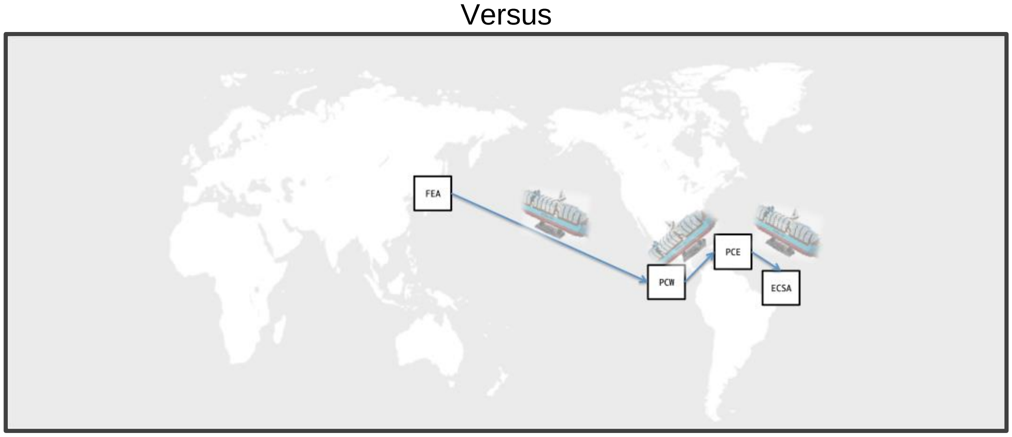
The aim of the model is to evaluate the two stages presented in the Research Design, Chapter 1.3, in order to assess the best alternative to the trade-off that shipping lines will face for the trade networks through Panama, after the Panama Canal expansion. For this model, the cost structure is similar to the one presented in previous studies as Barnes 2008, where she compared the Panama Canal Route versus the Northern Passage; Sabonge et al 2012 which compared the Panama Canal route, the US intermodal system and the Cape Horn, and Chaug-Ing Hsu et al 2004 and Chaug-Ing Hsu et al 2006 who compared direct route vs. transhipment as well as the optimum ship size and sailing speed for the latter. Costs will be calculated in terms of U.S Dollars for the whole voyage from FEA to ECSA, and then calculated per TEU. The transit time that will be considered for the whole voyage will be divided in legs: Leg 1, the average transit time from the ports in the FEA region to PCW. Leg 2, the transit time from PCW to PCE, depending on the modal choice, and leg 3, the average transit time for the leg from PCE to ECSA region. A TEU-factor of 1.6 will be assumed for the data gathered in terms of U.S Dollars per container (box) and the currency convertor rate of August 6th 2014 will be used for the costs gathered in a currency other than USD.

5.1 Stage 1: The "Land-bridge" Transhipment vs. The Panama Canal Route

Figure 12 Stage 1: Land-bride Transhipment vs. Panama Canal



Versus



In this first stage, the model will consist in calculating the total costs of the operation through the land-bridge transhipment, from a shipping line perspective, versus operating through the Panama Canal. The model will be applied for ships of 4000 TEU and 13200 TEU, presented in scenarios A1, A2, B1 and B2.

The parameters and nomenclature of the model are presented below:

Nomenclature

TC_{pc}: *Total Costs through the Panama Canal for the roundtrip*

TC_{pcrc}: *Total Costs through the land-bridge transhipment via the railroad PCRC round-trip*

$\mathrm{TC_{pc}}$ per TEU: *Total Costs through Panama Canal per TEU roundtrip*

$\mathrm{TC_{pcrc}}$ per TEU: *Total Costs via PCRC per TEU roundtrip*

OC: *Operating and Capital Costs*

FC: *Fuel Costs*

THC: *Terminal Handling Charges*

$Tolls_{pc}$: *Cost for the passage through the Panama Canal*

$Tolls_{pcrc}$: *Cost for the land − bridge transhipment operation via PCRC*

Parameters:

f_p: *Fuel price in USD per metric ton*

f_{cs}: *Fuel consumption at sea in metric tons per day*

f_{cb}: *Fuel consumption at berth in metric tons per day*

tt_i: *Transit time in days for i=1,2,3 corresponding to each of the legs in the voyage*

oc_d: *Operating cost per TEU per day according to the ship size*

C: *Ship capacity in TEU*

U: *Utilization of the vessel, fixed at 85%*

THC_k: *Terminal handling charge in USD for k=FEA, ECSA ports*

p_c: *Panama Canal Toll for ship capacity*

p_f: *Panama Canal Toll for each full TEU*

p_r: *PCRC average toll per TEU*

$\%_{feb}$: *Percentage of full containers in a vessel, fixed at 60% for the eastbound voyage*

$\%_{fwb}$: *Percentage of full containers in a vessel, fixed at 45% for the westbound voyage*

The structure of the model will be as follows:
Ship through Panama Canal route if:

$$TC_{pc}\ per\ TEU < TC_{pcrc}\ per\ TEU$$

Where:

$$TC_{pc} = OC + FC + THC + Tolls_{pc} \qquad \text{Equation I}$$

$$TC_{pcrc} = OC + FC + THC + Tolls_{pcrc} \qquad \text{Equation II}$$

$$TC_{pc}\ per\ TEU = {(OC + FC + THC + Tolls_{pc})}\Big/{C} \qquad \text{Equation III}$$

$$TC_{pcrc}\ per\ TEU = {(OC + FC + THC + Tolls_{pcrc})}\Big/_{C}$$ *Equation IV*

Operating Costs, OC, can be estimated by considering manning costs, insurance costs, fleet administration, repairs and maintenance and stores and lubes costs. The operating costs considered for this model are presented in the table below, gathered from Drewry Ship Operating Costs 2012-2013. In their report, they included a forecast for 2014 of the operating costs in USD/day for a range of vessel sizes until 12000 TEU. In table 8, the average of the range sizes was calculated. Then the cost in USD per day was divided by these average sizes, in order to obtain the cost in USD per TEU per day, as indicated in Equation V.

$$OC(USD/TEU/day) = \frac{OC(USD/day)}{C}$$ *Equation V*

Table 4 Operating Costs in the Containers Segment

Size (TEU)	USD/Day	USD/TEU/Day (oc_d)
625	4,427	7.08
1500	5,117	3.41
2500	6,444	2.58
3500	8,602	2.46
5500	9,583	1.74
8500	11,405	1.34
11000	12,868	1.17
13200	15,217*	1.15*
18000	18,861*	1.05*

Source: Modified from Drewry Ship Operating Costs 2012-2013
Note: Costs based on forecast for year 2014
**Estimate based on TREND function in Excel*

Since the given data just included until 12000 TEU, the Excel function TREND was used to estimate the cost in USD/day for the vessel of 13200 TEU and 18000 TEU. Then with Equation V cost in USD per TEU was gathered for both vessel sizes.

Equation VI will be used to calculate the total OC for the voyage from FEA to ECSA, where tt_i is the transit time in days for each leg of the voyage, assuming a vessel utilization, U, of 85%.

$$OC = oc_d * UC * \sum_{i=1}^{3} tt_i$$ *Equation VI*

Table 5 presents the average transit times that will be used for this research for each leg of the voyage (see also Appendix D).

Table 5 Transit Times FEA-PCW-PCE-ECSA

Voyage Legs	Transit Time (days)	
	PC	PCRC
FEA-PCW (1)	26	26
PCW-PCE (2)	1	0.21*
PCE-ECSA (3)	13	13

Source: Sea Rates, 2014

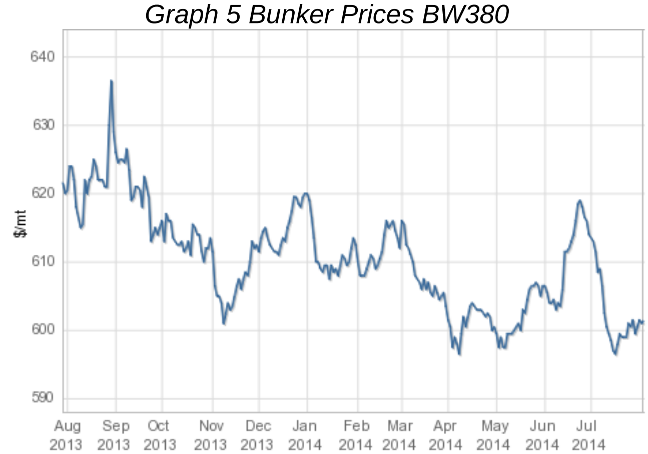
**For OC and FC calculations, this will be assumed 0, since this tt is through land and not sea.*

Fuel Costs, FC, can be estimated following the formula below, where f_p is the fuel price in US dollars per metric ton; f_{cs} is the fuel consumption at sea and f_{cb} is the fuel consumption at berth, both measured in metric tons per day; $\mathrm{tt_i}$ is the transit time in days for each of the legs from the voyage FEA-ECSA.

$$FC = f_p * (f_{cs} + f_{cb}) * \sum_{i=1}^{3} tt_i \qquad \textit{Equation VII}$$

Graph 5 presents the current bunker prices, according to Bunker World. The last updated bunker price for August 2014 was USD 601.50 per metric ton. It can be depicted from the graph that since August 2013 until the present date, bunker price has varied from the highest, USD 638.00 per metric ton, registered on September 2013, and the lowest, USD 598.00, registered on April and July 2014. For this reason, it can be considered safe to estimate the fuel price for this research as the average within this range, in about USD 620 per metric ton.

Graph 5 Bunker Prices BW380

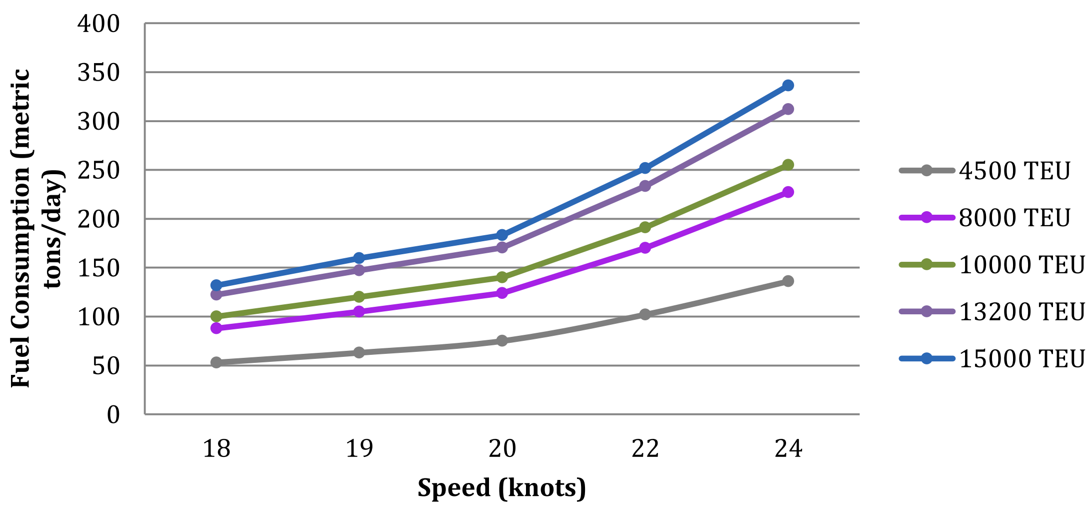


Source: (Bunker World, 2014) *BW380 Index*

The fuel consumption was gathered from the study previously conducted by Notteboom and Carriou, 2009 where they estimated the fuel consumption for a particular service, by adding the fuel consumed by the main and auxiliary engines when the vessel is at sea, manoeuvring in port or transiting through canals and waiting and berth times (Notteboom & Carriou, 2009). Their estimates were gathered for several sizes of ships at different speeds. The outcome of their study is presented in the graph as follows, including five ranges of ship sizes, and for each of these ranges, varying speeds.

