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The Expansion of the Panama Canal

A study of consequences in the container shipping industry

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Abstract

The Panama Canal has become a constraining factor on trade across the Pacific and Atlantic Ocean, and the expansion of the Canal is expected to have a positive influence on world trade. Our research investigates the competitiveness of the Panama Canal in the container shipping industry and the possible macroeconomic consequences of the canal expansion.

We have designed a model that compares costs and earnings for single voyages and round-trips, and with a basis in opportunity cost theory we compare the Panama Canal with alternative routes and analyze the sensitivity of key variables for different scenarios. From our analyses we see that the current bunker price forces vessels to slow-steam to maintain profits. This has led shipowners to prioritize cost savings at the expense of fewer annual voyages. Simultaneously, operators in the container industry are constantly seeking to exploit large-scale advantages and we find strong evidence that the unit cost and the size of vessels are inversely proportional. This has led to a relentless upsizing of container vessels, and our calculations suggest that the expanded Panama Canal will face competition from the Ultra-Large Container Vessel segment. Further, our findings suggest that the current Panama Canal toll system with a constant price per TEU transited will not be applicable when opening for Post-Panamax vessels. Therefore, the Panama Canal toll system should be adjusted to facilitate for economies of scale in order for the Canal to stay competitive with alternative routes.

As the world shipping market is still adjusting after the financial crisis in 2008, the expansion comes at an interesting point in time and the possible consequences are multidimensional. Our research suggests that the effects can be both positive and negative for shipowners depending on whether the expansion leads to an increase in tradable volume or a shift in existing trade.

Preface

Sharing a mutual interest for shipping, we started our work by assessing current topics of interest within the shipping industry. The study of the expansion of the Panama Canal gave us the opportunity to investigate consequences for both shipowners and for world commercial container shipping in general. Writing the thesis has been demanding, interesting and a great learning experience, and we are thankful for the possibility to explore aspects of such a significant event as the expansion of the Panama Canal.

We would like to thank our supervisor, Siri Strandenes Pettersen, for answering important questions and giving valuable feedback, as well as providing critical reviews throughout the process. A rightful thank to Terje Winther and Mads Bjørnerem from Grieg Star for providing useful information regarding their operations and use of the Panama Canal, and for allowing us to use this in our research. We would also like to thank the SHIPpers association at the Norwegian School of Economics for the support and funding of our thesis.

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List of Abbreviations

Abbreviations in order of appearance in the thesis:

ACP	Autoridad del Canal de Panamá (Panama Canal Authorities)
PC/UMS	Panama Canal Universal Measurement System
TEU	Twenty-foot Equivalent Unit
JIT	Just-in-Time
CWT	Canal Waters Time
ITT	In Transit Time
GUPC	Grupo Unidos por el Canal
AIS	Automatic Identification System
ULCV	Ultra-Large Container Vessel
MSC	Mediterranean Shipping Company
CSCL	China Shipping Container Lines
UASC	United Arab Shipping Company
DWT	Deadweight Tonnage
FEU	Forty-foot Equivalent Unit
SCA	Suez Canal Authorities
NY/NJ	New York/New Jersey
VLCC	Very-Large Crude Carrier
TCE	Time-Charter Equivalent
VLCV	Very-Large Container Vessel
USEC	U.S. East Cost
CMA CGM	Compagnie Maritime d'Affrètement/Compagnie Générale Maritime
CEO	Chief Executive Officer
IMO	International Maritime Organization

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1 Introduction

The Panama Canal connects the Atlantic Ocean with the Pacific, and has been a major shipping route over the last 100 years, ensuring trade possibilities between East and West. During the last years the Canal has become a constraining factor as the size and number of ships have grown exponentially. Shipbuilders have built vessels with specifications so accurate that they fit the Canal with a margin of only a few feet, pushing the limits for what is possible to bring through the Canal. However, with the increasing focus on cost saving, container-shipping companies operates with larger ships to exploit economies of scale and seek alternative routes to evade the constraining Panama Canal.

In 2006 the government of Panama decided to expand the Canal. The expansion is set to finish in December 2015, and there are many uncertainties regarding the impact of the expansion on current trade volumes and trade flows. One question is how this will affect the competition between the Panama Canal, the Suez Canal and other routes, and if the competition will increase on the Asia - U.S. East Coast trade line once the Panama Canal is able to accommodate larger vessels. Another interesting aspect is what the decisive factors will be when shipowners choose which route to sail. Further, the Panama Canal Authority has yet to unveil their new toll system for the expanded canal. These are some of the aspects we wish to discuss further in our thesis.

With a basis in opportunity cost theory, we will compare the costs for the different route alternatives to assess the competitiveness of the Panama Canal. We will perform an analysis based on scenarios before and after the Panama Canal expansion. Further, we will look at different round-trip scenarios to identify the consequences related to the trade-off between sailing time and voyage cost. Finally, we will discuss the sensitivity of key variables and potential macroeconomic effects of the expansion.

2 Literature Review

The proposal for the expansion of the Panama Canal developed by the Panama Canal Authority (2006) investigates the possibilities of benefiting from a growing commercial and transit demand by expanding the Panama Canal. They project the future demand to be both predictable and profitable. They argue that if the Canal were not expanded, it would lose competitiveness when reaching its maximum capacity. By not being able to capture any additional demand, it would lose its market share in the main routes that it serves. Their predictions were that this would lead the Canal to gradually lose its position as a key maritime route in world trade. The proposal includes a thorough assessment of its competitors, demand opportunities, the importance of the expansion and details on what the expansion should comprise.

In 2013, The U.S. Department of Transportation published a Panama Canal expansion study with the purpose of identifying the pending developments in world ocean trade routes that could possibly affect global and U.S. freight corridors relevant to the expansion of the Panama Canal. The report describes the possible effects of the expansion on shipping patterns, industry costs, trade flows and potential markets. It thoroughly explains the expansion process and looks at the possible gains from using larger ships through the Canal. The main focus of the report is the potential effects on U.S. ports and infrastructure. The report proposes that the expansion of the Canal will lead to better exploitation of economies of scale, which will lower transportation costs.

Notteboom and Rodrigue have produced several research articles on the Panama Canal and the expansion, both together and individually. One of their articles, *Challenges to and challengers of the Suez Canal* (2011a) describes the impact of bunker prices on the choice of routes. They describe shipping lines as less concerned about nautical distances when the bunker price is low. In addition, they compare the Suez Canal with the Panama Canal and the Cape of Good Hope.
In *The Panama Canal expansion: business as usual or game-changer?* (2011), an article from the same series, they discuss changes in trade patterns and the role of the Panama Canal toll system in the total cost structure.

In an extensive background study made for the Van Horne Institute in 2010, Rodrigue assess the impacts of the Panama Canal expansion. The study is called *Factors impacting the North American freight distribution in view of the Panama Canal expansion* and focuses on three main classes of factors: Macroeconomic factors, operational factors and competitive factors. Rodrigue allege that one of the important rationales behind the expansion is related to the improvement of economies of scale in maritime shipping.

For a low carbon shipping conference in 2012, Paul Stott did a research on the *New Panamax and its implications for ship design and efficiency*. His research claims that the world ship fleet has been constrained in case it has to use the Panama Canal, not necessarily because it actually uses it. Thus, vessels have been constructed to fit the Panama Canal for the sake of flexibility and re-sale value, even though their owners do not trade routes were the Canal is an option. His research further point to the fact that container vessels transiting the new locks will be able to carry a capacity of 13 200 TEU. He also believes that the expansion will lead to economies of scale and lower emissions by routing more containers through the Canal. In *The Panama Canal expansion: business as usual or game changer for ship design?* (2012) Stott suggests that the expansion will be influential in ship design irrespective of the effects on trade.

In 2012, AECOM prepared a study on *Vessel size vs. Cost* to explain the advantages of shifting to larger ships. Their study is one of the few that actually uses calculations to show the scale-advantages of sailing a Post-Panamax vessel through the Panama Canal after the expansion. AECOMs calculations take capital costs, fuel costs, Panama Canal tolls and labor costs into account when comparing a Panamax vessel with larger vessels in an annual round-trip scenario. This is a simplified calculation, and the conclusion is that the cost per TEU is lower for the larger vessel.

Common for most previous research is that when they look at the potential effects from the expansion, they have a macroeconomic perspective. Few studies have compared alternative routes by using models for cost calculations. Similar for most conclusions for the impacts of the expansion is that they are vague because of the many unknown variables and potential effects. However, there seems to be a consensus that the expansion will lead to better exploitation of economies of scale.

3 Background

3.1 The Panama Canal

Since its opening in 1914 the Panama Canal has established itself as a major passage point for world trade with 12 045 oceangoing transits in 2013[1]. This represent roughly 5 percent of total tonnage traded in the world today (ACP, 2013a). The Panama Canal currently serves more than 140 trade routes to over 80 countries. The largest volume of trade is on the East - West route, which dominates the container business (Stopford, 2009).

The Canal provides an all-water way passage between the Atlantic and the Pacific Oceans – facilitating trade between Asia, Europe, the Caribbean and America. During the last decade, the Panama Canal has been outgrown on two essential areas:

1. The Canal is no longer able to handle the current demand without vessels having to spend longer periods waiting to transit
2. The upsizing of vessels has led to an increasing amount of vessels outgrowing the Canal dimensions

3.1.1 History

On the 7th of January 1914, when the Canal was still under construction, the French crane boat *Alexandre La Valley* became the first vessel to ever transit the Panama Canal. The construction of the Canal was started by the French in 1880 and was completed by the U.S. merely 15 years after they acquired control of the project in 1899. The building project had a total cost of approximately 375 million dollars, nearly 300 million cubic meter of mass was removed[2] and cost over 25 000 people their lives. The project is still seen as one of the greatest engineering achievements ever.

The official opening of the Canal was scheduled for August in 1914, but never took place. This was because of the First World War that started on the 28th of July the same year. However, the ship *SS Ancon* became the first ship to officially transit the Panama Canal on the 15th of August the same year (ACP, 2014a).

[1] This includes only oceangoing vessels that are large enough to pay tolls greater than the minimum tariffs.
[2] The masses later provided the foundation for the Balboa district in Panama City.

3.1.2 Capacity

The Canal has a total length of nearly 80 kilometer and stretches from the Atlantic Ocean to the Pacific Ocean through the Isthmus of Panama. Entering at the Atlantic side, vessels first transit through the Gatun Locks. This lifts them 26 meters above sea level into the Gatun Lake. After crossing the Gatun Lake, the vessels enter Chagres River, which leads to the second and third set of locks, the Pedro Miguel Locks and the Miraflores Locks. These take the vessels down to sea level at the Pacific side. The dimension of the locks is the constraining factor that has led to the expansion. The lock chambers are 33.4 meter wide and 304.8 meter long with varying depth. The Pedro Miguel Locks are the shallowest with a depth of 12.9 meter. The air draft is restricted to 57.9 meter by the Bridge of the Americas in Balboa. The chamber specifics have been used as a basis for the vessel size known as Panamax, representing the maximum size of vessels operating in the Canal. A Panamax can have a maximum length of 294.1 meter, a beam of 32.3 meter and a draft of 12.04 meter (ACP, 2013b).

There are many factors that can impact the measured capacity of the Panama Canal, such as weather conditions, operating conditions and the size distributions of transiting vessels (USDT, 2013). The load capacity for ships transiting the Canal has been constantly optimized and the largest Panamax vessels has about four feet of clearance on each side when entering the current locks. To avoid accidents vessels transiting the Canal must give up control of the bridge to a designated pilot, while several tugboats are used to guide the vessel into the locks.

The Panama Canal Authority (also referred to as the ACP) employs the Panama Canal Universal Measurement System (PC/UMS) on the various segments using the Canal. A 20-feet container (1 TEU) is equivalent to 13 PC/UMS tons, and a tonne of PC/UMS is approximately 100 cubic feet of cargo space. Every vessel has a unique cargo carrying capacity, which is reflected in a unique PC/UMS-ratio for every vessel. This metric is used to calculate transit tolls, and based on these measures the current capacity of the Canal is estimated to be more than 300 million PC/UMS tons a year (ibid.), or 23 million TEUs if only container vessels were to use the Canal.

Since the year of 2001, the PC/UMS capacity has increased with nearly one-third. This has been achieved by incorporating several new measures, such as new tie-up stations and gradually eliminating nighttime restrictions at the locks. Consequently, the maximum capacity for the Canal was almost reached in 2007. Interestingly, the increased capacity is not related to an increase in annual transits, but an increase in PC/UMS per transits. The expansion project is expected to double the capacity of the Canal to 600 million PC/UMS tons (ibid.) even though only 12 - 14 additional vessels can be accommodated by the new lock system per day.

3.1.3 Administration

The U.S. was the administrator of the Canal since the opening in 1914. After years of discussion it was officially returned to the Republic of Panama on the 31st of December 1999. The two governments did in fact sign the Panama Canal Treaty in 1977, including the agreement of a future transfer of the rights of the Canal. The treaty also stated that the Canal always would remain open, safe, neutral and accessible to vessels from all nations (ACP, 2012a).

The Panama Canal Authority was established on the 27th of December 1997 and has the responsibility for operating the Canal as well as forming policies for operations, improvement and modernization (ACP, 2012b). After the ACP was given control over the Canal they implemented a market-oriented system to replace the former zero-sum approach of the U.S. This approach resulted in rising prices and increased differentiation, and has led to development and growth in the Republic of Panama. For the fiscal year of 2013 the ACP reported 2.4 billion Balboas[3] in revenues, representing an increase of 0.3 million compared to 2012. From this revenue, the ACP will make direct contributions to the National Treasury in the amount of 981.8 million Balboas (ACP, 2013a).

3.1.4 Transit reservation system

The ACP manages the Canal traffic in a market-oriented sense directing their focus towards customer satisfaction and profitability. The customers are offered three different options on how to use the transit system:

[3] Balboa is the currency in Panama, along with U.S. dollars, and is pegged against the latter.

- Book transits in advance
- Regular transits without pre-booked time
- Use a transit booking slot auction system

The auction system was launched as an extra service in 2006 to better the service for smaller customers, as advanced bookings favors larger customers in compliance with the Customer Ranking used by the ACP[4] (ACP, 2014b).

According to the *OP Notice to Shipping N-7-2014* (ACP, 2014c) the Canal Authorities operates with two general booking periods. The *special period is* designated to commercial passenger vessels and must be booked 547 to 366 days prior to the requested transit date. The *normal periods* are designated to commercial vessels and are split into three periods according to how far in advance customers can book:

- First period – 362 to 22 days prior to the requested transit date
- Second period – 21 to 4 days prior to the requested transit date
- Third period – 3 to 2 days prior to the requested transit date

There are 25 authorized transit slots available per day that will be allocated based on booking period and size of vessel as displayed in Table 1.

VESSEL	**Passenger Vessels**	**1st Booking Period**	**2nd Booking Period**	**3rd Booking Period**
Supers: 91ft. (27.74m) in beam and over	3	4	3	7
Regulars: under 91ft. (27.74m) in beam	3		1	4
Total of 25	**6**	**4**	**4**	**11**

Table 1: Panama Canal booking slots per period (ACP, 2014c)

In 2013 the ACP initiated a service called *Just-in-Time Service* (JIT) in order to improve service level and capacity. This allows booked vessels to arrive at the Canal

[4] Nippon Yusen Kaisha is currently ranked as the ACP´s best customer.

closer to the scheduled transit time – thereby reducing their waiting time. This value-added service allows vessels to stay longer in port and encourage navigation according to a fuel-saving practice. A maximum of four JIT booking slots may be offered per day to supers, of which two slots will be allocated for each transit direction. Similarly, a maximum of two JIT booking slots may be offered to regulars each day – one for each direction. At the start of a booking period JIT slots will be assigned to vessels that are awarded booking slots during the *tie-breaker competition*[5] for that period – where the first criteria is customer ranking and the second criteria is the order of frequency they have transited over the last twelve months. This emphasizes the service offered to the most loyal and profitable customers. After the competition the remaining JIT slots will be awarded in the order the requests were received.

To operate the Canal efficiently the Canal Authorities depend on transits performed according to schedule. As a measure to avoid unnecessary delays they have penalty systems for daylight transit cancellation, late arrivals and booking cancellations. To avoid a daylight transit cancellation fee, vessels must cancel more than 60 days in advance. In addition, a booking cancellation fee will always be included. At page 15 in the notice (ibid.) it is stated that vessels scheduled to arrive at 14:00 that arrive between 14:01 and 15:00 must pay 50 percent of the booking fee as a late arrival fee. The penalty fee increases each hour until it reaches a maximum of three hours and a penalty fee equivalent to 200 percent of the booking fee. This is to ensure maximum on-schedule transits.

3.1.5 Key figures

According to the latest annual report from the ACP (2013a), the Panama Canal ended its last fiscal year with 320.6 million PC/UMS tons transited. This represents a decrease of 13.1 million tons compared to 2012 and can be related to a decrease in demand due to changes in the maritime industry.

During fiscal year 2013 the full container vessel segment recorded 3 103 transits, representing 117.6 million PC/UMS or 12.1 million TEUs. This represents a 6.8

[5] A tiebreak competition is a competition where one uses different criteria to determine who is the winner when it is a tie. In our example this is how to allocate slots when several vessels has requested slots during a period.

percent decrease in total transits, 1.9 percent measured in PC/UMS and 0.8 percent measured in TEU compared to 2012. The reason for the rather significant difference in total transits compared to PC/UMS and TEUs is an increase in average vessel size from 3 659 TEU in 2012 to 3 895 in 2013.
Revenues from the container vessel segment accounted for 51.5 percent of the overall Canal toll income for fiscal year 2013.

In the report we find that *The Canal Waters Time* (CWT), which is the total time elapsed from the vessel arrives at the Canal plus the actual transit time, registered an average of 24.5 hours in fiscal year 2013 - a reduction of 4.53 percent compared to the 25.66 hour average in fiscal year 2012. First of all, this is a result of a reduction in the daily average of vessels waiting in queue – a decrease of 15.21 percent from 46 vessels in fiscal year 2012 to 39 in 2013. Secondly, the CWT is lower due to a reduction in booked vessels, which has decreased by 12.14 percent from 5 768 vessels in fiscal year 2012 to 5 068 in 2013. Finally, it is a result of a decrease in the quantity of vessels that were affected by fog – from 417 vessels in 2012 to 307 in 2013.

The average CWT for booked vessels in fiscal year 2012 was 14.86 hours compared to 14.36 hours in fiscal year 2013, representing a 0.5-hour decrease. On the other hand, the CWT average for non-booked vessels was down by 2.55 hours in 2013 to an average of 31.95 hours from 34.5 hours the latter fiscal year. According to ACP (2013a) this represents an important reduction.

Further we find that the *In-Transit-Time* (ITT), which is the elapsed time from the vessel arrives to the first lock until it exits the last one, registered an average of 10.78 hours in fiscal year 2013 – a 0.08 percent increase from a 10.7 hour average in 2012. This was slightly affected by a 152-hour programmed maintenance increase, performed during lane outages in the Gatun, Pedro Miguel and Miraflores Locks, which were 435 hours in 2013, compared to 283 hours in 2012.

As for the financial indicators, they present robust and solid levels. 50 cents of net profit was generated for each balboa of income. This 50 percent profit margin highlights the wealth capacity of the Panama Canal. The ability to deliver such results while substantial capital investments are being made underlines its robustness. The revenue stream stems from three sources:

- Toll revenues
- Transit related services
- Other revenues

For fiscal year 2013 the allocation of revenues were 1.85 billion balboas from tolls, 374 million from transit related services and 187 million from unspecified sources – making tolls the largest income source representing almost 77 percent of the total revenue. Total operating expenses amounted to 733.8 million balboas and represented 30.4 percent of the total income. Personal services accounted for 59 percent of the expenses.

3.2 The expansion plan

In their expansion proposal from 2006, the ACP lists four main objectives for the expansion (ACP, 2006):

- Achieve long-term sustainability and growth for the Canals contributions to Panamanian society through the payments it makes to the National Treasury
- Maintain the Canals competitiveness as well as the value added by Panama's maritime route to the national economy
- Increase the Canals capacity to capture the growing tonnage demand with the appropriate levels of service for each market segment
- Make the Canal more productive, safe and efficient

The expansion project is referred to as the *third set of locks project* and contains a series of projects:

- Both the Canal entrance at the Atlantic and the Pacific side must be deepened and widened
- The operating water level in the Gatun Lake must be raised in order to accommodate larger vessels

- The navigation channel must be widened and deepened in both the Gatun Lake and the Culebra Cut
- Four dry excavation projects will be executed in order to connect the Pacific locks and the Culebra Cut with a new 6.1 kilometer long access channel
- Build a new access channel on the Atlantic side

The two new locks that are under construction on each side of the Gatun Lake will have three consecutive chambers designed to move vessels from sea level to the level of the Gatun Lake and back down again. The new lock chambers will have a length of 427 meter, a width of 55 meter and a depth of 18.3 meter. The locks will be able to accommodate vessels that are 366 meters long, with a 49-meter beam and a draft of 15.2 meter. The air draft will still be constrained to 57.9 meter because of the Bridge of the Americas.

3.2.1 Project progress

About 70 percent of the expansion work is already finished, but a dispute that began on the 1st of January 2014 put the project in danger. After postponing the initially planned opening from 2014 to 2015, the dispute put even the rescheduled opening in danger. The dispute was related to cost overruns of approximately $ 1.6 billion, and Grupo Unidos por el Canal (GUPC), the consortium that won the multi-billion dollar deal, threatened to halt the construction unless ACP agreed to cover half the overrun. ACP on their side accused the consortium for breaching contract obligations. The consortium, led by the Spanish construction company Sacyr, won the contract with a bid that was $ 1 billion lower than the next lowest bidder. The current Canal Administrator blames the former administrator for accepting an unrealistic low bid.
On the 7th of February 2014, five years after GUPC won the $ 3.1 billion contract-bid they suspended work and 10 000 jobs were at risk. On the 20th of February, after 13 days of total stop in construction, a temporary agreement was reached to start the work again. Given the size of the project, its impact on maritime trade and the significant cost overruns, governments in Europe and the U.S. has been involved in an attempt to find a solution. The ACP made it clear that they would cancel the agreement if a solution were not found. To make matters even more complex, the project has been considered a lifeline for Sacyr after contracts dried up in the aftermath of the Euro debt crisis. The project also has direct implications for the

Spanish government who provided a financial guarantee to the insurer of the project (New York Times, 2014).

On the 27th of February 2014 the ACP published a press release stating that they had reached a conceptual agreement with the consortium. The agreement was signed on the 14th of March and states that the opening of the Canal will be further delayed 6 months until December 2015. The price of the contract remains the same and the consortium did not achieve successful payment claims. Both the ACP and GUPC will pay $ 100 million to ensure the immediate continuation of the project. GUPC has arranged for $ 400 million in further financing through performance bonds, which can only be released by the Zürich lender (ACP, 2014d).

3.2.2 Vessel capacity

The size specifications of the new locks are set, but there seems to be some disagreements on how much capacity the new locks actually will be able to accommodate.

Today only 2.5 percent of the world seaborne trade passes through the Canal. However, approximately 25 percent of the deep-sea commercial fleet has a Panamax beam, representing approximately 8 500 vessels in total (Stott, 2012). The flexibility of the Panamax vessel is one of the reasons why it is preferred. Less flexibility for the shipowner is equivalent with higher risk and is directly reflected in the re-sale value of the ship. Stott argues that this has led the Canal to become a constraining factor because of the possibility that a ship *might* use it at one point, not because it actually uses it.

According to the ACP`s predictions (2006) the size of the largest container ship that will be able to transit the Canal laden will increase from around 4 800 TEU (this is now more than 5 000 TEU) to around 12 000 TEU after the expansion. In his research, Stott (2012) suggests that the *Maersk Edison* is a vessel that would fit the new dimensions. The Maersk Edison has a capacity of approximately 13 100 TEU, with a scantling draft of 15.5 meter and design draft of 14.5 meter. The scantling draft is the deepest draft the strength of the hull can safely bear, whereas the design draft is the optimal draft the ship was designed to operate with. Stott further used AIS data for a sample of 39 container ships with a 15.5-meter scantling draft – where only two vessels indicated an operating draft of more than 15.2 meter, which is the new constraint. In his study, the mean draft was 13.5 meter with a median of 13.2 meter. This indicates that Post-Panamax ships with a capacity up to 13 200 TEU will be able to make the transit, with the length of the vessel being the constraining factor rather than the draft.