From Graph 6, it can be depicted that when the ship size increases, fuel consumption increases, as well as the fuel costs, since higher fuel consumption leads to higher fuel costs. Furthermore, in the graph it can also be depicted the effect in fuel consumption when the speed varies from extra slow steaming, also known as economical speed which is around 15 to 18 knots, slow steaming estimated around 18 to 22 knots, also considered to be the dominant operational speed in the containership segment, to normal speed estimated around 20 to 24 knots, that is the optimal speed for which a containership and its engine has been designed (Rodrigue J. , 2014). For instance, a containership of 4000 TEU at a speed of 18 knots consumes about 50 tons per day of fuel, but when sailing at a speed of 24 knots, it consumes about 150 tons per day of fuel, an estimate of three times more fuel consumption per day. This also means that the fuel cost of a containership decreases when the sailing at extra slow steaming or slow steaming speed when compared to the normal speed. For this research, an extra slow steaming speed of 19 knots will be considered.

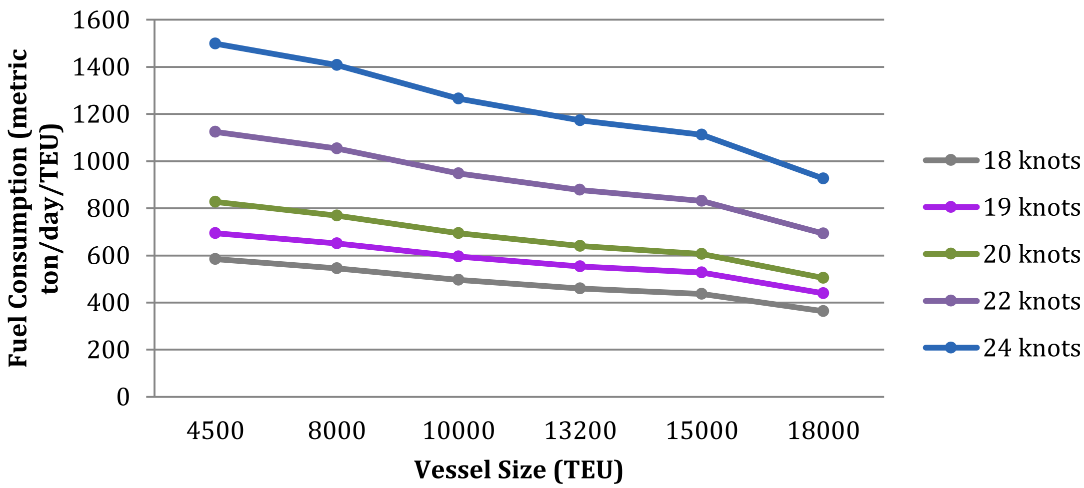
Graph 6 Fuel Consumption versus Speed: Varying Ship Size



Source: Modified from Notteboom and Carriou, 2009

Similar to Graph 6, Graph 7 presents the fuel consumption in metric tons per day but per TEU. In this graph it can be observed the effect of economies of scale in the fuel cost per each TEU-slot. For instance, for a fuel price of USD 620 per metric ton, a speed of 19 knots and a transit time of 80 days, which is the estimate round-trip from FEA to ECSA, the fuel cost per TEU for a 10000 TEU vessel is USD 600. However, following the same assumption but for an 18000 TEU vessel, the fuel cost per TEU is USD 440, which is about 27% of savings in the fuel cost per TEU resulting from the deployment of bigger vessels.

Graph 7 Fuel Consumption per TEU vs. Ship Size: Varying Speed



Terminal handling charges, THC, include the costs from loading and unloading operations as well as handling containers in the yard of the terminal. These will be estimated considering the main ports of the regions FEA, Panama, ECSA respectively, and calculating the average of the THC per TEU for each of these regions. These estimations were generated through the terminal handling charge levels published by Maersk Line. Appendix C includes all the ports used to estimate the THC for FEA, the ports in Panama and the ports in ECSA. The table below presents the THC rate that will be used for this research.

Table 6 THC Average for FEA-Panama-ECSA (USD per TEU)

FEA	Panama	ECSA
150.00 USD/TEU	190.00 USD/TEU	120.00 USD/TEU

Source: Modified Maersk Line Terminal Handling Charge Levels

In order to calculate the THC costs, the following formula will be used:

$$THC = THC_k * UC$$ *Equation VIII*

Toll Charges depend on the route chosen; for the land-bridge transhipment using the PCRC, as mentioned in chapter 3, tolls are charged based on the type of container, whether it is dry or reefer and if it is full or empty, regardless of the size of the box. For the transit through the Panama Canal, as mentioned in chapter 4, a part of the tolls are charged per TEU ship capacity and the other part per full TEU. For the calculation of the costs for the $Tolls_{pc}$, the equation IX will be used, where p_c is the Panama Canal price per ship capacity C, added to the percentage share of full TEU in the vessel for the eastbound trip, $\%_{feb}$, which was estimated through the Panama Canal Authority Annual Reports as presented in Table 7, multiplied by the p_f, which is the Panama Canal price per each full TEU, again assuming 85% of utilization of the vessel. For the westbound trip, same equation applies, but just varying the $\%_{fwb}$, which is the percentage of full containers for the return trip (see Equation X).

$$Tolls_{pc} = (p_c * C) + (\%_{feb} * p_f * UC) \quad \textit{Equation IX}$$

$$Tolls_{pc} = (p_c * C) + (\%_{fwb} * p_f * UC) \quad \textit{Equation X}$$

Table 7 Estimates of Full containers vs. MT containers based on Tolls Revenue

Annual Report 2012 ACP		Annual Report 2013 ACP	
12.2	Million TEU	12.1	Million TEU
7.4	Million TEU loaded	7.2	Million TEU loaded
61%	**Full containers**	**60%**	**Full containers**
39%	**Empty containers**	**40%**	**Empty containers**

Source: Modified from Panama Canal Authority Annual Reports, 2012-2013

For the calculation of the $Tolls_{pcrc}$, the following formula will be used, where p_r is the average price for one leg trip, for instance from Balboa Terminal to Manzanillo terminal, and it is estimated between USD 175 and USD 194 per TEU. This p_r will be multiplied by the capacity of the vessel, C, assuming 85% of utilization.

$$Tolls_{pcrc} = p_r * UC \quad \textit{Equation XI}$$

For each of the scenarios, the Total Costs will be calculated on the basis of USD per TEU, after adding these main four costs categories and dividing them by the vessel size studied, as stated in Equations III and IV.

5.2 Stage 2: Full Economies of Scale vs. Semi Economies of Scale

For the second stage, the same concept of the model described for stage 1 applies, with slightly differences presented as follows:

Best Alternative for shipping lines in terms of cost-performance is:

$$Min(TC_{B1}\ per\ TEU, TC_C\ per\ TEU, TC_D\ per\ TEU, TC_E\ per\ TEU, TC_F\ per\ TEU)$$

Where:

$\boldsymbol{TC_{B1}}$: *Total Costs for scenario B1, where 13200 TEU are deployed through PC*
$\boldsymbol{TC_C}$: *Total Costs for scenario C, where 18000 TEU are deployed from FEA-PCW and 10000 TEU from PCE-ECSA*
$\boldsymbol{TC_D}$: *Total Costs for scenario D, where 18000 TEU are deployed from FEA-PCW and 13200 TEU from PCE-ECSA*
$\boldsymbol{TC_E}$: *Total Costs for scenario E, where 18000 TEU are deployed for the complete voyage*
$\boldsymbol{TC_F}$: *Total Costs for the hypothetical scenario F, where 18000 TEU are deployed through PC*

$$TC\ per\ TEU = \left(OC_{i,k} + FC_{i,k} + THC_{i,k} + Tolls_{pc_{i,k}}\right) \Big/ C_{i,k}$$ *Equation XII*

$$\text{TC per TEU} = \left\{(\text{OC}_\text{i}+\text{OC}_\text{j,k})+(\text{FC}_\text{i}+\text{FC}_\text{j,k})+(\text{THC}_\text{i}+\text{THC}_\text{j,k})+(\text{ Tolls}_{\text{pcrc}_\text{i}}+\text{Tolls}_{\text{pcrc}_\text{j,k}})\right\} \Big/ \text{C}_\text{i} + \text{C}_\text{j,k}$$ *Equation XIII*

i: 18000 $TEU\ ships$
j: 10000 $TEU\ ships$
k: 13200 $TEU\ ships$

In this second stage of the research, Equations XII and XIII will be used for the different scenarios. Equations V, VI, VII, VII, and XI will be used for this stage as well. The data gathered, previously explained in stage 1 also applies for stage 2, except for the THC costs in scenario E, where for the ports in the region ECSA, an increase of 10% in the handling fee will be used, considering the investment efforts that these terminals will have to make to upgrade their facilities to receive vessels of 18000 TEU, as presented in Table 8. For the other scenarios the THC costs presented in Table 6 will still apply.

Table 8 THC Average with updated costs for ECSA ports (USD per TEU)

FEA	Panama	ECSA
150 USD/TEU	190 USD/TEU	132 USD/TEU

Source: Modified Maersk Line Terminal Handling Charge Levels

5.3 Model Verification and Validation

One of the most important aspects in this research is to verify and validate the cost model in order to make sure that the model is correctly constructed and that it is a good representation of the "real world". Since the model constructed for this research is very simple and basic, it was verified and validated through the opinion and intuition of experts in the field, external to the research. This was performed through informal interviews that were sustained with professionals in Maersk Line Panama, The Panama Canal Authority and Panama Ports Company, which outcomes also served for the construction of certain assumptions already explained in this chapter and to acknowledge limitations in the model, that are presented in Chapter 7.

Chapter 6 Results

The following subchapters will present the results of the four different scenarios that were considered for this research. The sub-chapter 6.1 will present the results for the scenarios A and B, and the sub-chapter 6.2 will present the results for the scenarios C and D.

6.1 Stage 1

Table 9 Model Data Stage 1

	Source of Result	Parameter/Description	PC 4000 TEU	PC 13200 TEU	PCRC 4000 TEU	PCRC 13200 TEU
A	Data	*fp: Fuel price in USD per metric ton*	620	620	620	620
B	Data	*fcs: Fuel consumption at sea in metric tons per day*	63	147	63	147
	Data	*fcb: Fuel consumption at berth in metric tons per day*				
C	Data	*tt1: Transit time in days FEA-PCW*	26	26	26	26
D	Data	*tt2: Transit time in days PCW-PCE*	1	1		
E	Data	*tt3: Transit time in days PCE-ECSA*	13	13	13	13
F	(C+D+E)*2	*tti: Transit time in days (round trip)*	80	80	78	78
G	Data	*ocd: Operating cost per TEU per day according to the ship size*	2.3	1.15	2.3	1.15
H	Data	*C: Ship capacity in TEU*	4000	13200	4000	13200
I	Data	*U: Utilization of the vessel, fixed at 85%*	0.85	0.85	0.85	0.85
J	Data	*THCfea: Terminal handling cost for FEA ports*	150	150	150	150
K	Data	*THCecsa: Terminal handling cost for ECSA ports*	120	120	120	120
L	Data	*pc: Panama Canal Toll for ship capacity*	74	74		
M	Data	*pf: Panama Canal Toll for each full TEU*	8	8		
N	Data	*pr: PCRC average toll per TEU*			194	194
P	Data	*%feb: Percentage of full containers in a vessel, fixed at 60% for the eastbound voyage*	0.6	0.6	0.6	0.6
Q	Data	*%fwb: Percentage of full containers in a vessel, fixed at 45% for the westbound voyage*	0.45	0.45	0.45	0.45

Source: Own Elaboration

Table 9 presents all the data used for the results in each of the scenarios in stage 1, according to the model parameters described in Chapter 5. The first column contains letters from A to Q, which represent each of the inputs used to calculate the total costs.

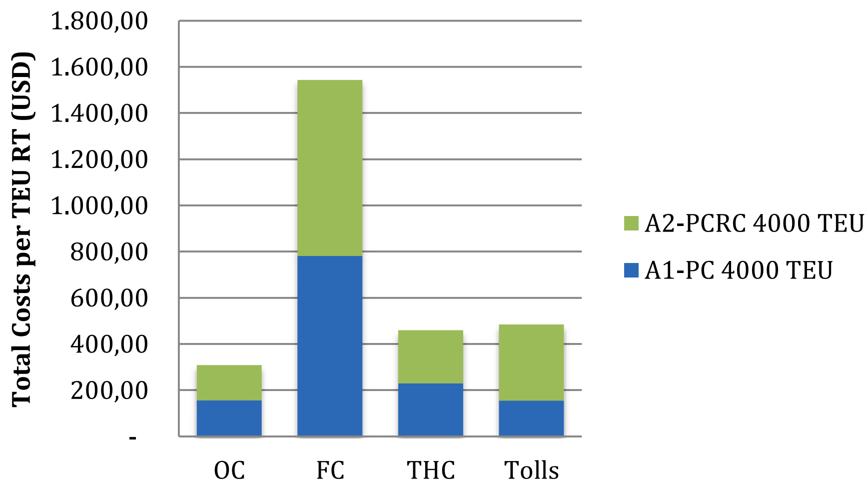
6.1.1 Scenario A1 and Scenario A2: 4000 TEU vessel

Table 10 Results Stage 1-Scenarios A1 and A2: PC vs. PCRC 4000 TEU vessels

	Source of Result	Parameter Description	Total Costs/TEU PC Round-trip (USD)	Total Costs/TEU PCRC Round-trip (USD)
R	(F*G*H*I)/H	Operational Costs (OC)	156.40	152.49
S	(A*B*F)/H	Fuel Costs (FC)	781.20	761.67
T	((J+K)*H*I)/H	Terminal Handling Costs (THC)	229.50	229.50
U	((H*L)+(P*I*H*M))/H	Tollspc eb:	78.08	
V	((H*L)+(Q*I*H*M))/H	Tollspc wb:	77.06	
W	(H*I*N)/H	Tollspcrc		329.80
TCpc per TEU RT	R+S+T+U+V	**TCpc**	**1,322.24**	
TCpcrc per TEU RT	R+S+T+W	**TCpcrc**		**1,473.46**

Table 10 presents the results for each of the costs, OC, FC, THC, TCpc and TCpcrc calculated for the round-trip, RT, considering a vessel of 4000 TEU. From the table it can be depicted that even though OC and FC costs are higher through the Panama Canal, mainly due to the extra sailing day through the canal, the PCRC tolls are considerable more expensive, which makes the Total Costs per TEU through the Panama Canal 10% cheaper than using the PCRC. Graph 8 presents the total costs per TEU wherein the difference in the PCRC tolls versus the PC tolls is illustrated.

Graph 8 Scenarios A1 and A2: PC vs. PCRC 4000 TEU



Source: Own Elaboration based on model results

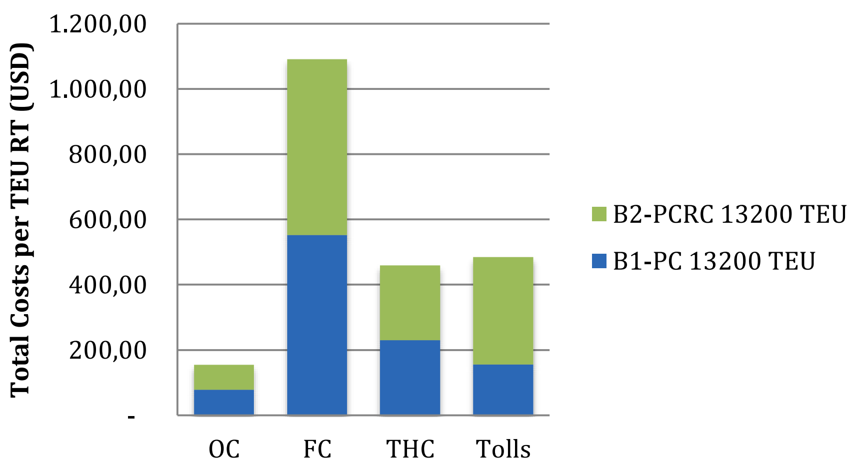
6.1.2 Scenario B1 and Scenario B2: 13200 TEU vessel

Table 11 Results Stage 1- Scenarios B1 and B2: PC vs. PCRC 13200 TEU vessels

	Source of Result	Parameter Description	Total Costs/TEU PC Round-trip (USD)	Total Costs/TEU PCRC Round-trip (USD)
R	(F*G*H*I)/H	Operational Costs (OC)	78.20	76.25
S	(A*B*F)/H	Fuel Costs (FC)	552.36	538.55
T	((J+K)*H*I)/H	Terminal Handling Costs (THC)	229.50	229.50
U	((H*L)+(P*I*H*M))/H	Tollspc eb	78.08	
V	((H*L)+(Q*I*H*M))/H	Tollspc wb	77.06	
W	(H*I*N)/H	Tollspcrc		329.80
TCpc per TEU RT	R+S+T+U+V	**TCpc**	**1,015.20**	
TCpcrc per TEU RT	R+S+T+W	**TCpcrc**		**1,174.10**

Similarly, Table 11 presents the results for each for the costs calculated for a vessel of 13200 TEU. As presented in the table, the total cost per TEU is 14% lower when crossing the Panama Canal versus utilizing the PCRC. From Graph 9, it can be depicted that the PC is a better alternative in this scenario, again due to the high costs arising from the PCRC tolls.

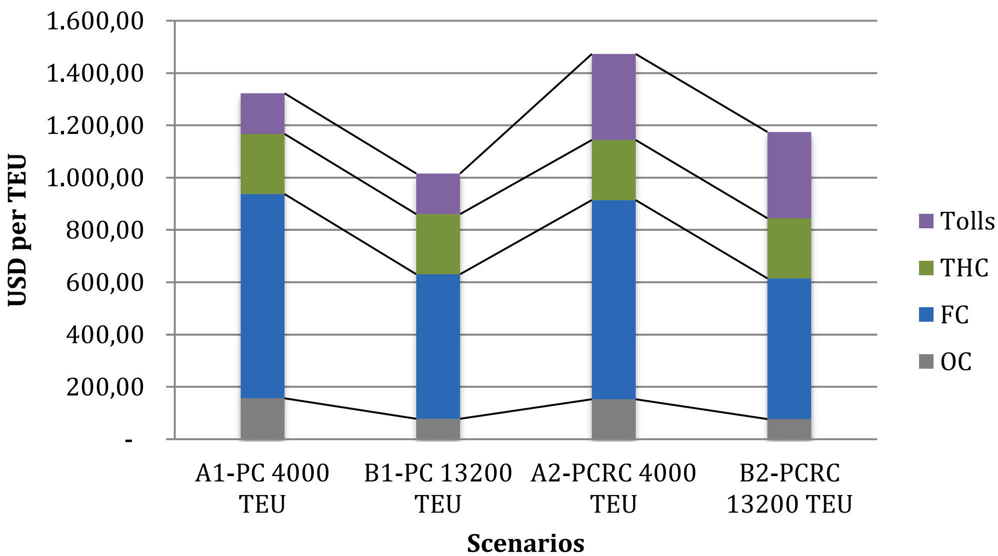
Graph 9 Scenarios B1 and B2: PC vs. PCRC 13200 TEU



Source: Own Elaboration based on model results

According to the model, from a cost per TEU perspective, the Panama Canal route is the best alternative for shipping lines, when compared to the Panama Canal Railroad in all scenarios, mainly due to the higher cost in the tolls per TEU to tranship the containers. It is estimated that the effect that the widened Panama Canal will have in shipping lines is a decrease of 23% in the total costs per TEU when a 13200 TEU vessel is used instead of a 4000 TEU vessel. These results are presented in Graph 10 where the overview of the results and the variations in the costs per TEU for each of the cots categories evaluated, OC, FC, THC and tolls for Stage 1 are presented.

Graph 10 Stage 1 Results-Total Costs per TEU



Source: Own Elaboration based on model results

6.2 Stage 2

In this stage, the model was used to compare the costs per TEU for scenarios B1, C, D, E and scenario F. Table 12 includes all the inputs used to calculate the results for each scenario. As explained in Chapter 5, the column *"i"* contains the input values corresponding to the 18000 TEU ship, the column *"j"* corresponds to the input values for the 10000 TEU ship and the column *"k"* for the input values for the 13200 TEU ship.

Table 12 Model Data Stage 2

	Source of Result	Parameter/Description	*i (18000 TEU)*	*j (10000 TEU)*	*k (13200 TEU)*
A	Data	*fp: Fuel price in USD per metric ton*	620	620	620
B	Data	*fcs: Fuel consumption at sea in metric tons per day*	160	120	147
	Data	*fcb: Fuel consumption at berth in metric tons per day*			
C	Data	*tt1: Transit time in days FEA-PCW*	26	26	26
D	Data	*tt2: Transit time in days PCW-PCE*	1	1	1
E	Data	*tt3: Transit time in days PCE-ECSA*	13	13	13
F	(C+D+E)*2	*tti: Transit time in days (round trip)*	80	80	80

G	Data	*ocd: Operating cost per TEU per day according to the ship size*	1.05	1.2	1.15
H	Data	*C: Ship capacity in TEU*	18000	10000	13200
I	Data	*U: Utilization of the vessel, fixed at 85%*	0.85	0.85	0.85
J	Data	*THCfea: Terminal handling cost for FEA ports*	150	150	150
K	Data	*THCecsa: Terminal handling cost for ECSA ports*	132	120	120
L	Data	*pc: Panama Canal Toll for ship capacity*	74	74	74
M	Data	*pf: Panama Canal Toll for each full TEU*	8	8	8
N	Data	*pr: PCRC average toll per TEU*	194	194	194
P	Data	*%feb: Percentage of full containers in a vessel, fixed at 60% for the eastbound voyage*	0.6	0.6	0.6
Q	Data	*%fwb: Percentage of full containers in a vessel, fixed at 45% for the westbound voyage*	0.45	0.45	0.45

6.2.1 Scenario C: 18000 TEU + 10000 TEU through PCRC

Table 13 contains the results for Stage 2, Scenario C. From the table it can be depicted the total cost from FEA to ECSA, deploying 18000 TEU in the trip from FEA to PCW and a 10000 TEU vessel in the trip from PCE to ECSA, using the PCRC between PCW and PCE. The total cost for the round-trip is USD 1112.25 per TEU.

Table 13 Results Stage 2-Scenario C

	Source of Result	Parameter Description	Total Cost/TEU Scenario C (USD)
R	$((G_i*H_i*I_i*2*C_i)+(1.8*G_j*H_j*I_j*2*E_j))/ H_i$	OC	72.93
S	$((A_i*B_i*2*C_i)+(1.8*A_j*B_j*2*E_j))/ H_i$	FC	480.02
T	$((J_i*I_i*H_i)+(1.8*H_j*I_j*K_j))/ H_i$	THC	229.50
U	$((H_i*I_i*N_i)+(1.8*H_j*I_j*N_j))/ H_i$	Tollspcrc	329.80
TCpcrc per TEU RT	R+S+T+U	**TCpcrc per TEU**	1,112.25

6.2.2 Scenario D: 18000 TEU + 13200 TEU through PCRC

Table 14 contains the results for Stage 2, Scenario D, where it can be depicted the total cost from FEA to ECSA, deploying 18000 TEU in the trip from FEA to PCW and a 13200 TEU vessel in the trip from PCE to ECSA, using the PCRC between PCW and PCE. The total cost for the round-trip is USD 1095.96 per TEU.