During the five years prior to the announced expansion plan the largest existing ship was constant at a 9 600 TEU capacity. However, over the next five years the size of ships dramatically increased with the introduction of Ultra-Large Container Vessels (ULCV) with a capacity of 15 500 TEU (ibid.) – represented by the *Emma Maersk*. In 2013 Maersk introduced a new class of container ships, the *Triple-E class*. With a capacity of more than 18 000 TEU it represents the largest container vessels ever built. After Maersk ordered 20 Triple-E vessels in 2011 it is a fair assessment that these ships will be a major player on long-haul routes. According to the Container Orderbook the Mediterranean Shipping Company (MSC), the China Shipping Container Lines (CSCL) and the United Arab Shipping Company (UASC) are also looking to add Triple-E ships to their fleet (Clarkson SIN, 2014).

Dry-bulk *Capesize* vessels of 180 000 DWT (deadweight tonnage[6]) are within the constraint considering length and beam, but the draft is too deep when laden (Stott, 2012). They will, however, be able to transit the Panama Canal in ballast. The largest laden dry-bulk carrier that will be able to transit will be approximately 120 000 DWT. New *Handysize (Supramax)* and 85 000 DWT designs will benefit from the increase in beam, as designers will be able to optimize hull designs without the beam constraints. Regarding tankers, the *Suezmax* will be able to transit the new canal in ballast or partly laden. The largest fully loaded standard tanker that is certain to fit is an Aframax of approximately 120 000 DWT.

3.3 Container shipping

"There has to be a better way of loading cargo aboard ship piece by piece." – Malcolm McLean, 1937.

[6] Deadweight tonnage is a measure of how much weight a ship is carrying or can safely carry.

Looking back more than 70 years ago, a small trucking firm-owner by the name of Malcolm McLean was beginning to grow tired of the time-consuming and labor-intensive process of loading his cargo, in this case cotton, from trucks aboard ships heading for Istanbul. He was determined there would be a way of making the loading process more efficient. Why couldn't an entire truck be hoisted aboard ship? He asked. Two decades later, in 1956, he did something about it. The result was a redesigned World War II tanker named Ideal X, with a reinforced deck carrying 58 metal container boxes as well as 15 000 tons of bulk petroleum from Port Newark to Houston. This would later be referred to as the first successful containership, and revolutionized the world of intermodal freight transport (Cudahy, 2006).

Intermodal freight transport combines multiple modes of transport such as rail, ship and truck in the transport of goods without directly handling the freight itself when changing modes. This has later become an important part of the definition of containerization, which is a system of intermodal freight transport using standardized containers. This system has improved the efficiency of freight transport by allowing the goods to be transported between modes with a minimum of interruption and by avoiding the risk of damaging the goods. It has also been an important step towards exploiting economies of scale in the vessels (Strandenes, 2012).

Containers have become standardized to twenty-foot (TEU), forty-foot (FEU) and forty-five-foot containers, with a majority of 75 percent being 40 feet. These are known as intermodal containers as they are designed in such a way that they can be easily moved between different modes of transport. The containers are equipped with a simple twist lock fitting system to make them easier to handle when craning, stacking and locking.

A TEU is short for Twenty-Foot Equivalent Unit and is based on the volume of a twenty-foot container, which is twenty feet long and eight feet wide. The height is not standardized and can vary from 4.25 feet to 9.5 feet. However, the most common height is 8.5 feet. The Twenty-foot equivalent unit has become a standardized measurement and is widely used when defining container ship capacity.

3.3.1 Container ships

The container fleet currently consists of ships ranging in capacity from 100 TEU to over 18 000 TEU (Clarkson SIN, 2014). The ships in the lowest capacity range are so-called Feeders and Handy (Sub-Panamax) container vessels. They tend to be used on short-haul operations (also called "feeder"-operations) carrying coastal traffic to and from transshipment ports or for direct short sea services (USDT, 2013). Feeder vessels have a capacity between 100 - 1 000 TEU, while Handy vessels have a capacity between 1 000 - 3 000 TEU. Next we find ships specially designed to fit the Panama Canal called Panamax vessels, which usually have a capacity between 3 000 - 5 000 TEU (The largest Panamax vessel in the register have a capacity of 5 117 TEU). Further up on the capacity range we find Post-Panamax (or New-Panamax) vessels. These ships usually have a capacity ranging from 5 000 - 18 000 TEU. However, we find Post-Panamax vessels with a capacity down to 3 500 TEU. These vessels are classified as Post-Panamax vessels due to their size specifications rather than their TEU capacity. In addition, ships above 14 000 TEU are also categorized as Ultra-Large Container Vessels (ULCV). The current largest Post-Panamax vessels have a capacity of 18 270 TEU. Panamax and Post-Panamax vessels are mostly used for long-haul, intercontinental deep-sea routes.

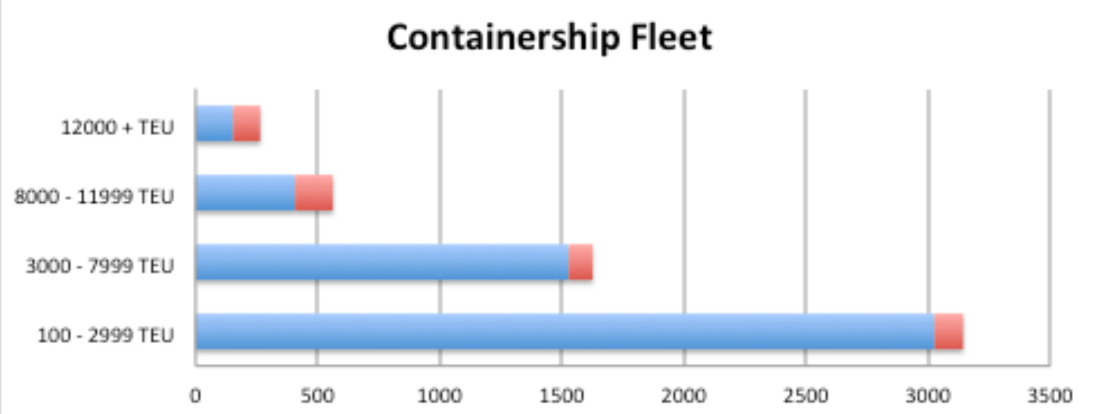
3.3.2 Containership fleet size

According to Clarksons Container Intelligence Quarterly (2013) operators continue in their quest for economies of scale. This is demonstrated by relentless vessel upsizing. There have been insinuations that this may potentially be encouraged by the expansion of the Panama Canal. Following, a study by the U.S. Department of Transportation (2013) shows that the worldwide fleet of container ships is projected to grow in TEU capacity by 30 percent from the end of 2011 to the end of 2015[7]. However, it is worth mentioning that even with the industry pursuing economies of scale in the ultra-large sectors, the 5 000 - 10 000 TEU sectors have grown significantly (Stott, 2012).

Container ships is currently the largest and fastest growing market segment for the Panama Canal (USDT, 2013) and as of February 2014 the world containership fleet consisted of a total of 5 114 vessels. According to the containership orderbook the

[7] Based on current orders for new ships and does not count for any scrapping of older ships.

number of vessels is expected to grow with a total of 22 percent within 2015 (Clarkson SIN, 2014). An overview of the current fleet and its expected growth is presented in Figure 1.



	100 - 2999 TEU	3000 - 7999 TEU	8000 - 11999 TEU	12000 + TEU
Current fleet	3026	1528	407	153
Orderbook	117	98	155	111

Figure 1: Container fleet and orderbook overview (Clarkson SIN, 2014)

Figure 1 shows that a large amount of new ships are in the range of 10 000 TEU and greater. This is a reflection of the rapidly changing composition of the global containership fleet, with an emphasis on larger, more fuel-efficient ships (USDT, 2013).

As mentioned in Chapter 3.2.2, the new Panama Canal Locks will be restricted to handle ships up to approximately 13 200 TEU. We can therefore observe that an increasing percentage of the world's containership fleet still will not be able to transit through the Panama Canal after its expansion. It is expected that these larger ships will be engaged in Europe - Asia trade via the Suez Canal or the trans-Pacific routes, and there is a likelihood that they eventually will engage in direct U.S. East Coast trade via the Suez Canal (USDT, 2013).

3.3.3 Current challenges

"The economics are much, much better via the Suez Canal simply because you have half the number of ships" - Søren Skou, CEO Maersk Line (2013)

According to Bloomberg (2013a), the world´s biggest container shipping company, Maersk Line, has threatened to stop using the Panama Canal to transport their cargo from Asia to the U.S. East Coast. With an increasing fleet of larger vessels, Maersk will be able to move their cargo more profitably through the Suez Canal. With Maersk being one of the Panama Canals largest customers, one might also wonder if this threat is a stunt to force the ACP to lower the future canal tolls when the expanded canal is finished. Following, some of the reasons for the global shipping shift are not only results of the size constraining Panama Canal, but also a result of the increasing costs of transit and waiting times for entering the locks. Companies have also shown their concerns regarding the limited number of U.S. East Coast ports that can service Post-Panamax ships.

3.4 Alternative routes

Since its birth, the Panama Canal has connected the Atlantic and Pacific oceans, providing the shortest maritime route option between Northeast Asia and the U.S. East Coast. However, due to its capacity constriction, other alternative routes have become competitive solutions for trade across the two oceans. In the following section we will present the routes that we believe are viable alternatives to the route passing through the Panama Canal, and that might be affected by the expansion.

3.4.1 The Suez Canal

The Suez Canal is often considered to be the most obvious competitor to the Panama Canal. The Suez Canal is an artificial waterway running north to south across the Isthmus of Suez in Egypt, connecting the Mediterranean Sea and the Red Sea. This is a sea-level canal and is therefore the world’s longest canal without locks, making it a more efficient and attractive pathway for larger ships. It provides the shortest route between Europe and South-Asia, and has become a viable route alternative for vessels traveling from the U.S. East Coast to Northeast Asia. Most of the Suez Canal is limited to a single lane of traffic, but the Canal has four doubled zones with six bypasses located along the way. This allows for transit of ships in both directions (SCA, 2014a). Vessels are able to transit the Canal both during the day and night with an average transit time between 12 - 16 hours. Vessels must arrive at a designated waiting area outside the Canal entrance 5 hours before the convoy sails. Vessels are able to arrive closer to the convoy start if they pay a penalty fee. 16 596 vessels transited the Canal in 2013, of which 36 percent were container vessels. The navigation is run as a convoy system, with three convoys daily:

1. Southbound from Port Said at 00:00 hours
2. Northbound from Port Tawfiq at 06:00 hours
3. Southbound from Port Said at 06:30 hours

The Suez Canal has the advantage of allowing carriers to use Post-Panamax vessels. This gives the shipowner the possibility to increase his revenue due to a higher productivity per Post-Panamax vessel, even if the operational costs of using more ships through the Suez Canal may be greater (ACP, 2006). In 2006, the ACP made a simple comparison between the two route alternatives based on TEU capacity as a part of their expansion proposal. The results are presented in Figure 2.

Route: Northeast Asia - U.S. East Coast				
Round trip travel time (Panama)	56 Days			
Trips per vessel per year	6,5			
Round trip travel time (Suez)	77 Days			
Trips per vessel per year	4,7			
Via	**Ship size (TEU)**	**Ships needed (weekly service)**	**Annual productivity per ship**	**Total service capacity**
Current Panama Canal	4 800 TEU	8	31 286 TEU	250 286 TEU
Suez Canal	8 000 TEU	11	37 922 TEU	417 143 TEU
New Panama Canal	8 000 TEU	8	52 143 TEU	417 143 TEU

Figure 2: Route comparison (ACP, 2006)

According to their calculations, a weekly containership liner service[8] between Northeast Asia and the U.S. East Coast requires eight ships rotating to cover all port calls and sailing times without interruptions. Based on the comparison in Figure 2 we can see that the current annual service capacity for carriers using eleven 8 000 TEU Post-Panamax vessels through the Suez Canal is much higher (417 143 TEU) than the capacity for carriers using eight 4 800 TEU Panamax vessels through the Panama Canal. However, Figure 2 also shows that the same service capacity of 417 143 TEU can be delivered through the expanded Panama Canal with the use of only eight vessels rather than eleven through the Suez Canal. As this comparison was made in 2006, it lacks some relevance with regards to the ship sizes used. With todays information available, we know that the new Panama Canal will be able to handle ships with a 13 200 TEU capacity. We also know that ships with a capacity of

[8] A containership liner service transits regular routes on fixed schedules.

approximately 18 000 TEU are sailing through the Suez Canal. Therefore, we have updated the numbers used in the ACP comparison, to make it more realistic.