Table 14 Results Stage 2-Scenario D

	Source of Result	Parameter Description	Total Cost/TEU Scenario D (USD)
R	$((G_i*H_i*I_i*2*C_i)+(1.36*G_k*H_k*I_k*2*E_k))/H_i$	OC	71.76
S	$((A_i*B_i*2*C_i)+(1.36*A_k*B_k*2*E_k))/H_i$	FC	465.62
T	$((J_i*I_i*H_i)+(1.36*H_k*I_k*K_k))/H_i$	THC	229.23
U	$((H_i*I_i*N_i)+(1.36*H_k*I_k*N_k))/H_i$	Tollspcrc	329.36
TCpcrc per TEU RT	R+S+T+U	**TCpcrc per TEU**	1,095.96

6.2.3 Scenario E: 18000 TEU PCRC

Table 15 contains the results for Stage 2, Scenario E, where it can be depicted the total cost from FEA to ECSA, deploying 18000 TEU for the complete voyage, using the PCRC between PCW and PCE. The total cost for the round-trip is USD 1068.98 per TEU.

Table 15 Results Stage 2-Scenario E

	Source of Result	Parameter Description	Total Cost/TEU Scenario E (USD)
R	$(G_i*H_i*I_i*(C_i+E_i)/H_i$	OC	69.62
S	$((A_i*B_i*(C_i+E_i)/H_i$	FC	429.87
T	$((J_i+K_i)*I_i*H_i)/H_i$	THC	239.70
U	$(H_i*I_i*N_i)/H_i$	Tollspcrc	329.80
TCpcrc per TEU RT	R+S+T+U	**TCpcrc per TEU**	1,068.98

6.2.4 Scenario F: 18000 TEU PC

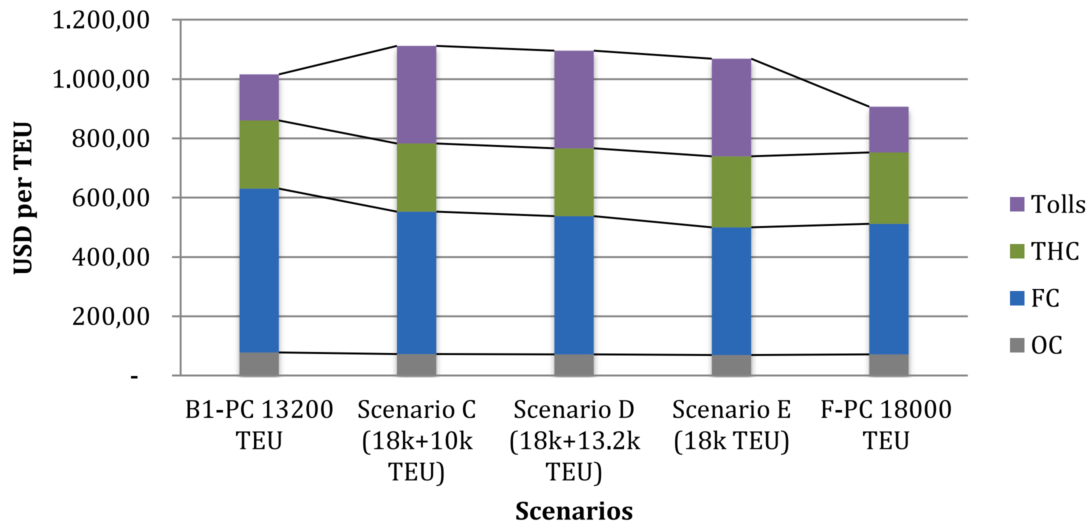
Table 16 contains the results for Stage 2, Scenario F, where it can be depicted the total cost from FEA to ECSA, deploying 18000 TEU for the complete voyage, using the PC. The total cost for the round-trip is USD 907.13 per TEU.

Table 16 Results Stage 2-Scenario F

	Source of Result	Parameter Description	Total Cost/TEU Scenario F (USD)
R	$(G_i*H_i*I_i*F_i)/H_i$	OC	71.40
S	$((A_i*B_i*F_i)/H_i$	FC	440.89
T	$((J_i+K_i)*I_i*H_i)/H_i$	THC	239.70
U	$((H_i*L_i)+(P_i*I_i*H_i*M_i))+(H_i*L_i)+(Q_i*I_i*H_i*M_i))/H_i$	Tollspc	155.14
TCpc per TEU RT	R+S+T+U	**TCpc per TEU**	907.13

Graph 11 presents the results gathered according to the model for each of the costs considered for these scenarios, in USD per TEU. As it can be depicted, the best alternative in this stage for shipping lines is the hypothetical situation presented in Scenario F, where a fourth set of locks in the Panama Canal was assumed to exist in which vessels of 18000 TEU are deployed for the whole voyage through the PC, allowing shipping lines to take full advantage of economies of scale, by achieving lower fuel consumption and operational costs per TEU.

Graph 11 Stage 2 Results-Total Costs per TEU



Source: Own Elaboration based on model results

6.3 Best Scenario for Shipping Lines

As mentioned previously, the quantitative part of this research was divided in two stages, each of them containing different scenarios. According to the model, for stage 1 the best alternative is to deploy vessels of 13200 to transit through the Panama Canal Expansion, since these allow shipping lines to reduce around 23% the total costs per TEU. This is mainly due to the fact that the Panama Canal Railroad tolls namely the transhipping costs in the ship to-rail-to ship model, make the cost per TEU more expensive when compared to crossing the Panama Canal. The benefits are enhanced when a 13200 TEU vessel is deployed versus a 4000 TEU due to the savings in operational and fuel costs per TEU arising from the principle of economies of scale.

Moreover, for stage 2, the best alternative is to deploy UCLVs of 18000 TEU through the Panama Canal for the round-trip from FEA to ECSA, in spite of the 10%-increase assumption in the handling rates in ECSA ports, considering the fact that these ports would need to invest in updating their infrastructure. In this scenario, shipping lines would be able to reduce its cots per TEU in about 31% when compared to crossing the PC with a 4000 TEU vessel (presented in Scenario A1), and about 18% when compared to scenario C in which the PCRC is used jointly with a 10000 TEU vessel in the PCE-ECSA leg, this last being the least cost-efficient according to the model. This, obviously, is assuming that the Panama Canal Authority builds an additional set of locks that enables the transit of these 18000 TEU vessels. Nevertheless, neglecting this hypothetical scenario, the best alternative in terms of costs remains within the PC, deploying 13200 TEU vessels as presented in Scenario B1.

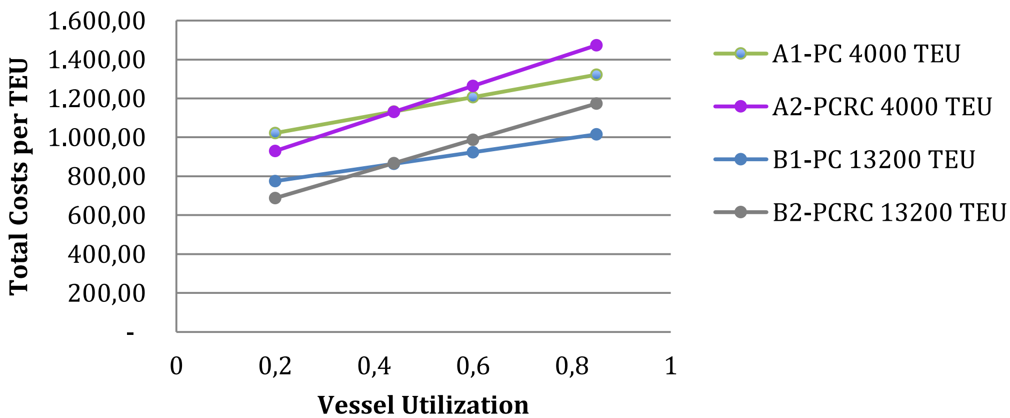
As presented in Graph 11, the scenario F is the best alternative mainly due to the lower tolls, operational and fuel costs per TEU achieved through economies of scale. This will remain true as long as the Panama Canal Authority decides to build a new Panama Canal with greater capacity. The second best alternative is scenario B1, followed by scenario E, then scenario D and the last one, which is scenario C. It is important to highlight that these results are driven by the robustness of the principle of economies of scale, wherein the costs per TEU-slot are greatly reduced when bigger vessels are deployed.

6.4 Sensitivity Analysis

The purpose of this sub-chapter is to evaluate and analyse the impact in the output of the model due to possible changes in the input variables, taking into account that maritime transportation, shipping, trade and international economic activities exist in a constant changing environment. In other words, this sub-chapter studies the effects in the model results that may arise from uncertainty in the inputs. For the first stage, the sensitivity analysis answers the following questions:

What happens if the vessel utilization varies for both scenarios?

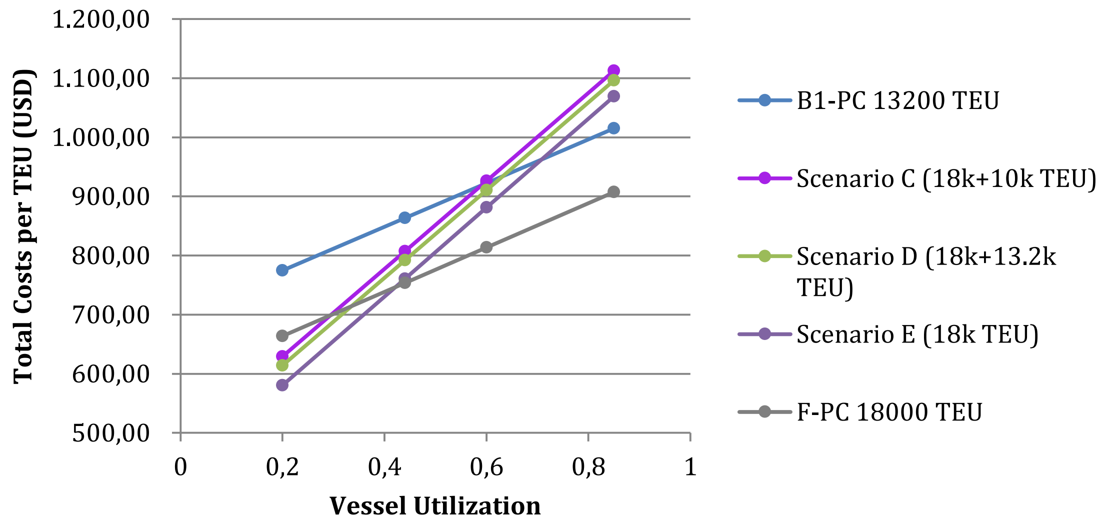
Graph 12 Stage 1: TC per TEU varying vessel utilization



Source: Own Elaboration based on model results

For Stage 1, if the vessel utilization increases, the PC remains the best alternative for both vessel sizes. However, as presented in Graph 12, when the vessel utilization drops to 44%, the PCRC becomes a better alternative in terms of costs per TEU for the 4000 TEU vessel. If the vessel utilization drops further to 42% then the PCRC becomes a better alternative for both vessel sizes. This is mainly due to the fact that when the vessel utilization is low, the OC and FC per TEU are higher when sailing through the PC, as well as the tolls, since the transhipment costs are based on the amount of TEUs handled.

Graph 13 Stage2: TC per TEU varying vessel utilization



Source: Own Elaboration based on model results

For Stage 2, if the vessel utilization increases it is still better to cross the Panama Canal with an 18000 TEU vessel or with a 13200 TEU vessel. However, if the vessel utilization drops to 70%, instead of crossing the PC with a 13200 TEU, the best alternative would be to use the land-bridge transhipment through PCRC with an 18000 TEU vessel for the complete voyage. This is due to the OC and FC per TEU for the extra day of sailing through the PC. Moreover, if the vessel utilization drops further to 44%, then the best alternative would be the land-bridge transhipment through PCRC with the 18000 TEU. This is mainly due to the fact that if the vessel utilization is not high, the benefits from economies of scale through the PC are decreased, resulting in higher FC, OC and even tolls per TEU. These sensitivity analysis' results are presented in Graph 13.