Route: Northeast Asia - U.S. East Coast				
Round trip travel time (Panama)	56 Days			
Trips per vessel per year	6,5			
Round trip travel time (Suez)	77 Days			
Trips per vessel per year	4,7			
Via	**Ship size (TEU)**	**Ships needed (weekly service)**	**Annual productivity per ship**	**Total service capacity**
Current Panama Canal	5 117 TEU	8	33 352 TEU	266 815 TEU
Suez Canal	18 000 TEU	11	85 325 TEU	938 571 TEU
Suez Canal	13 200 TEU	11	62 571 TEU	688 286 TEU
New Panama Canal	13 200 TEU	8	86 036 TEU	688 286 TEU

Figure 3: Updated route comparison

In Figure 3 we use a ship with the new maximum capacity for the expanded Panama Canal, we updated the current Panama Canal ship size to 5 117 TEU by using the biggest ship currently able to transit the Canal, and finally we added a vessel carrying the maximum capacity able to transit through the Suez Canal. By using a ship with a 13 200 TEU capacity, the same service capacity can be delivered through the expanded Panama Canal with the use of only eight vessels rather than eleven through the Suez Canal. On the other hand, a ship with a 18 000 TEU capacity can deliver a much larger service capacity running through the Suez Canal, even if a ship this size will have a slightly lower annual productivity than a 13 200 TEU-ship running through the Panama Canal.

As this comparison excludes several important details, it is not accurate. It does, however, indicate that the expansion of the Panama Canal may increase its attractiveness once again for shipowners carrying cargo to and from the U.S. East Coast to Northeast Asia.

3.4.2 Cape Horn (Magellan Strait)

The route through the Magellan Strait and the route around Cape Horn are the two alternatives rounding the southern tip of South America. Historically the route around Cape Horn has been an important path for trade and passenger ships taking goods and people from the U.S. East Coast to the U.S. West Coast (GlobalSecurity, 2014). It has been feared for its notorious weather conditions with sailing hazards such as strong winds, large waves and icebergs drifting up from Antarctica. With todays bigger, powered vessels, better navigation equipment and weather knowledge, Cape Horn is less feared than it used to be, but the weather is still the same. This taken into consideration, in addition to the large sailing distance compared to the Panama Canal, makes this a less attractive alternative. It is however without capacity constraints, allowing for the use of larger ships and possible advantages from economies of scale.

3.4.3 Cape of Good Hope

Located at the southern tip of South Africa, the Cape of Good Hope route represent an alternative when sailing from Asia to U.S. East Coast. The route around Good Hope also facilitates trade between Asia and South America, Asia and West Africa and South America and East Africa (Notteboom & Rodrigue, 2011a). The route had an upturn in traffic in 2008 when the piracy activity outside the coast of Somalia increased[9]. The weather conditions are similar as those for the Cape Horn route, presenting a challenging sailing environment.

3.4.4 The U.S. Intermodal System

The U.S. Intermodal System offers an alternative to the all-water route from Asia to the U.S. East Coast by providing a land-based extension of the transpacific route. This allows for companies to ship their cargo from Asia to the U.S. West Coast and further to the destination by land-based transportation modes such as trains or trucks. The U.S. Intermodal System has proved to be a viable solution to the all-water route much due to the fact that it can make use of Post-Panamax vessels for the sea-transport between Asia and the U.S. West Coast.

The U.S. Intermodal System connects the U.S. West Coast ports with the main consumption centers in the U.S. by railroads and the transcontinental road system. This system is not an integrated operational unit, which has been pointed out as one of its main challenges due to the many bottlenecks that form (USDA, 2010). The U.S. Intermodal System relies on a large number of commercial operators such as port operators, transshipment area operators and railroad and trucking companies. The increase in transpacific trade has had an overwhelming effect on the system capacity. This has led to congestion and labor conflicts, which affects the reliability of the route compared to the more stable and reliable Panama Canal route (ACP, 2006). Due to the many commercial operators, the intermodal land-based route is more costly than

[9] The number of reported attacks near Somalia and in the Gulf of Aden increased from only 10 in 2006 to 111 in 2008 (Notteboom & Rodrigue, 2011a).

the Panama Canal route. On the other hand, it offers a higher variability in service dependability, and may be less time-consuming depending on the cargo destination.
Through the last decade, there has been a growth in the Panama Canal market share on the Northeast Asia - U.S. East Coast trade route, with a similar reduction in the U.S. intermodal market share. This can be related to several factors such as reduced transit times in the Canal, congestion problems in the intermodal system, and an increase in distribution centers located closer to the U.S. East Coast (ibid.). The United States Department of Agriculture (2010) believes that the Canal expansion will increase the efficiency of the U.S. Intermodal System by decongesting the West Coast main ports such as the Port of Los Angeles. They also claim that large investments in U.S. infrastructure and a more integrated approach will be necessary for the U.S. Intermodal System to remain competitive to the Panama Canal after the expansion.
An expected consequence of the Panama Canal expansion is that it will increase aggregated volumes, directly effecting both inland rail and highways. Increased unloads from larger, but fewer ship calls, would result in volume spikes and rising demand in landside connections.

When shipowners consider using the intermodal alternative there is a variety of concerns to address. These concerns may include port and terminal access, road congestion, environmental issues and government regulations on local, regional, state or federal level. These variables are not directly related to the Panama Canal expansion but will influence the total incremental cost of transportation and thereby indirectly affect the Panama Canal and the impact of the expansion.

3.4.4.1 U.S. West Coast

According to U.S. Census Bureau data, U.S. West Coast ports handle most containerized U.S. imports – approximately 69 percent of 2010 and 2011 total U.S. tonnage (USDT, 2013). Southern California (Los Angeles, Long Beach and San Diego) is the largest gateway region for moving goods into the United States, followed by Pacific Northwest (Seattle, Tacoma and Portland), while Canadian and Mexican ports have relatively small shares. These ports serve both local markets and act as a gateway to inland U.S. regions, moving goods by one of three means:

- By North American rail intermodal services provided by the West Coast Class 1 railroads
- By truck to inland destinations
- By truck to trans-load centers where the contents are repacked from 40-foot international containers into 53-foot domestic containers for more efficient transport to inland locations

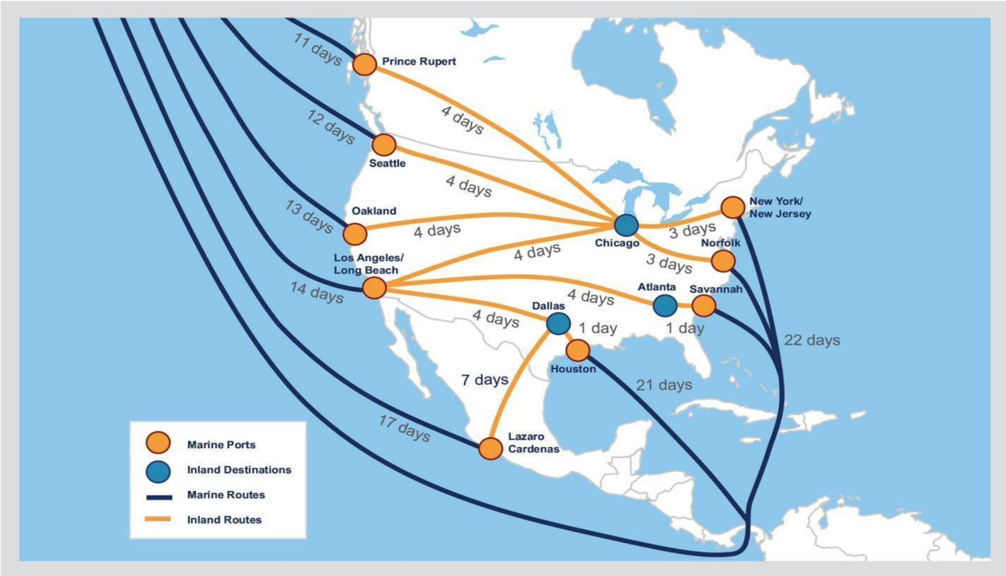


Figure 4: Inland and all-water transportation time (USDT, 2013)

The escalation of container carriage has increased train size as well as vessel size. Until 1990 there were only 100 double-stack trains moving East - West to and from California, whereas today more than 3 000 double-stack trains move weekly in all directions from both maritime gateways and domestic intermodal facilities (USDT, 2013). A double-stack container unit train has typically had a length ranging from 6 000 to 7 500 feet, being able to carry from 200 to 250 containers. On high-volume routes such as Los Angeles - Chicago, trains range from 10 000 up to 12 000 feet and a container capacity of 325 to 400 has been introduced in later years. Train companies are also experimenting with prototype trains of about 18 000 feet with a 600 container capacity. These larger unit trains offer lower unit cost per container when moving inlands and could enable West Coast ports to better compete for cargo that otherwise would be destined to travel through the expanded Panama Canal.

3.4.4.2 Trucking

Trucking is an essential part of the U.S. Intermodal System – carrying in excess of 70 percent of total U.S. cargo tons imported through West Coast ports. There are few substitutes, no matter the cost or how congested local highways and bridges may be – making trucking the primary mode of transportation when serving markets close to ports. For some intermediary distances long-haul trucking could compete with rail, especially when intermodal nodes are far from the origin, requiring additional local trucking. However, on longer distances rail becomes the preferred alternative (USDT, 2013).

3.4.5 Other alternatives

In a long-term perspective, new trading routes may emerge. These will not propose an immediate threat to the Panama Canal, but we will give a short introduction to some of the potential routes.

In Nicaragua, one of Panama´s neighbor countries in Central America, there have existed plans to build a canal connecting the Atlantic and Pacific for more than 150 years. These have presumably gathered pace the last years. In 2013, the Nicaraguan Congress gave a 50-year concession to the HK Nicaragua Canal Development Investment Company, a Beijing-based entrepreneur (New York Times, 2013). Experts question the realism of the project, partly due to a lack of location details in the concession. In addition, the government lacks support from the public, there are several environmental issues and the existing Panama Canal makes economists question the basis for future cash flow. On the other side, the leader of the HKND-group, Wang Jing, claims that the project has investors and that the work will start in 2014 – taking 6 years to finish (Bloomberg, 2013b).

Due to changes in the climate, shipowners are investigating the possibility to sail both the Northwest Passage and the North Sea Route (also known as the Northeast Passage), and there has been an increase in traffic through these passages each year. The arctic routes enjoy shorter distances and sailing time from both the U.S. and Europe to most of Asia compared to the other route alternatives, but are prone to harsh weather and ice, making them both risky and un-assessable parts of the year.

Estimates on when these routes could become more accessible linger from 20 - 50 years.

3.5 Ports

According to U.S. Census Bureau data, U.S. ports handled 99 percent of the overseas U.S. trade, whereas just 1 percent was transported by air (USDT, 2013). The expansion of the Panama Canal will have a great impact on ports around the American continent. As many ports do not have the necessary means to serve vessels of Post-Panamax size, they face the dilemma of either expanding or hoping that the traffic of Panamax size vessels are enough to stay operative and remain profitable. Factors that could represent both opportunities and problems are:

- The navigability of the ports (water draft)
- Air draft restrictions
- Terminal capacity
- Landside connectivity

As the largest fully laden Post-Panamax requires 47.6 feet of draft without tidal restrictions, it is safe to assume that ports that want to be able to accommodate these ships must have channels, water depths and berths with a depth of 50 feet. This is not a problem at the U.S. West Coast where the most trafficked ports such as Los Angeles, Long Beach, Oakland, Seattle, Tacoma, Vancouver and Prince Rupert are all deep-water container ports. On the U.S. East Coast only two ports, Baltimore and Norfolk, have sufficient water depth. However, by the time the new Panama Canal opens, the Port of Miami, Fort Lauderdale and New York/New Jersey will have been dredged and expanded to accommodate Post-Panamax vessels.

3.5.1 New York

The port of New York/New Jersey (NY/NJ) has a water depth of 50 feet in parts of its harbor and the dredging to accommodate larger vessels will be completed in 2014 (Port of New York and New Jersey, 2014).