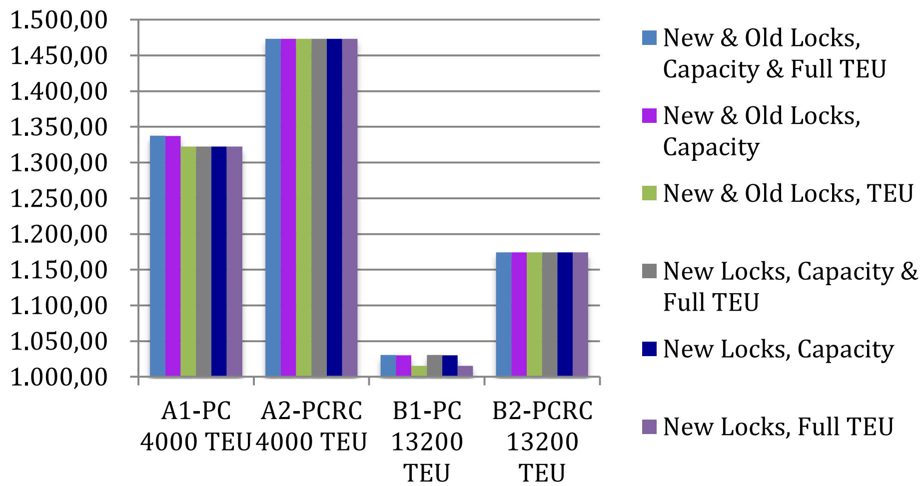
What happens if the Panama Canal toll varies per capacity, per full TEU or for both?

As mentioned in chapter 4.3.2, previous studies have estimated an increase of 3.5% per year in the tolls, which leads to an estimate of 15% of increase from 2011, the last year of toll revisions in the containership segment, until 2015. For this study, the increase rates in tolls will be assumed to be of 10%, 15% and 25%, to study a conservative scenario, an expected scenario and an ambitious scenario. For each of these rates, the sensitivity analysis will be conducted first assuming an increase in the toll per capacity plus the toll per full TEU, then an increase just in the toll per capacity and finally an increase just in the toll per full TEU. These three possibilities of toll increase will be evaluated first, in both set of locks, the old one for the passage of up to

4000 TEU and the new locks for 13200 TEU and second, just in the new locks for the 13200 TEU. This means that for each of the rate increases, 10%, 15% and 25%, six combinations of scenarios will be evaluated that will be: 1) New & Old Locks, Capacity & full TEU; 2) New & Old Locks, Capacity; 3) New & Old Locks, Full TEU; 4) New Locks, Capacity & Full TEU; 5) New Locks, Capacity; 6) New Locks, Full TEU.

Graph 14 presents the results in total costs per TEU, for each of the six combined alternatives for the 10 % toll increase scenario.

Graph 14 Sensitivity Analysis Stage 1: TC per TEU for 10% increase in PC Tolls

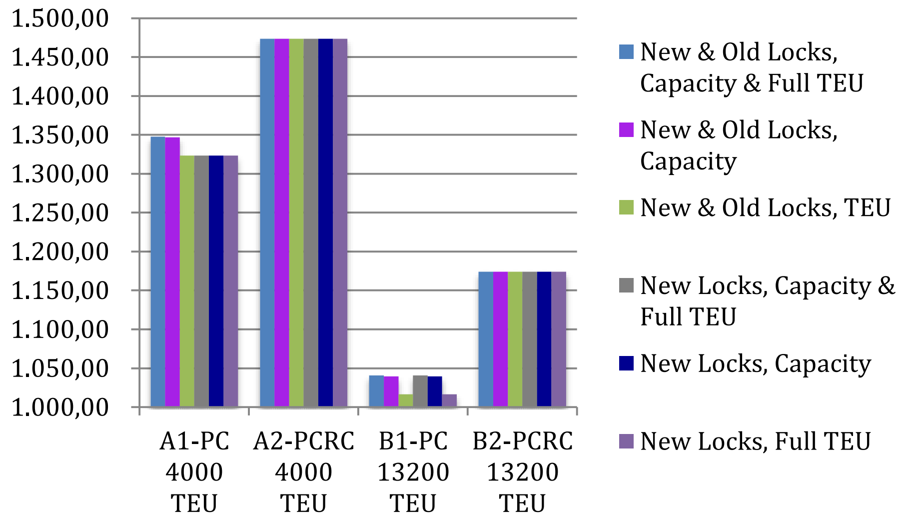


Source: Own Elaboration based on sensitivity analysis model results

From the graph, it can be seen that in spite of the 10% increase in the PC tolls, this route remains as the best choice from a costs per TEU perspective, for both vessel sizes, regardless if the increase is per capacity, per TEU, or for both new locks and old locks.

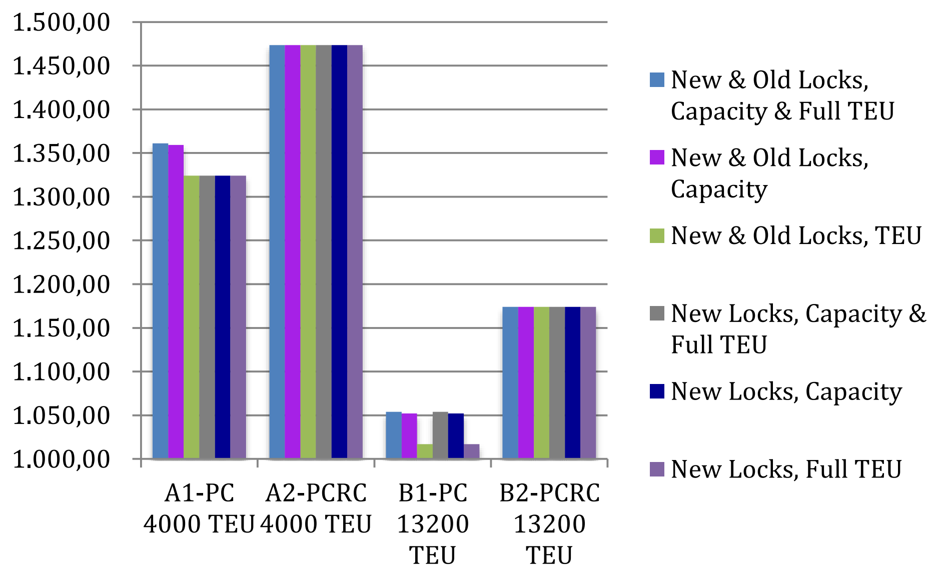
Graph 15 and Graph 16 presents the results in total costs per TEU, for each of the six combined alternatives for the 15 % and 25% toll increase scenario, respectively. Similar to the results in Graph 14, for these percentages increase the PC route is still the best alternative for the 4000 TEU and the 13200 TEU vessels. This means that the transhipment cost per TEU exceeds the PC tolls per TEU to such an extent that not even an increase of 25% in the current tolls influences the results in terms of TEU. However, this will remain true as long as the vessel utilization is high, as was previously analysed.

Graph 15 Sensitivity Analysis Stage 1: TC per TEU for 15% increase in PC Tolls



Source: Own Elaboration based on sensitivity analysis model results

Graph 16 Sensitivity Analysis Stage 1: TC per TEU for 25% increase in PC Tolls

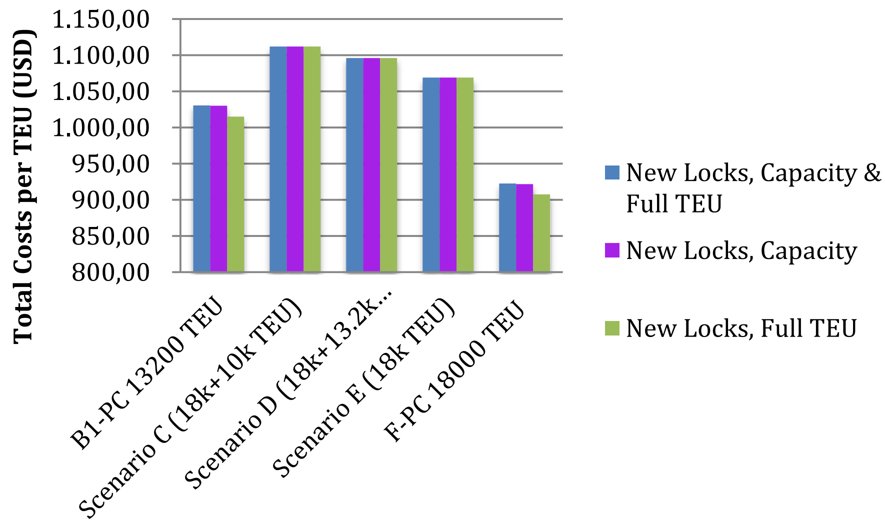


Source: Own Elaboration based on sensitivity analysis model results

Conversely for Stage 2, the same sensitivity analysis was performed but for this stage just studying the variation in the total costs per TEU assuming PC tolls increase just in the new locks. In other words, just evaluating the 10%, 15% and 25% for the locks that will allow the transit of 13200 TEU vessels. Graph 17, Graph 18 and Graph 19 presents the results of the total costs per TEU assuming PC tolls increases of 10%, 15% and 25% respectively. From the graphs it can be depicted that for all the cases, the transit through the PC is the best alternative, whether it is with a 13200 TEU vessel or with an

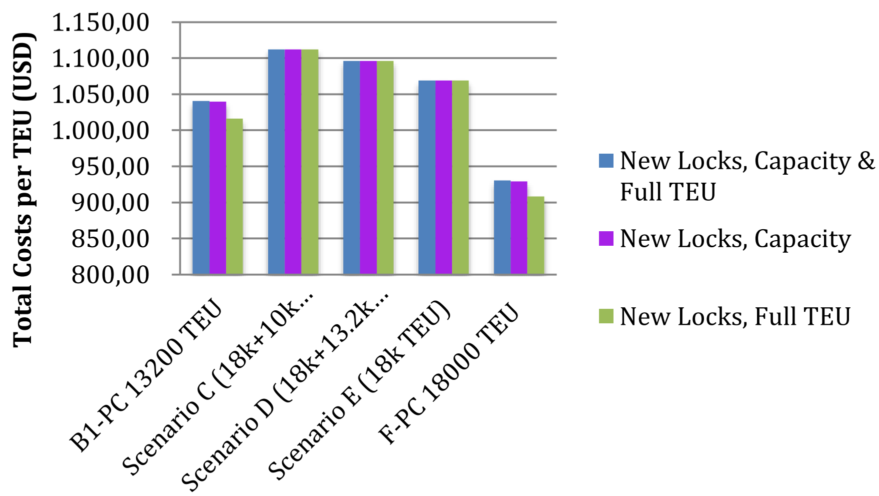
18000 TEU vessel. As mentioned previously, this is mainly due to the significantly higher costs per TEU to tranship containers through the land-bridge model.