A project that will not finish before the opening of the new Panama Canal is the raising of the Bayonne Bridge. The bridge limits access to four of the five container terminals and can therefore be considered restraining for larger vessels. With a height clearance of less than 151 feet, it limits the possibility for the largest Post-Panamax vessels to use these terminals. The $ 1.3 billion project was approved in 2013 and is planned to finish in 2017. This will raise the deck with 64 feet – allowing Post-Panamax vessels to access the entire port.

The Global Marine Terminal is located in front of the entrance to the Kill Van Kull Strait and ships calling this terminal will not have to transit beneath the Bayonne Bridge. This terminal can therefore handle Post-Panamax vessels arriving from the new Panama Canal, as well as from the East through the Suez Canal without being constrained by the height specifics of the vessels. The Global Marine Terminal is scheduled to open a new expanded terminal this year, offering a capacity of 1.7 million TEUs per year. In addition, they have the possibility to enlarge the Newark Container Terminal and to add an adjacent berth to the New York Container Terminal on Staten Island (ibid.).

As one of the most trafficked ports in the U.S. the Port of NY/NJ had a container flow of 5 529 909 TEUs in 2012, accounting for both import and export. The share between imports and exports is quite evenly distributed with 2 817 805 TEUs imported and 2 712 104 exported (PANYNJ, 2012).

3.5.2 Los Angeles

The Port of Los Angeles is located at the San Pedro Bay in Los Angeles. The port has sufficient water depth to accommodate Post-Panamax vessels – and is assessed in our research as part of the intermodal route alternative. It is the number one port in the United States measured both in container value and volume, and has held this position since year 2000 (Port of Los Angeles, 2014a). The Port handled 8.5 million TEUs in the record year of 2006, while they in 2013 handled 7.9 million TEUs (ibid.). In 2011 the containerized cargo was valued at $ 234.3 million (Import: 200.7, Export: 33.6) (USDT, 2013). Imported containerized cargo accounts for almost 86 percent of the total value, as containerized import significantly outgrows exports in most U.S. ports. China is the number one trade partner and had a port market share of nearly 40 percent in 2012 (WC, 2013).

3.5.3 Hong Kong

In 2012 the Port of Hong Kong handled 23.1 million TEU and is therefore one of the most trafficked and efficient international container ports in the world (PHK, 2012). 410 container liner services have calls every week connecting about 520 destinations worldwide. The Kwai Chung-Tsing Yi container terminal handled 17.5 million TEUs in 2012, representing 76 percent of the total amount of containers handled by the port. Its total handling capacity is approximately 20 million TEUs. The port of Hong Kong has a total of nine terminals handled by five different operators. Providing 24 berths, 7 694 meter of deep-water frontage and a water depth of 15.5 meter (50 feet), there are currently no restrictions on which vessel type that can use the port (ibid.).

In 2005 Hong Kong actually lost its position as the world's busiest port to Singapore. Two years later the Port of Shanghai also surpassed Hong Kong (Legco, 2013). There is also a possibility that the rapid growing Shenzhen Port surpassed Hong Kong in 2013, after Shenzhen handled 17.3 million TEUs in the first nine months of 2013 compared to 16.4 million by Hong Kong. Hong Kong, Guangzhou and Shenzhen are in close competition as they are in close proximity to each other. The latter two have the advantage of lower handling costs. The three ports serve the Guangdong province, which has a population of 104 million people and is one of the most densely populated areas in China. All three ports have deep-water berths and cranes that can accommodate the largest container vessels.

Guangzhou and Shenzhen are situated further inlands and the lower cost of inland transportation and storing more than offsets the cost of calling the port compared to the Port of Hong Kong. The cluster of ports in South China makes on-land costs more important. The advantages of Guangzhou and Shenzhen are highlighted in the following speckle and are based on a competitiveness report by the Hong Kong Legislative Council (Legco, 2013):

- Closer proximity to the Pearl River Delta cargo sources, resulting in lower operational costs and transportation convenience
- Lower terminal handling charges and road haulage costs

- The efficiency development are resulting in diminishing intangible cost advantage for Hong Kong, e.g. short vessel turnaround time
- The Chinese government has undertaken substantial actions to boost competitiveness of Guangzhou and Shenzhen, including heavy investments in port infrastructure and the development of advanced logistic parks to facilitate trade flows

3.5.4 Guangzhou

The Port of Guangzhou is positioned in the center of the Pearl River Delta, which forms a well-developed transportation network. With a 400-kilometer coastline and 173 kilometers of navigation channels the port is the largest trading port in South China – connecting in excess of 100 domestic ports and more than 350 foreign ports in over 80 countries and regions (Port of Guangzhou, 2014a). In 2011, 431 million tons and over 14 million TEUs were handled at the 510 berths at Guangzhou. The port administration estimates that the Port of Guangzhou will handle 600 million tons of cargo with a container throughput of 25 million TEUs by the year of 2020 (Port of Guangzhou, 2014b).

3.5.5 Shenzhen

Situated south in the Pearl River Delta with a 260-kilometer coastline, the Port of Shenzhen is about 20 sea miles from Hong Kong in the south and 60 sea miles from Guangzhou in the north. According to World Shipping Council (2014a) Shenzhen handled 22.94 million TEUs in 2012.

3.5.6 Shanghai

The Port of Shanghai is located east in China, facing the East China Sea to the east and Hangzhou Bay to the south. It is situated in the estuarial area of the Yangtze River, the Huangpu River and the Qiantang River – connecting the port with the Chinese inlands. Having handled a record number of 33.7 million TEU in 2013, the Port of Shanghai has been ranked as the number one port in the world for four consecutive years since 2010 (Port of Shanghai, 2014a). The Port of Shanghai has outperformed the Port of Hong Kong since 2007, but they do not serve the same cargo sources, as Shanghai is situated further east (Legco, 2013). Container terminal operation is a core business for the Shanghai International Port Group (SIPG), having three major container port areas; namely Wusongkou, Waigaoqiao and Yangshan (Port of Shanghai, 2014b). These areas include seven large container terminals, operated by several companies. The Port of Shanghai does not have any vessel constraints.

4 Theory

4.1 Shipping market model

The maritime economy is complex, and the model presented in Figure 5 is used to explain the dynamics. The demand module (A) centers on the cargo shippers. They determine how trade develops by making sourcing decisions (location of oil refineries, distribution centers, cargo handlings hubs etc.) as well as negotiating freight rates and time charters. On the supply side (B) there are shipping investors (shipping companies, private shipowners etc.). These are on the other side of the negotiations and have to make decisions regarding the ordering of new ships and scrapping of old ones. A and B balance and intervene in the freight market (module C). The freight rates are constantly adjusting to changes in the balance of supply and demand, controlling the amount of money paid by shippers to shipowners and thereby the flow of money which drives the shipping market. In our research the Panama Canal can be related to *2. Fleet Productivity* in module B on the supply side. The expanded Panama Canal is part of an intricate market and may directly or indirectly influence different parts of the industry.

From the model we see that the shipping industry derives from the world economy. Business cycles determine short-term cycles in sea trade, and a better shipping industry is expected in strong economic periods. Regional development cycles determine medium- to long-term trends in sea trade. Sourcing and manufacturing decisions will affect trade flows, as these shifts according to the decisions. Today there is a discrepancy between container trade flows to the U.S. from Asia. As more cargo is traded from Asia to the U.S., shipowners receive a higher freight rate on the fronthaul voyage than the backhaul voyage. In this case, fronthaul refers to the voyage from Asia to the U.S., and backhaul refers to the return trip from the U.S. to Asia.

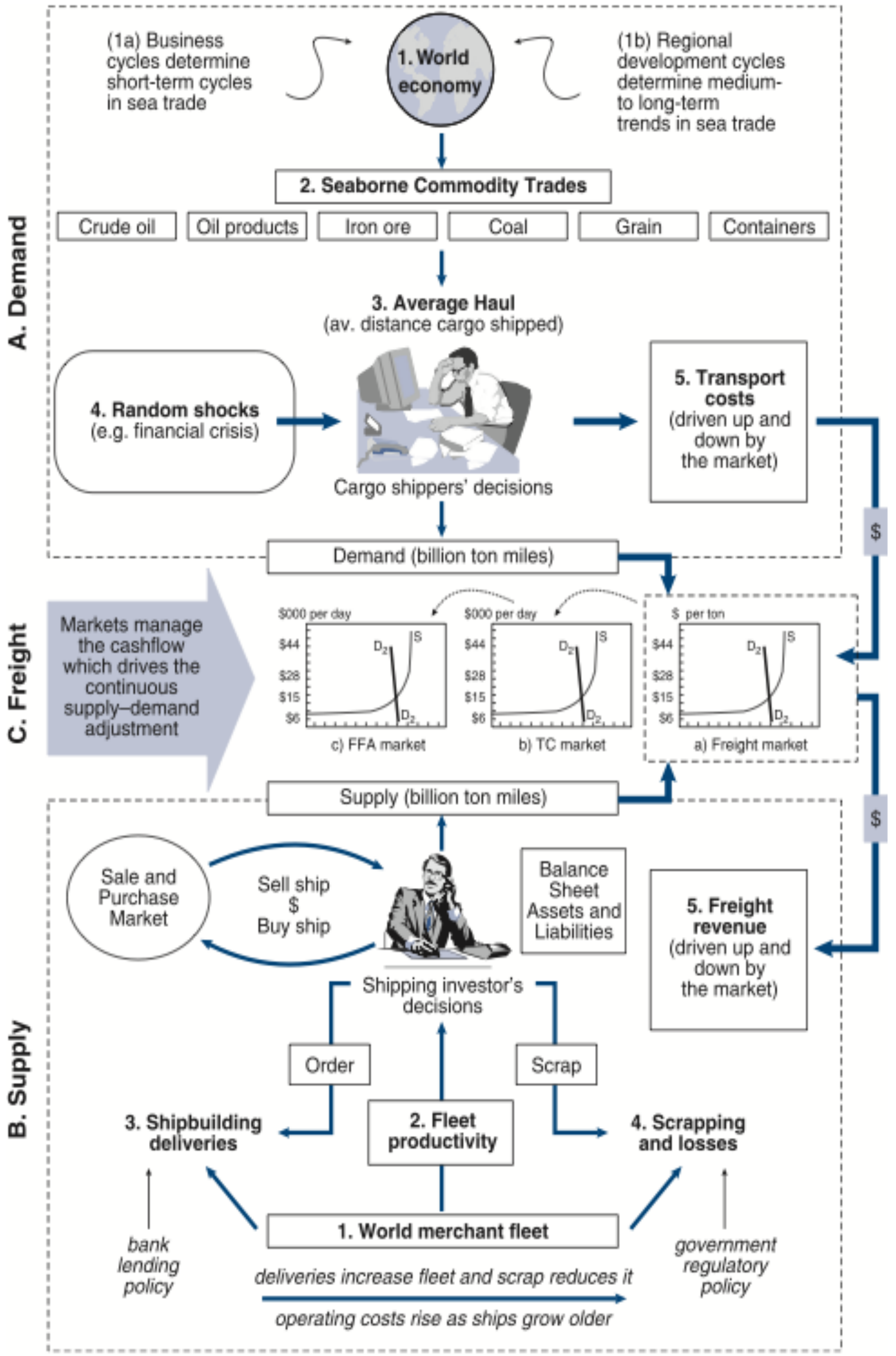


Figure 5: Shipping market model (Stopford, 2009)

4.2 Classification of costs

In order to get an insight of the different costs a shipping company face, we must first distinguish between the natures of the different types of costs. We can divide costs into three main groups; Fixed costs, variable costs, and sunk costs. Fixed costs can be defined as costs that do not vary with the amount of goods or services produced by the company. Variable costs will be the costs that vary with the amount of goods or services that are produced, and sunk costs are costs that do not vary in accordance with the decision alternatives because they have already incurred and cannot be recovered.