Graph 17 Sensitivity Analysis Stage 2: TC per TEU for 10% increase in PC Tolls



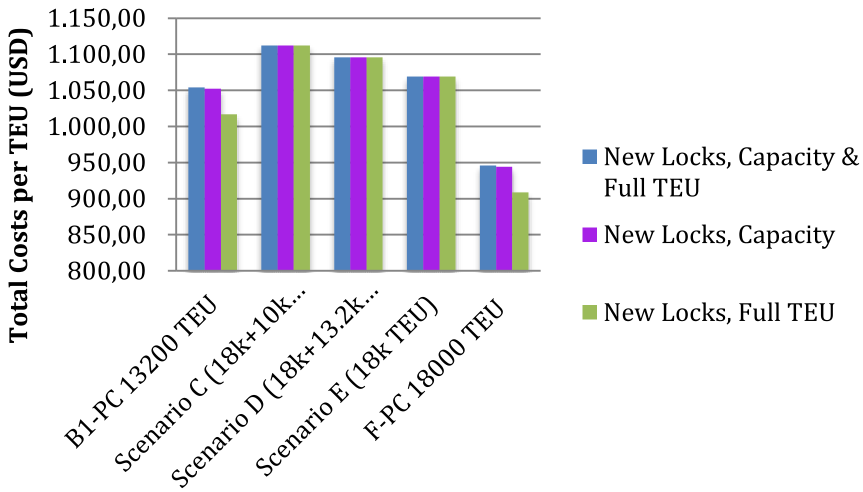
Source: Own Elaboration based on sensitivity analysis model results

Graph 18 Sensitivity Analysis Stage 2: TC per TEU for 15% increase in PC Tolls



Source: Own Elaboration based on sensitivity analysis model results

Graph 19 Sensitivity Analysis Stage 2: TC per TEU for 25% increase in PC Tolls

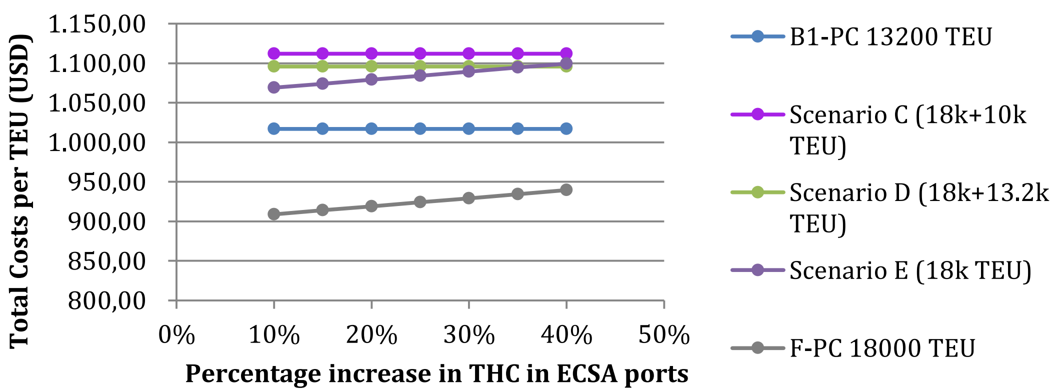


Source: Own Elaboration based on sensitivity analysis model results

What happens if THC increases further in stage 2?

For Stage 2, the main assumption that should be tested is that an increase in the THC of ECSA ports was assumed due to the significant investments that these ports would have to make to upgrade their facilities and infrastructure in order to operate UCLVs of 18000 TEUs. Thus, the sensitivity analysis will focus on how much expensive for shipping lines should the THC in ECSA ports become in order to favour scenario D as the preferred alternative.

Graph 20 Sensitivity Analysis Stage 2: Increase in THC in ECSA ports



Source: Own Elaboration based on sensitivity analysis model results

As presented in Graph 20, THCs should increase at least 40% before scenario D becomes a better alternative compared to scenario E. These results are focused on the scenarios where the PCRC is deployed, since regardless of the increase in ECSA THC, the PC is still a better alternative.

Chapter 7 Conclusions

The Panama Canal expansion will enable the passage of ships of up to 13200 TEU, which will allow container shipping lines to deploy bigger vessels whilst taking advantage of economies of scale. This also means that shipping lines will have an additional routing alternative to consider, especially for the trans-pacific trade from Asia to the East Coast of North America, South America and the Caribbean. More specifically, this research evaluated the trade-off that shipping lines will have post-Panama Canal expansion, concerning their current transhipment operations through Panama via the Panama Canal Railroad Company versus the possibility to cross the canal deploying bigger vessels. As presented in the previous chapter, the results of the research indicated that for the Stage 1, whether shipping lines decide to deploy vessels of 4000 TEU or 13200 TEU, it is better to route their vessels through the Panama Canal. The main reason behind this result is the fact that the transit through the Panama Canal results in lower costs per TEU in the tolls, compared to the tolls through the land-bridge transhipment, namely the transhipment and handling costs incurred per TEU when using the PCRC. Moreover, the widened Panama Canal will lead to a decreased in the total costs per TEU of 23% if a 13200 TEU vessel is deployed instead of a 4000 TEU, thus the benefits of economies of scale in operational and fuel costs are enhanced through the Panama Canal route. For Stage 2, the results gathered from the model indicated that in a future scenario, if the Panama Canal Authority decides to build a fourth set of locks that enables the passage of UCLVs and if the market conditions are favourable meaning that there will be enough demand and cargo to fill vessels of up to 18000 TEU then the best alternative will be to deploy UCLVs through the Panama Canal, mainly because the costs per TEU are lower based on the principle of economies of scale. If shipping lines could deploy UCLVs through the Panama Canal instead of the future maximum capacity allowed of 13200 TEU, then the savings in total costs per TEU are estimated to be around 11%, an extra decrease in the costs that would definitely attract shipping lines towards the PC all-water route. The model also indicated that this result is true even though ECSA ports increase their handling fees to recover the significant investment costs that they would need to incur to be able to handle UCLVs.

Furthermore, after conducting the sensitivity analysis in which different values were considered to evaluate uncertainty in the input variables, the main conclusions derived in regards to the effects that the cost-performance of the Panama Canal versus the Panama Canal Railroad will have on shipping lines are that first, in order for the Panama Canal to be the preferred alternative the vessel utilization has to be high, otherwise PCRC would become a better alternative. Second, assuming enough cargo is materialized from FEA to ECSA market, the Panama Canal tolls will have little influence in the total costs per TEU, since the transhipment costs per TEU are about twice the Panama Canal tolls. Therefore, the PC tolls would have to be doubled before the PCRC becomes a better alternative. However, it is important to highlight that the major effects were registered when tolls increased per capacity rather than per full TEU, and also when tolls increased just for the new set of locks, maintaining the current level tolls for the old locks. This is of special importance since it indicated that there are several strategies that the Panama Canal could hold to structure its new tolls into a “win-win” situation, for the Canal and for the shipping lines. Last but no least, an important remark of the effects in the liner shipping operations in Panama is that, even though the Panama Canal results as the best alternative for the transport of cargo from FEA to ECSA, the PCRC could represent a competitor for the Panama Canal, and if shipping lines continue operating through this land-bridge transhipment, then the possibilities that Panama grows and develop further as a hub in the Pacific and in the Atlantic increases, since both sides of the Isthmus could serve as transhipment centres were cargo could be consolidated and transported through the PCRC.

7.1 Limitations of the Research

This research focused on the study of extreme scenarios, in which for the first stage, shipping lines deploy vessels with the maximum size and capacity that the current and the new locks´ dimensions will allow and for the second stage, the extreme assumption that shipping lines will deploy the current biggest vessels available in the market, namely 18000 TEU containerships. This last assumption was constructed under the basis that in a future scenario there will be enough cargo to fill the ships in the Asia-Latin America market. As previously mentioned, this research does not evaluate a scenario in which vessels could call the Panama Canal for half-voyage and the PCRC for the other half-voyage, which could be interesting to analyse in terms of costs as well. One of the most determinant limitations that could be mentioned is the fact that costs as capital costs or depreciation costs were not taken into account, as well as the cost of time. This last one is very important to clarify, since for this particular system, despite the PCRC has the capability of transporting containers within 5 hours from the East to the West and vice versa, these containers usually stay in the terminal yards for an average of 3 to 5 days until the connection vessel arrives, which could represent extra storage costs and port dues. In addition to this, the total costs were calculated from a shipping line´s perspective, which means that any inventory costs that could be extremely important when developing this type of study from a supply chain´s perspective were neglected. In regards to the data collection, it is important to highlight that most of the data gathered are based on estimations that could vary, which means that some of the input data used for the calculations in the cost model have a degree of uncertainty. Even though a sensitivity analysis was performed to manage the uncertainty in the variables, results should be considered as estimations that not necessarily offers and exact representation of the real systems, when considering all the aforementioned limitations of the research.

7.2 Recommendations for Future Research

The current research serves as the basis to develop further research, especially considering all the limitations previously mentioned, which are good and clear opportunities to enhance and enrich this study. The first recommendation for further research is to include the cost of time and storage incurred per TEU when the land-bridge transhipment is executed. This will allow a more realistic comparison of the PC versus the PCRC from a cost perspective. The second recommendation is to develop the analysis from a supply chain perspective rather than a shipping line perspective. By doing so, the costs for shippers are also taken into account, which could lead to better competitiveness, better customer experience and overall maximization of profits. A final recommendation is to incorporate intermediate scenarios to the research in which both routes, PC and PCRC are combined together to develop network designs in which the total costs per TEU could be potentially lower. It has to be taken into account that there are still wide ranges of possibilities that shipping lines would have to evaluate after the completion of the Panama Canal Expansion. Considering that the advantages of economies on scale in the costs per TEU are robust, crossing the Panama Canal with vessels of up to 13200 TEU could be the best alternative for shipping lines if the costs per TEU are attractive for an interesting combination of port call as FEA/ECSA/CAR or FEA/CAR/USEC.

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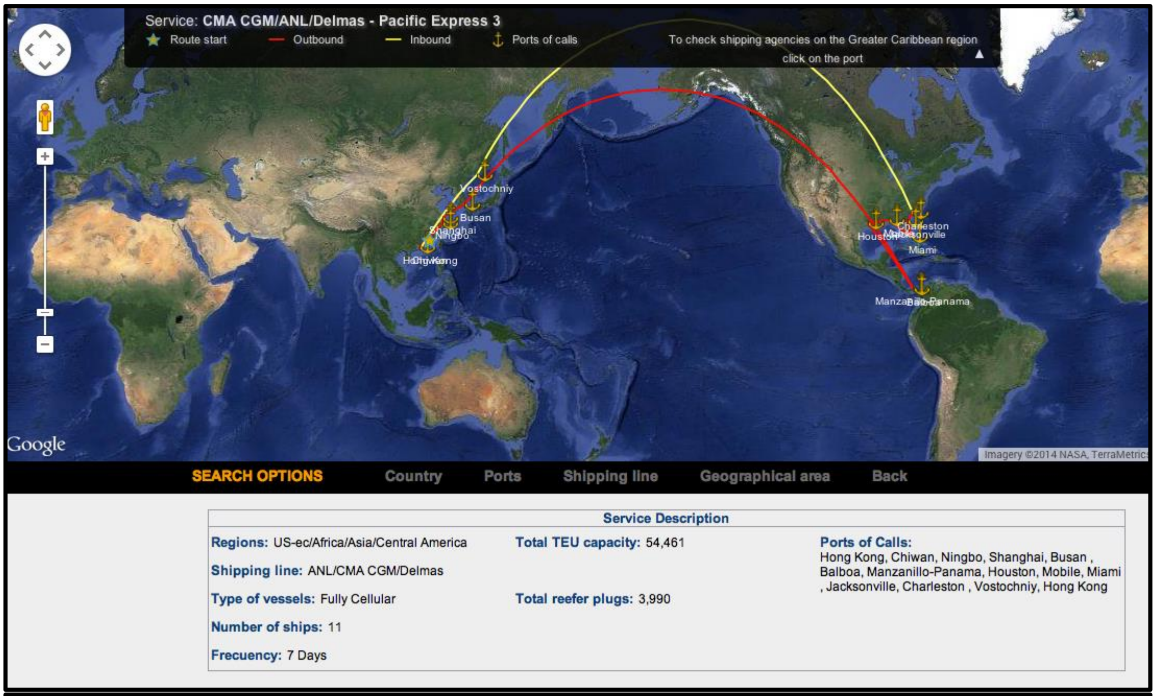
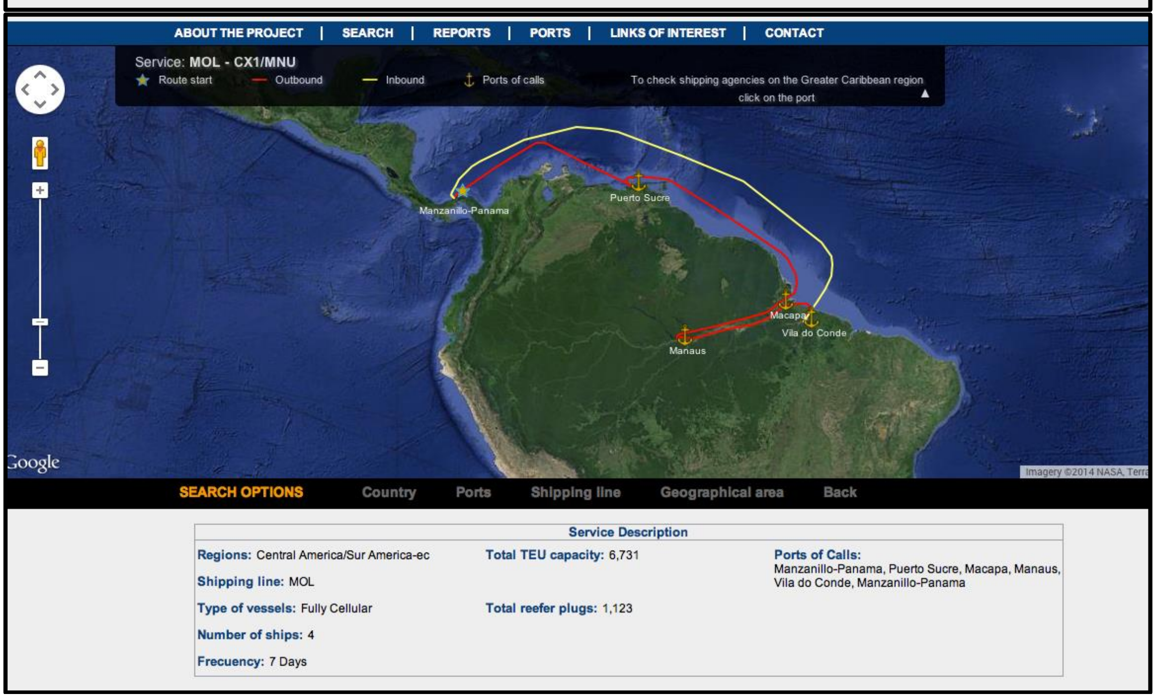
Appendices