According to Stopford (2009) the shipping industry has no internationally accepted standard cost classification, but in general we can classify costs into five categories. The first category is *operating costs*. These are the costs and expenses involved in the day-to-day running of a ship and usually include manning, insurance, stores, repairs and maintenance costs. The second category is *voyage costs*. These costs are directly related to a specific voyage and include costs such as fuel, canal fees and cargo handling fees. This is normally the biggest variable cost category for a shipping company. Operating costs occur regardless of voyage specifics, and are therefore calculated separately from voyage costs. The third category is *cargo-handling costs*. This category represents costs related to the loading, stowing and discharging of cargo, and has been given considerable attention, particularly in the liner business due to its significance in the total cost equation. In our model we will include cargo-handling costs in the voyage costs because this is a common practice in container shipping. The fourth category is *periodic maintenance costs*. These costs normally incur when the ship is dry-docked for major repairs, and are generally treated separately from operating costs due to the large expenditure they may involve. This expenditure is normally more significant the older the ship is. The last and fifth category is *capital costs*. These costs depend on the way the ship has been financed.

Operating costs are variable and related to the day-to-day running of the ship. Voyage costs, hereunder cargo-handling costs, are variable and related to each voyage. Capital costs are fixed and are usually considered as sunk cost. Periodic maintenance costs are a result of the usage of the ships and in that sense variable, but they are not considered when calculating the costs for a specific voyage. Consequently, we will not include capital costs and periodic maintenance costs in our model.

4.3 Opportunity cost

Opportunity cost, or alternative cost, is one of the most important and useful concepts in economic analysis because it highlights the consequences of making choices under conditions of scarcity (Keat et. al., p.277, 2014). Opportunity cost can be defined as the amount or subjective value that must be sacrificed in choosing one activity over the next best alternative. In our research the opportunity cost will represent the cost of the alternative routes and which route is cheapest when compared directly. We will also treat the opportunity cost as the potential loss of income when spending more time at sea for a specific voyage. An alternative could also be to avoid sailing by docking the ship.

4.4 Pricing

A critical factor that must be considered when making pricing decision is the environment in which a company operates and competes (Keat et. al., p.79, 2014). In perfect competition the sole determinants for pricing decisions would be supply and demand. This would in turn make everyone a price taker (ibid.). In the case of the Panama Canal the market environment cannot be described by perfect competition. One could argue that parts of the Panama Canal market could conform to the monopoly assumption. Vessels travelling from Lima in Peru to the U.S. Gulf[10] would presumably have few alternatives but to transit through the Canal. The difference between using the Panama Canal and sailing the Magellan Strait from Lima to Houston is 7 244 nautical miles and approximately 17 days when sailing 18 knots, which is not a realistic alternative.

The container market is assumed to conform to the imperfect market condition assumption. This is a competitive market where the canals are price makers and can exercise a certain degree of control of their pricing (Keat et. al, 2014). This could give the ACP market power. One could further argue that the Panama Canal has oligopolistic power on the Asia - U.S. East Coast trade route alongside the Suez Canal, as both canals have large market shares on this route. Knowing what market the Panama Canal operates in makes it easier to discuss realistic pricing and scenario alternatives.

4.5 Economies of scale

If a firm`s long-term average cost declines as output increases, the firm is said to be experiencing economies of scale (Keat et. al., p.289, 2014). In shipping this relates to the connection between cost and ship size. This relationship is particularly important because operating, voyage and capital costs do not increase in proportion to the size of the vessel. Thus, using a bigger ship will reduce the unit freight cost (Stopford,

[10] Grieg Star sails this voyage. The port is called Callao and is situated close to Lima.

p.224, 2009). For example, a VLCC vessel of 280 000 DWT requires the same crew size as a 29 000 DWT tanker, but will only use a quarter as much fuel per deadweight tonne (Stopford, 2009).
In 2005 the annual cost for a 170 000 DWT Capesize bulker was $ 74 per cargo tonne compared to $ 191 for a 30 000 DWT vessel. Thus, the owner of a large ship has a substantial cost advantage given that cargo volume and port facilities are available. It could further add an interesting element to the cost and income equation, as bigger vessels loose flexibility. This will impact the revenue side by limiting the ports the vessels can enter and the time spent in available ports. Those investing in the next generation of bigger ships will therefore always face the risk that they have overstepped the market (Stopford, 2009). This happened with crude oil tankers when the upsizing limited vessels to certain routes. The market went bust and changed, demanding vessel and route flexibility.

We may potentially have two effects pulling in opposite directions. Shipowners pursue economies of scale by upsizing vessels, exemplified by Maersk and their 18 000 TEU Triple-E vessels described in Chapter 3.2.2, while the Canal Authorities makes pricing decisions based on an imperfect market condition in a canal limited to 13 200 TEU ships.

5 Model Description

Following is a short description of the model we have developed in order to perform our analysis. The data used and assumptions taken are described in Chapter 6. A detailed *model guide* is presented in Appendix 1. The model is a macro-activated model developed in Microsoft Excel. It is dynamic, and gives the user the option to change the model input. The input cells are marked in red, and are all equipped with a scroll-down menu or a description of which values to insert.

Cost comparison

Fuel unit cost per metric ton	$ 614,00

	Route alternative 1	**Route alternative 2**	**Route alternative 3**	**Route alternative 4**
Freight rate per FEU	$ 3 328,00	$ 3 328,00	$ 3 328,00	$ 3 328,00
Route	Shanghai - New York (via Panama)	Shanghai - New York (via Suez)	Shanghai - New York (via Cape Horn)	Shanghai - New York (via Good Hope)
Ship category	Panamax	Panamax	Panamax	Panamax
Name	Octavia	Octavia	Octavia	Octavia
Operating speed	23	23	23	23
Load factor	80 %	80 %	80 %	80 %
Sea margin	5 %	5 %	8 %	8 %
1. Route information				
Route distance	10 582	12 370	16 746	14 468
Days at sea	20,18	23,59	32,97	28,49
Days in port	6,01	5,47	5,26	5,26
Fuel consumption at sea tonnes/day	130,10	130,10	130,10	130,10
Fuel consumption at port tonnes/day	6,51	6,51	6,51	6,51
2. Ship information				
Ship size TEU	5 117	5 117	5 117	5 117
TEUs carried	4 094	4 094	4 094	4 094
Ship size DWT	66 160	66 160	66 160	66 160
Design speed	*25*	*25*	*25*	*25*
3. Voyage costs				
Fuel costs	$ 1 635 965	$ 1 906 166	$ 2 655 108	$ 2 296 787
Cargo handling	$ 2 192 859	$ 2 192 859	$ 2 192 859	$ 2 192 859
Canal fees	$ 435 437	$ 359 227	$ -	$ -
Total voyage costs	**$ 4 264 261**	**$ 4 458 252**	**$ 4 847 967**	**$ 4 489 646**
Gross revenue	**$ 6 811 750**	**$ 6 811 750**	**$ 6 811 750**	**$ 6 811 750**
Voyage result	$ 2 547 489	$ 2 353 498	$ 1 963 783	$ 2 322 104
Time-Charter Equivalent (TCE)	***$ 97 259***	***$ 80 986***	***$ 51 356***	***$ 68 797***
4. Operating costs				
Operating costs	$ 235 184	$ 260 936	$ 343 343	$ 303 066
Total costs	**$ 4 499 446**	**$ 4 719 188**	**$ 5 191 310**	**$ 4 792 712**
Cost per TEU	*$ 1 099*	*$ 1 153*	*$ 1 268*	*$ 1 171*
Daily contribution to capital costs	***$ 88 280***	***$ 72 007***	***$ 42 377***	***$ 59 818***

Back
Export results
Fuel sensitivity
Speed sensitivity
Load factor sensitivity
Freight rate sensitivity
Sea margin sensitivity

Figure 6: Cost comparison model

The model displays the basic route and vessel information used in its calculations. It calculates all costs connected to each voyage, each vessel's revenue and result for each of the four routes. The results are displayed in three different ways of measure:

1. The *Time-Charter Equivalent* is calculated by dividing the voyage result on total days spent on a route or the period you analyze. The TCE is a shipping industry standard used to calculate the average daily revenue performance of a vessel. It is a measure that makes comparison between the spot market and the time-charter market possible. It also facilitates comparison across routes.

2. The *Cost per TEU* is calculated by dividing the total cost on the TEU carried. This is especially useful when comparing vessels of different size. This measure can be used to highlight large-scale advantages.

3. The *Daily Contribution to Capital* is calculated by subtracting the daily operation cost from the TCE. This measures the daily profits for a vessel.

Further the model contains the option to export a summary of the results to a new Excel workbook. There are also options to perform different sensitivity analyses for the four routes. These will be exported and calculated in a new Excel workbook. The different sensitivity analyses are:

1. *Fuel Sensitivity* measures the Cost per TEU for each bunker price ranging from $ 400 to $ 800. The interval is based on historical data for Houston 380CST bunker prices from 2009 to 2014 (Clarkson SIN, 2014).

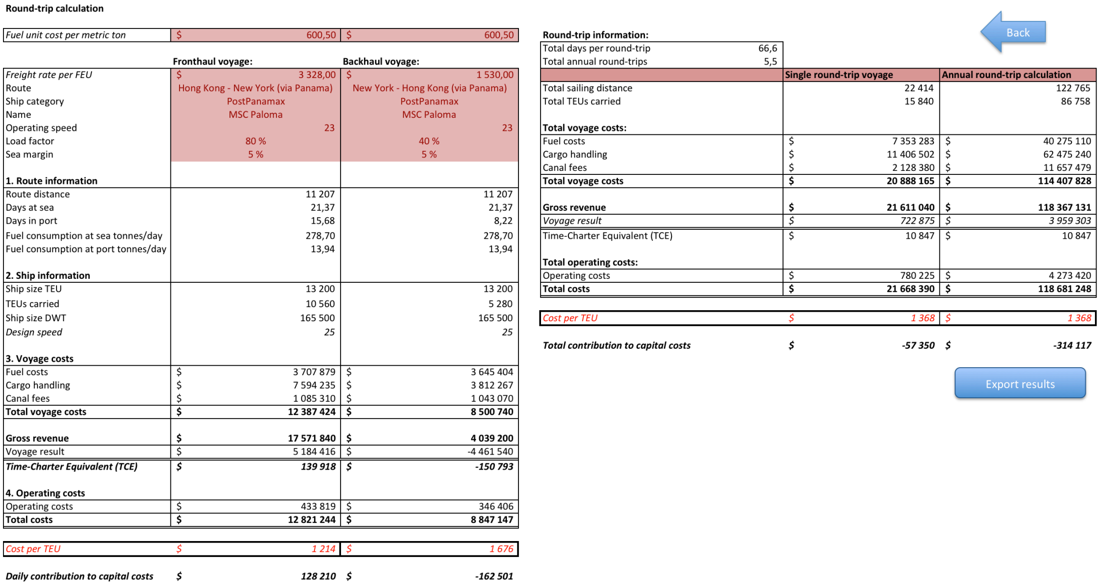
2. *Speed Sensitivity* gives us the change in Cost per TEU based on days at sea for vessel speeds ranging from 18 to 25.

3. *Load Factor Sensitivity* calculates the change in Cost per TEU for load factors ranging from 40 to 100 percent. This is based on the lowest load factor used by Stopford (2009), which is a 40 percent load factor on backhaul trips to Asia.

4. *Freight Rate Sensitivity* calculates the Cost per TEU for freight rates ranging from 2 000 USD/FEU to 4 000 USD/FEU. The interval is based on historical data for the SCFI Shanghai - EC America freight rate from 2009 to 2014 (Clarkson SIN, 2014).

5. *Sea Margin Sensitivity* calculates the change in Cost per TEU for sea margins ranging from 0 percent to 15 percent. Grieg Star normally operates with a sea margin of 5 percent on their voyages, and account for severe circumstances by adding to this sea margin if necessary.

The model also provides the option to perform a round-trip scenario. It takes into account the difference between the fronthaul and backhaul voyage, and displays calculations for a single round-trip voyage and an annual round-trip scenario. The model contains the option to export a summary of the results to a new Excel workbook.