Appendix A. Services through Panama Canal-Top 5 Shipping Lines

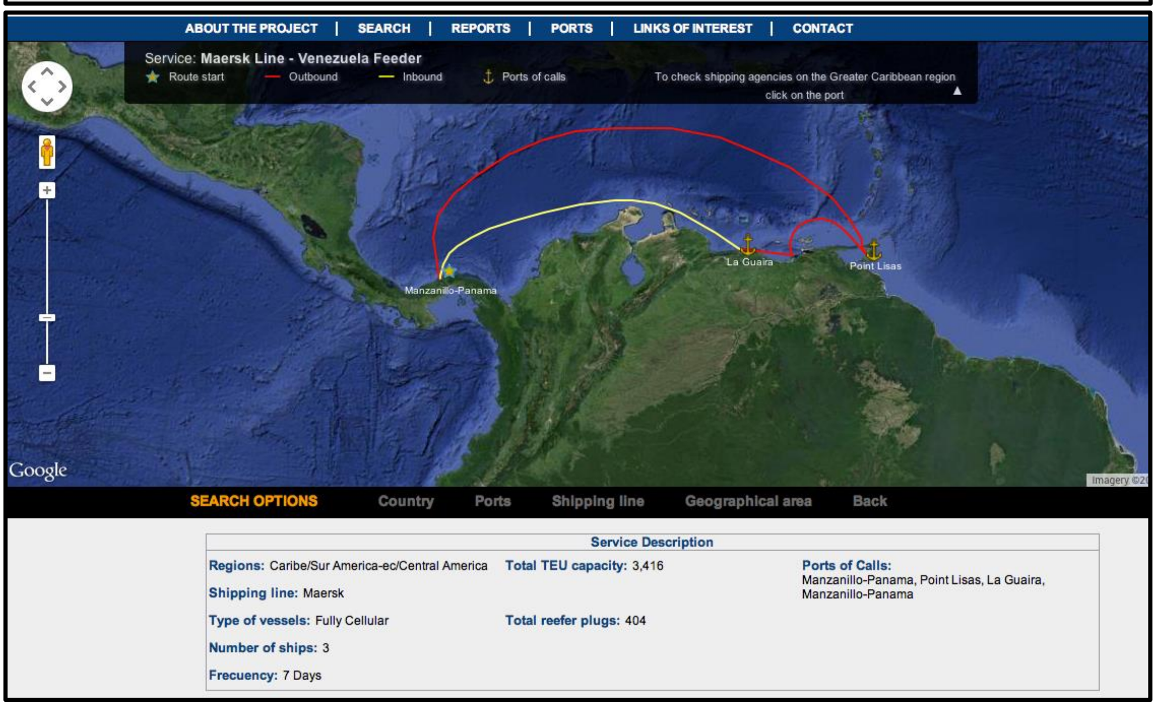
Shipping Line	Service	No. Transits 2012
Maersk Line	Oceania America Service (OC1)	572
	Ecuador Banana Express (ECUBEX)	
	Ecuador Mediterranean (ECUMED)	
Mediterranean Shipping Company MSC	North West Continent to WCSA (Northbound and Southbound)	387
	USA to WCSA (Northbound and Southbound)	
	Caribbean	
	South America East Coast	
Hapag-Lloyd	North and Central China East Coast Express (NCE)	301
	New York Express (NYE)	
	Pacific Atlantic (PA1)	
	South China Express (SCE)	
	Australia-New Zealand via Panama (ANP)	
	Mediterranean Pacific Service (MPS)	
	Chile-Peru Express (SW1)	
	Caribbean-Ecuador Service (SW2)	
Evergreen	North Asia-USEC (NUE)	301
	North Asia-USEC (NUE 2)	
	Gulf of Mexico Express (GME)	
	Panama West Coast of South America (PWS)	
CMA-CGM	Atlanta Bridge (ECUSA-WCSA)	199
	Manhattan Bridge (China-USEC)	
	Pacific East Coast 2 (PEX2)	
	Pacific Express 3 (PEX3)	
	Panama Direct Line (RTWPAN)	
	Panama Direct Line 2 (PANAMA2)	
	West Coast Chile Eurosal Sling 1 (WCC)	
	West Coast Venezuela Eurosal Sling 2 (WCV)	

Appendix B. Network Configurations: Panama as a Hub in the Pacific and Atlantic complementing its services through PCRC