Round-trip calculation

	Fronthaul voyage:	Backhaul voyage:
Fuel unit cost per metric ton	$ 600,50	$ 600,50
Freight rate per FEU	$ 3 328,00	$ 1 530,00
Route	Hong Kong - New York (via Panama)	New York - Hong Kong (via Panama)
Ship category	PostPanamax	PostPanamax
Name	MSC Paloma	MSC Paloma
Operating speed	23	23
Load factor	80 %	40 %
Sea margin	5 %	5 %
1. Route information		
Route distance	11 207	11 207
Days at sea	21,37	21,37
Days in port	15,68	8,22
Fuel consumption at sea tonnes/day	278,70	278,70
Fuel consumption at port tonnes/day	13,94	13,94
2. Ship information		
Ship size TEU	13 200	13 200
TEUs carried	10 560	5 280
Ship size DWT	165 500	165 500
Design speed	*25*	*25*
3. Voyage costs		
Fuel costs	$ 3 707 879	$ 3 645 404
Cargo handling	$ 7 594 235	$ 3 812 267
Canal fees	$ 1 085 310	$ 1 043 070
Total voyage costs	**$ 12 387 424**	**$ 8 500 740**
Gross revenue	**$ 17 571 840**	**$ 4 039 200**
Voyage result	$ 5 184 416	$ -4 461 540
Time-Charter Equivalent (TCE)	***$ 139 918***	***$ -150 793***
4. Operating costs		
Operating costs	$ 433 819	$ 346 406
Total costs	**$ 12 821 244**	**$ 8 847 147**
Cost per TEU	*$ 1 214*	*$ 1 676*
Daily contribution to capital costs	***$ 128 210***	***$ -162 501***

Round-trip information:

Total days per round-trip	66,6	
Total annual round-trips	5,5	
	Single round-trip voyage	**Annual round-trip calculation**
Total sailing distance	22 414	122 765
Total TEUs carried	15 840	86 758
Total voyage costs:		
Fuel costs	$ 7 353 283	$ 40 275 110
Cargo handling	$ 11 406 502	$ 62 475 240
Canal fees	$ 2 128 380	$ 11 657 479
Total voyage costs	**$ 20 888 165**	**$ 114 407 828**
Gross revenue	**$ 21 611 040**	**$ 118 367 131**
Voyage result	*$ 722 875*	*$ 3 959 303*
Time-Charter Equivalent (TCE)	$ 10 847	$ 10 847
Total operating costs:		
Operating costs	$ 780 225	$ 4 273 420
Total costs	**$ 21 668 390**	**$ 118 681 248**
Cost per TEU	*$ 1 368*	*$ 1 368*
Total contribution to capital costs	***$ -57 350***	***$ -314 117***

Figure 7: Round-trip calculation model

6 Data

6.1 Route Information

The model will render the possibility to sail the trade route between Asia and the U.S. East Coast. There is a substantial cargo imbalance on this trade. In 2012, eastbound exports from Asia to the U.S. were 14.4 million TEU, while the westbound exports only were 7.5 million TEU (World Shipping Council, 2014b). In 2013, total Chinese exports to the U.S. were $ 370 billion, while imports from the U.S. to China were $ 152 billion (CIA, 2014). This is also the trade route that has the most traffic amongst the trade routes transiting through the Panama Canal (ACP, 2013c).[11]

We have chosen the port of New York and Los Angeles as the ports to represent the U.S. in our model as these will be able to accommodate Post-Panamax and ULCV vessels in time for the finished expansion, as well as being in the top bracket of

[11] Note that Container Liner Services normally have several port calls on a voyage. This is not accounted for in the model.

trafficked container ports in the U.S. (WSC, 2014). In Asia we have chosen the Port of Shanghai and the cluster of ports in South China, represented in the model by Guangzhou, Hong Kong and Shenzhen. These ports are heavily trafficked by container vessels both in port calls and volume, and are able to accommodate ULCV. Shanghai is the largest container port in the world measured in volume throughput and a large part of the trade going through the Panama Canal is therefore linked to the Port of Shanghai.

The different sea distances are measured in nautical miles and are collected from Sea Distances (2014) and Sea Rates (2014). Each voyage could be traveled via five waypoints in our model: through the Panama Canal, the Suez Canal, round the Cape Horn, the Cape of Good Hope or by using the U.S. Intermodal System. The different sea distances are presented in Table 2.

From	To	Route	Sea distance
Shanghai	New York	Panama Canal	10 582 Nm
		Suez Canal	12 370 Nm
		Cape Horn	16 746 Nm
		Good Hope	14 468 Nm
		Intermodal (LA)	5 708 Nm
Hong Kong	New York	Panama Canal	11 207 Nm
		Suez Canal	11 593 Nm
		Cape Horn	16 684 Nm
		Good Hope	13 686 Nm
		Intermodal (LA)	6 363 Nm
Guangzhou	New York	Panama Canal	11 290 Nm
		Suez Canal	11 676 Nm
		Cape Horn	16 769 Nm
		Good Hope	13 769 Nm
		Intermodal (LA)	6 446 Nm
Shenzhen	New York	Panama Canal	11 122 Nm
		Suez Canal	11 508 Nm
		Cape Horn	16 601 Nm
		Good Hope	13 601 Nm
		Intermodal (LA)	6 278 Nm

Table 2: Route distances

6.1.1 Time at sea

To calculate how many days a vessel spend at sea, we use a simple formula:

$$T_S = \frac{\frac{D}{V}}{24}$$

where T_S is total travelling time in days, D is total distance travelled in nautical miles, and V is average speed of the vessel in knots. This is then divided by 24 hours to get the total travelling time in days.

Usually, a sea margin is added when calculating the total time spent at sea. The sea margin accounts for changes in speed and possible detours from the route due to e.g. bad weather, and is often calculated in percentage or days. To account for these unforeseen factors we will add a sea margin of at least 5 % to all voyages[12].

It is also normal for vessels to spend time waiting in line to pass through the Suez and Panama Canal, and to use a lower travelling speed when passing through the canals. To avoid waiting in line, shipowners have the alternative to pay for a Just-In-Time (JIT) service, where the vessel will pass through the canals directly upon arrival. When using this service, shipowners will often regulate the vessel's speed to arrive directly at the scheduled transit time. To account for the time a vessel spend waiting to transit, we will use the average waiting time for each canal. This is approximately 18 hours for the Panama Canal (ACP, 2013a) and 5 hours for the Suez Canal (SCA, 2014a). The fuel consumption while waiting will be equivalent to the fuel consumption in port. Thus, the time spent waiting will therefore be added to the time spent in port and the calculation for fuel consumption in port will, in that way, also account for the fuel costs while waiting.

6.1.2 Time in port

The time spent in port for a vessel relies on several different factors, such as (Harries et. al., 2013):

- Actual distribution of containers onboard
- Container slots scheduled for loading and unloading
- Availability and utilization of cranes
- Speed and equipment of cranes (e.g. spreaders)
- On-shore handling of containers
- Time needed for maneuvering and mooring

[12] Grieg Star normally operates with a sea margin of 5 % on their voyages.

- Delays due to wind and waves in port (causing container swaying and ship motion)
- Possible idle times (e.g. waiting for availability of special equipment and personnel)

Another important factor is the amount of cargo the vessel is scheduled to load or unload. In most instances for container liner services, a vessel will stop by several ports on its way to its final destination. However, in our model we assume that a vessel will load all its cargo in one single port and unload all its cargo in another. Since the total time spent in port is related to the amount of cargo a vessel is scheduled to carry on its voyage, we will base our calculations on the average berth productivity per hour, i.e. how many containers (measured in TEU) a port is able to move on average per hour. This information is collected from a research on port productivity by the Journal of Commerce (2013) which indicate that more and more ports and terminals now operate close to 24 hours a day. The closer a port comes to running a round-the-clock operation, the higher its berth productivity becomes, given that this leads to less down time for its operations. We will assume that all ports in our analysis will run a 24/7 operation. We also assume that all the administrative work related to the voyage will be performed during the loading and unloading of the cargo, making the vessel ready to leave the port when the cargo handling is finished. For our U.S. ports, the average berth productivity per hour is 52 TEUs for both New York and Los Angeles. For the Asian ports, the research shows that Shanghai and Hong Kong are amongst the top 10 transshipment ports in the world with an average berth productivity of 86 and 68 TEUs per hour, while Guangzhou moves an average of 73 TEUs per hour and Shenzhen an average of 75 TEU. To calculate the time spent in port we use the following formula:

$$T_P = \frac{L}{(P \times 24)}$$

Where T_P is time spent in port, L represents the amount of containers loaded or unloaded to the vessel, and P is the average berth productivity per hour. This is then multiplied with 24 hours to get the time in days.

6.2 Ship information

All the information on the different container ships is collected from Clarkson Shipping Intelligence Network (2014) and is up-to-date real information down to each individual vessel. We have chosen to include the current container ship fleet of Panamax and Post-Panamax vessels in our model – in total 875 Panamax vessels and 1 208 Post-Panamax vessels (1^{st} of April, 2014). Since our main focus is directed towards achieving economies of scale by using larger vessels, and the fact that large vessels are preferred for long-distance voyages, we do not see it necessary to include the smaller ship classes as these are of less relevance for our research.
The most important information derived for each vessel is their design speed and TEU capacity. In our model we use the design speed proposed by Notteboom and Carriou (2009) for different vessel categories based on TEU capacity to quantify the fuel consumption. The ship information is also used when calculating travelling time, cargo handling and when calculating the cost of transiting through the canals. It is important to notice that the design speed used in our model is based on an average for different vessel categories and may not be entirely accurate as to what the design speed for a specific vessel might be. However, we will be able to account for these inaccuracies by completing fuel sensitivity analyses that will account for all speeds for the vessels (between 18 - 25 knots), not only the average design speed. The actual calculation of fuel consumption is further explained in Chapter 6.5.1.

6.3 Key variables

Bunker prices are collected from Bunker World (2014) and Ship & Bunker (2014). Bunker prices vary for each port, and depending on which port the vessel starts its voyage, the fuel costs might be significantly different.

Freight rates also differ and depend on where the cargo is exported. For example, cargo sent from Shanghai to New York can have a freight rate per FEU of $ 3 000, i.e. $ 1 500 per TEU, while on the same distance, only from New York to Shanghai, the same cargo can have a freight rate per FEU of $ 1 500, or $ 750 per TEU. This pricing difference is a product of the cargo imbalance between Asia and the U.S. mentioned in Chapter 6.1. Freight rates are collected from Drewry Container Insight Weekly

(2014) and the different shipping exchanges such as the Shanghai Shipping Exchange (2014).

6.4 Operating costs

The operating costs are collected from the Drewry Annual Report for Ship Operating Costs (2013). These costs are based on a daily average for different ship size categories. The Drewry report does not account for all ship sizes when presenting the daily average operating costs. For vessels that fall outside the categories presented by Drewry, we will simply use the costs represented by the category closest to the actual vessel. For example, a vessel with a capacity of 7 000 TEU will have the same daily operating costs as the vessels in the category 8-9 000 TEU. For the largest vessels with a capacity up to 18 000 TEU, we will use the daily operating costs presented for vessels in the category 10-12 000 TEU. It is fair to assume that cost items such as *insurance* and *stores, spares and lubricating oil* will be more sensitive to the size of a vessel. However, we will only use available data.
Daily operating costs are calculated by using the following formula:

$$OP = M + I + S + RM + MA$$

Where *OP* is operating costs, *M* is manning, *I is* insurance, *S* is stores, spares and lubricating oils, *RM* is repairs and maintenance, and *MA* is management and administration.

The total operating costs (*OC*) will be calculated by using a formula based on the amount of days the vessel is operated for each voyage:

$$OC = (T_S + T_P) \times OP$$

6.5 Voyage costs

Total voyage costs are calculated by using the following formula:

$$VC = FC + PA + CHC + CD$$

where *VC* is voyage costs, *FC* is fuel costs for main engine and auxiliaries, *PA* is port administrative fee, *CHC* is cargo handling costs in port, and *CD* is canal dues (including administrative fees and cargo fees). This formula is based on the formula used by Stopford (2009), with some alterations. As mentioned earlier, we calculate cargo-handling costs as part of the total voyage costs.