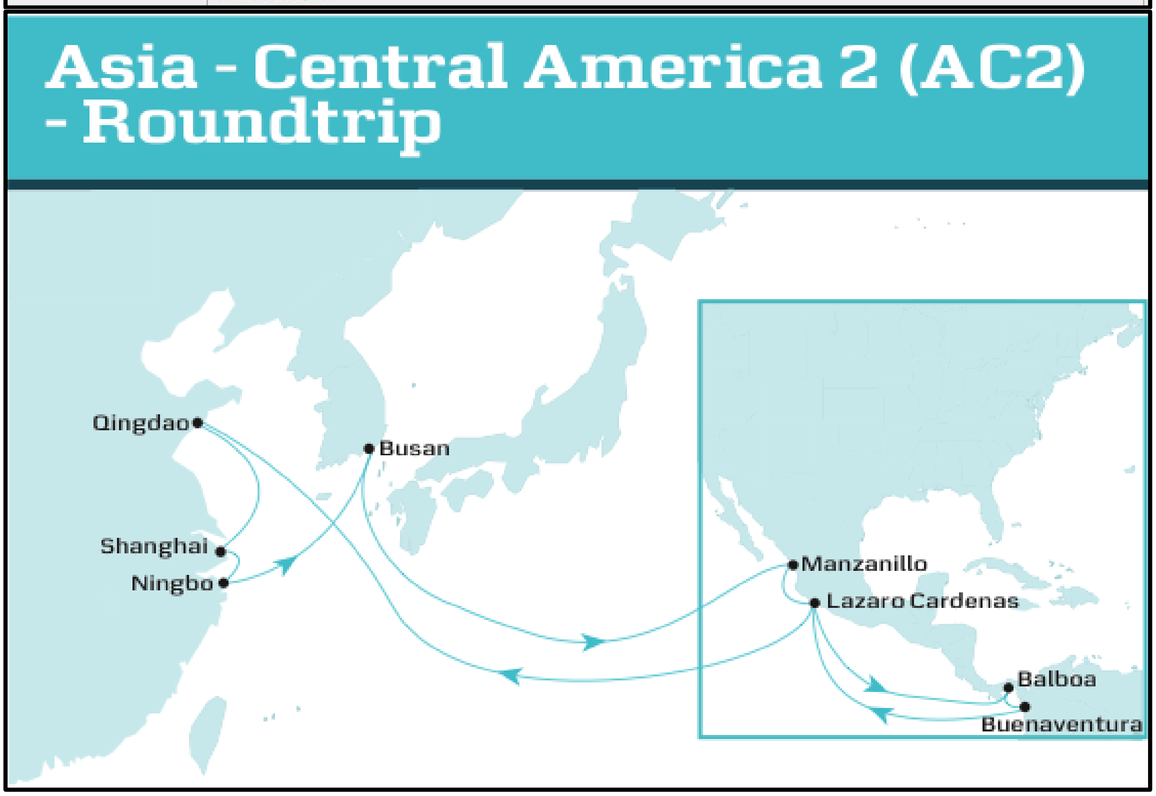


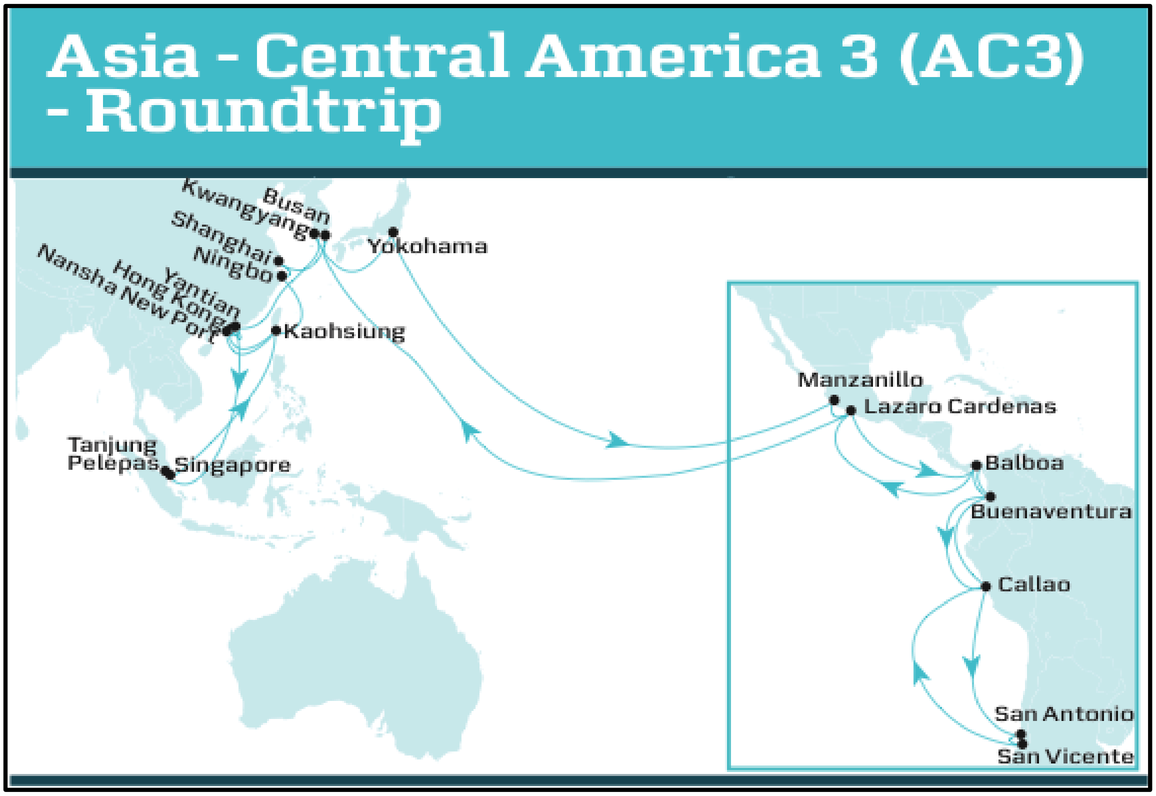



ABOUT THE PROJECT | SEARCH | REPORTS | PORTS | LINKS OF INTEREST | CONTACT
Service: CMA CGM/Delmas - Brazil Express
Route start
Outbound
Inbound
Ports of calls
To check shipping agencies on the Greater Caribbean region click on the port
Kingston
Cartagena
Manzanillo-Panama
Port of Spain
Manaus
Vitoria
Rio de Janeiro
Santos
Paranagua
Itajai
Rio Grande
Google
SEARCH OPTIONS
Country
Ports
Shipping line
Geographical area
Back
Service Description
Regions: Caribe/Sur America-ec/Central America
Total TEU capacity: 16,279
Ports of Calls:
Suape, Vitoria, Zarate, Buenos Aires, Montevideo, Rio Grande, Itajai, Paranagua, Santos, Rio de Janeiro, Salvador, Port of Spain, Cartagena, Manzanillo-Panama, Kingston, Manaus, Suape
Shipping line: CMA CGM/Maersk/Delmas
Type of vessels: Fully Cellular
Total reefer plugs: 2,936
Number of ships: 9
Frecuency: 7 Days


ABOUT THE PROJECT | SEARCH | REPORTS | PORTS | LINKS OF INTEREST | CONTACT
Service: Maersk Line - Venezuela Feeder
Route start
Outbound
Inbound
Ports of calls
To check shipping agencies on the Greater Caribbean region click on the port
La Guaira
Point Lisas
Manzanillo-Panama
Google
SEARCH OPTIONS
Country
Ports
Shipping line
Geographical area
Back
Service Description
Regions: Caribe/Sur America-ec/Central America
Total TEU capacity: 3,416
Ports of Calls:
Manzanillo-Panama, Point Lisas, La Guaira, Manzanillo-Panama
Shipping line: Maersk
Type of vessels: Fully Cellular
Total reefer plugs: 404
Number of ships: 3
Frecuency: 7 Days


ABOUT THE PROJECT | SEARCH | REPORTS | PORTS | LINKS OF INTEREST | CONTACT
Service: MSC - Manaus Pecem Express
Route start
Outbound
Inbound
Ports of calls
To check shipping agencies on the Greater Caribbean region click on the port
Houston
Cristobal
Port of Spain
Manaus
Vila do Conde
Pecem
Santos
Navegantes
Google
SEARCH OPTIONS
Country
Ports
Shipping line
Geographical area
Back
Service Description
Regions: US-ec/Caribe/Sur America-nc/Central America
Total TEU capacity: 16,149
Ports of Calls: Houston, Cristobal, Port of Spain, Manaus, Navegantes, Santos, Pecem, Vila do Conde, Cristobal, Houston
Shipping line: MSC
Type of vessels: Fully Cellular
Total reefer plugs: 1,901
Number of ships: 7


Asia - Central America 2 (AC2) - Roundtrip
Qingdao
Busan
Shanghai
Ningbo
Manzanillo
Lazaro Cardenas
Balboa
Buenaventura



Appendix C. Terminal Handling Charge Levels for FEA-Panama-ECSA ports

Central America, South America and Caribbean

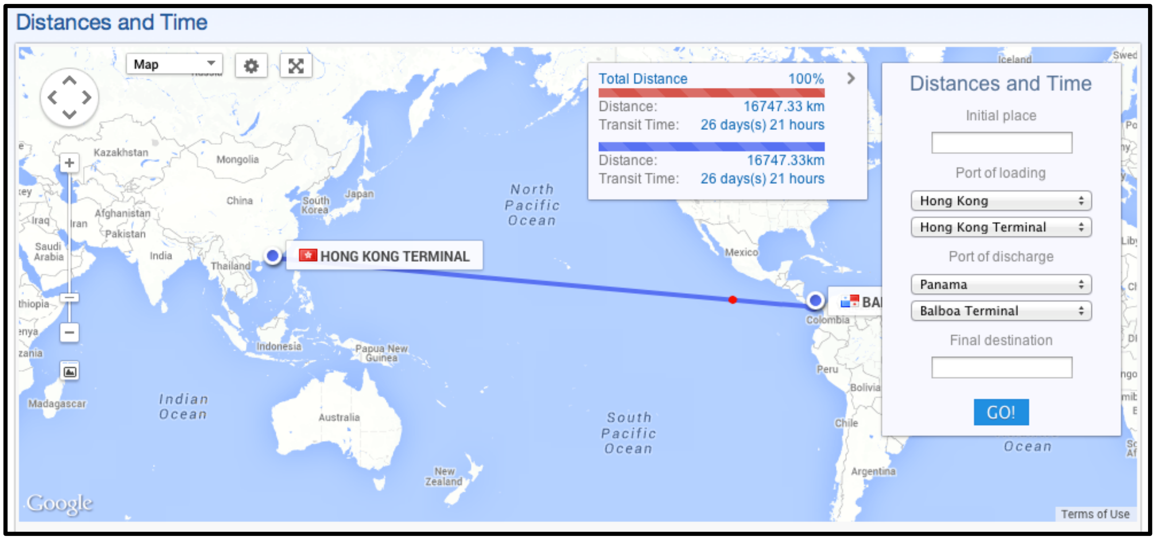
Argentina									
Buenos Aires	USD	165		215		185		215	No change
Rest of Argentina	USD	195		360		225		360	
Brazil (Capatazia)									
Pecem	BRL	310		376		310		376	
Itajai	BRL				420				
Sao Francisco do	BRL				390				
Suape	BRL		445				463		
Manaus	BRL				425				
Paranagua	BRL				450				No change
Rio Grande	BRL				400				
Sepetiba	BRL				215				
Salvador	BRL			375				435	
Santos	BRL	430		460		430		460	
Vila Do Conde	BRL	430		490		430		490	
Vitoria	BRL	380		400		380		400	
Panama									
Intra-America trades	USD		75				100		15 January, 2009
All other trades	USD		200				225		
Colombia - Import	USD				90				15 January, 2009
Venezuela	USD				100				15 January, 2009

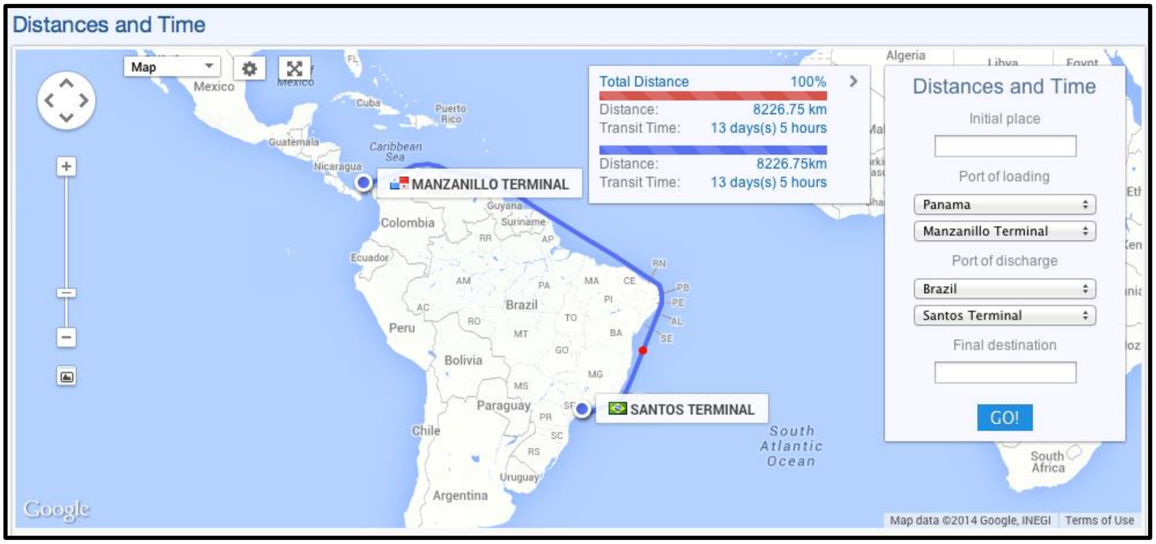
Global Maersk Line Terminal Handling Charge (THC) levels

MAERSK LINE

Country	Currency	Container type / size 20' Dry	20' Reefer	40'/45' Dry	40'/45' Reefer	Effective date
Far East Asia						
Brunei	BND	190	240	270	350	15 January, 2009[2]
Cambodia	USD	80		115		15 January, 2009[2]
China						
Hong Kong	HKD	2,050	2,675	2,750	3,550	
South (Provinces Hainan to Guangdong excluding Hong Kong) - only Europe Trades	USD	140		270		15 January, 2009[3]
South (Provinces Hainan to Guangdong excluding Hong Kong) - all trades except Europe and Transpacific						
Rest of China	RMB	475		750		
Indonesia		No change				No change
Japan						
Europe/Mediterranean (Imp/Exp), Middle East/India/Pakistan (Imp/Exp), Africa (Exp), Central America/Caribbean (Exp), Australia and New Zealand (Exp)	JPY	24,000	34,500	35,000	45,500	From 1 July, 2009
Import from Central America/Caribbean (except Mexico) and Africa	JPY	24,000	16,800	35,000	23,950	
Import from Australia and New Zealand	JPY	24,000	24,500	35,000	33,500	
Import from Mexico	JPY	24,000	27,300	35,000	37,700	
Import/Export USA and Canada	JPY	21,000	27,300	29,000	37,700	
South Korea	KRW	100,000	210,000	140,000	290,000	15 January, 2009[2]
Malaysia						
Penang and Port Klang	MYR	340		500	700	15 January, 2009[2]
Others (Kuantan, Tanjung Pelepas and East Malaysia)	MYR	300		450	650	
Philippines	USD	110	140	120	160	15 January, 2009[2]
Singapore	SGD	190	240	270	350	15 January, 2009[2]
Taiwan	TWD	5,800	7,600	7,000 (40') 8,500 (45')	8,800	1 April, 2009[2]
Thailand	THB	2,600	3,150	3,900	5,000	1 February, 2009[2]
Vietnam	USD	76		114		15 May, 2009 (Non-FMC)[2] 16 May, 2009 (FMC)[2]

Appendix D. Transit Times Calculations for FEA-PCW-PCE-ECSA





Distances and Time
Map
Total Distance
100%
Distance:
8226.75 km
Transit Time:
13 days(s) 5 hours
Distance:
8226.75km
Transit Time:
13 days(s) 5 hours
MANZANILLO TERMINAL
SANTOS TERMINAL
Mexico
Cuba
Puerto Rico
Guatemala
Nicaragua
Caribbean Sea
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Chile
Uruguay
Argentina
South Atlantic Ocean
South Africa
Algeria
Distances and Time
Initial place
Port of loading
Panama
Manzanillo Terminal
Port of discharge
Brazil
Santos Terminal
Final destination
GO!
Google
Map data ©2014 Google, INEGI
Terms of Use