6.5.1 Fuel costs

When finding the specific voyage fuel costs we have based our calculations on a fuel consumption model developed by Notteboom and Carriou (2009):

	2000-3000	**3000-4000**	**4000-5000**	**5000-6000**	**6000-7000**	**7000-8000**	**8000-9000**	**9000-10000**	**10000+**	**Total #**
Number of vessels #	764	350	469	285	146	60	122	46	17	2259
Mean size (TEU)	2530	3432	4385	5491	6505	7372	8293	9307	11660	4332
Mean design speed (nm) - v_0	21.2	22.4	23.9	24.5	25.3	25.1	24.9	25.1	23.6	23.04
Mean age (year)	10.1	11.6	6.5	5.2	4.4	4.7	1.9	1.4	0.6	7.8
Mean main engine (kW)	20699	26741	38616	49243	57764	61436	64353	67259	66580	36084
Engine type										
- Two Stroke/Slow speed (%)	93	98	99	97	99	98	99	100	100	2184
- Other *(a)* (%)	7	2	1	3	1	2	1	0	0	75
Fuel consumption in tonnes/day *(b)*	80	102	142	199	229	233	255	N/A	N/A	121
Fuel consumption in grams//teu/mile	62	55	56	62	58	52	51	N/A	N/A	0.000051
	Estimations on fuel consumption at sea for various speed									
FC_{mi1} **in tonnes/day *(c)***	**78.1**	**106.4**	**136.4**	**171.3**	**203.4**	**230**	**260**	**292**	**367 *(d)***	**134.8**
Vessel speed (knots)										
18	47.0	54.9	52.8	57.9	68.8	77.8	87.9	98.8	124.1	66.0
19	56.1	65.6	63.1	69.3	82.2	93.0	105.1	118.1	148.4	78.9
20	66.5	77.7	74.7	82.0	97.4	110.1	124.5	139.8	175.7	93.5
21	**78.1**	91.3	87.8	96.4	114.4	129.4	146.2	164.2	206.4	109.8
22	-	**106.4**	102.4	112.3	133.4	150.8	170.5	191.5	240.7	128.0
23	-	-	118.5	130.1	154.5	174.7	197.5	221.8	278.7	**148.3**
24	-	-	**136.4**	149.7	177.8	201.0	227.2	255.2	320.7	-
25	-	-	-	**171.3**	**203.4**	**230.0**	**260.0**	**292.0**	**367.0**	-

(a) Not Specified

(b) HFO consumption is only available for the main engine and for 594 observations.

(c) Estimation from equation (4) for main engine and at the mean size in TEU and design speed v0 of the category.

(d) Due to the limited number of observations for vessels more than 10,000 TEU (17 vessels), we assume that the design speed for this category is 25 knots (Man B&W Diesel A/s, 2008)

Table 3: Fuel consumption model (Notteboom & Carriou, 2009)

This model is based on 594 observations, and contains fuel consumption in tonnes per day for vessel speeds from 18 to 25 knots for different vessel categories divided by TEU capacity. After comparing the fuel consumption provided in this model with similar studies, we have found it to be accurate for vessels with a capacity ranging from 2 000 to 10 000 TEU. Due to a limited number of observations for vessels with 10 000+ capacity (17 observations) the fuel consumption for these ships is not quite as accurate. Significant reductions in speed for Ultra-Large Container Vessels have become a widely accepted practice, and it is not unnatural for one of Maersk´s Triple-E vessels to sail at 12 knots instead of 24 knots (Maersk, 2014). The model does not account for extra slow steaming which would be of more relevance for ULCV vessels. This is due to the lack of fuel consumption data for vessel speeds below 18 knots. However, for our purpose this model provides enough information to calculate a fairly accurate estimate for fuel consumption even if we are not able to calculate consumption for speeds lower than 18 knots.

The total fuel costs are calculated by using the following formula:

$$FC = \left((T_S \times F_S) + (T_P \times F_P) \right) \times P$$

Where FC is total fuel costs, T_S is days spent at sea, F_S is fuel consumption at sea measured in tonnes/day, T_P is days spent in port, F_P is fuel consumption in port measured in tonnes/day, and P is fuel unit cost per metric ton.

Fuel consumption at sea can be derived from the fuel consumption model for each individual vessel based on the capacity (TEU) and speed of the vessel (V).

Fuel consumption in port is calculated as a percentage of the vessels fuel consumption at sea when sailing at its design speed. This percentage is set at 5 % of consumption at sea[13]. This is an estimation we have chosen due to lack of precise information and to avoid going too deep into the specifications of vessel engines. For our purpose, we assess this to be representative for all vessels.

6.5.2 Port and cargo-handling costs

When calculating cargo-handling costs (also referred to as terminal handling charges) we use an average handling cost per TEU based on a report on terminal handling charges by the European Commission (2009):

Port	Handling fee original valuta		Range	Exchange rates	In US dollars	
New York	$	414,00	330-550	1	$	414,00
Los Angeles	$	414,00	-	1	$	414,00
Shanghai	¥	681,00	465 - 1403	0,162877	$	110,92
Hong Kong		2 347,00 $	1700 - 2500	0,128795	$	302,28
Guangzhou	¥	741,00	465 - 1427	0,162877	$	120,69
Shenzhen	¥	1 120,00	465 - 1850	0,162877	$	182,42

Table 4: Terminal handling charges (European Commission, 2009)

The handling charges are port specific, and even if they are not recent figures we still assess them to be of satisfying relevance after comparing several sources that provides us with similar handling charges. It is worth mentioning that in some cases the handling cost per TEU may be discounted if the vessel loads or unloads larger

[13] A Grieg Star vessel with a 41.5 mt consumption at sea has an average consumption in port of 2 mt. This is approximately 5 %.

amounts of containers, i.e. the more containers handled, the lower the cargo handling price per TEU. Stopford (2009) claims that THC benefits from economies of scale since they are levied on ship tonnage. This will not be accounted for in our analysis, as we do not have access to more information than the average cost.

Individual port-cost items are costs that do not directly relate to the actual loading and unloading of cargo, and often include:

- Harbor and light dues
- Pilotage
- Towage
- Mooring/unmooring
- Other ancillary charges

Our port cost calculations are based on a port benchmarking research performed by the Hong Kong Marine Department (2006), presenting the benchmarking port costs for the top 20 container ports in 2005. This is an updated report based on a comparative study performed in 2001, and include a benchmark for all the ports we use in our research except Guangzhou, for which we will use a regional average benchmark that we have calculated based on the findings in the report. Note that mooring and ancillary charges for New York and Los Angeles are included in the other charges. The calculations are presented in Table 5.

	New York	Los Angeles	Shanghai	Hong Kong	Shenzhen	Guangzhou	Global average	Regional average (China) *
Harbor and light dues	$ 6 797	$ 6 797	$ 4 585	$ 2 073	$ 4 676	-	-	-
Pilotage charge	$ 4 770	$ 3 457	$ 5 635	$ 1 752	$ 3 293	-	-	-
Towage charges	$ 7 868	$ 3 300	$ 6 733	$ 1 933	$ 2 659	-	-	-
Mooring/unmooring charges	-	-	$ 66	$ 147	$ 604	-	-	-
Ancilliary charges	-	-	$ 405	$ 13	$ 178	-	-	-
Total port charges (2005)	**$ 19 435**	**$ 13 554**	**$ 17 424**	**$ 5 918**	**$ 11 410**	**$ 11 930**	**$ 16 678**	**$ 11 930**
Port charges 2014**	$ 23 227	$ 16 198	$ 20 823	$ 7 072	$ 13 636	$ 14 257	$ 19 932	$ 14 257

**Port charges for Guangzhou are based on the regional average du to lack of information*
***Estimated port charges for 2014 are based on an annual growth rate of 2 %*

Table 5: Port administration charges

As the figures found in this report can be assumed to be somewhat outdated, we have compared them to the average port costs in Houston for a L-class Open Hatch vessel operated by Grieg Star[14] (Appendix 2). Based on this, we have set an average annual growth rate of 2 % to convert the 2005-figures into more realistic figures for 2014[15].

6.5.3 Canal dues

The Panama Canal toll is measured using tariffs collected from the ACP website (ACP, 2014e)[16]. The toll structure is designed by charging by the total capacity of a vessel, and the amount of containers carried. The ACP charges transits per TEU based on the following tolls (2011):

1. Toll per TEU capacity $ 74
2. Toll per container with cargo $ 8
3. Toll per TEU capacity (ballast) $ 65.60

This means that a vessel will pay $ 74 per TEU of its total capacity, and for each container with cargo there will be an additional toll of $ 8. A vessel that transits the Canal in ballast, i.e. without cargo, will be charges $ 65.60 per TEU of its total capacity. Other significant fees when a vessel transits the Canal are:

- Tug hire
- Line handling
- Locomotive and wires
- Security fee
- Inspection fee
- PCSOPEP fee (Panama Canal Shipboard Oil Pollution Emergency Plan)
- Bank fees
- Fumigation fee
- Launch service
- Agency fee
- Incidentals

[14] In addition, Grieg Star pays a daily port charge. However, due to the lack of information about daily port charges on the specific ports, we will only use the figures presented in Table 7.

[15] The port charges are not assumed to be a perfect reproduction of reality. However, it is natural to believe that the charges have increased.

[16] We do not account for possible long-term contracts between the ACP and Container Liner Services, which could lead to lower transit costs.

These vary depending on the vessel size, type and its maneuvering system, but will not be considerably different from the figures in our calculations. Our calculations are based on a transit invoice from a Grieg Star vessel transiting the Canal in January 2014 (Appendix 3).

The Suez Canal transit costs can be calculated by using a transit calculator provided by the Suez Canal Authority (SCA, 2014b). However, we have found it more reliable to use the calculations made by Notteboom & Rodrigue (2011a) presented in Table 6, as they have calculated the transit fees based on a vessels TEU capacity.

TEU-capacity	Typical SCNT*	Canal transit fees	Net tonnage fee	Fee on-deck containers	Per TEU average
3 000	30 659	$ 221 403	$ 205 002	$ 16 400	$ 73,80
4 000	41 625	$ 271 939	$ 251 796	$ 20 144	$ 67,98
6 000	63 557	$ 373 589	$ 339 627	$ 33 963	$ 62,26
8 000	85 489	$ 455 770	$ 414 336	$ 41 434	$ 56,97
10 000	107 421	$ 536 782	$ 483 588	$ 53 195	$ 53,68
13 000	140 319	$ 654 455	$ 584 335	$ 70 120	$ 50,34
18 000	-	$ 851 798	-	-	$ 47,32 **

*Suez Canal Net Tonnage = 10,966 x TEU-capacity - 2238,7 (R-square = 0,9861)

**Based on an average decline in cost per TEU-average from 8 000 to 10 000 TEU and 10 000 to 13 000 TEU of approximately 6 %

Table 6: Suez Canal transit fees

The tolls for a container vessel transiting the Suez Canal are based on the weight of the vessel rather than the amount of TEUs carried. Thus, a vessel transiting the Canal will pay a certain fee per tonne for the first 5 000 tonnes carried, then a slightly lower fee per tonne for the next 5 000, and so on. Based on the average cost per TEU calculated in Table 6, we have estimated the average cost for an 18 000 TEU vessel. Since the change in cost from 8 000 TEU to 10 000 TEU and 10 000 TEU to 13 000 TEU has an average decrease per TEU of 6 %, we have estimated the cost per TEU based on the same percentage. The stable decrease in cost per TEU related to the TEU-capacity of the vessels is presented in Figure 8.

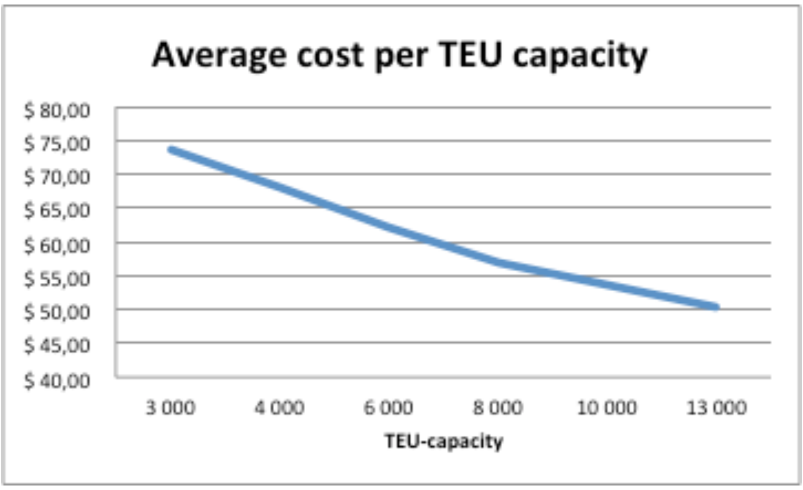


Figure 8: Average cost per TEU-capacity for the Suez Canal

The SCA also charge for other services related to the transit, such as:

- Tugs
- Mooring
- Pilotage
- Disbursements

We use the SCA transit calculator to find the fees for other services related to transits through the Suez Canal. We assume a fully laden container ship in three different sizes – a Panamax vessel with a capacity of 5 200 TEU, a Post-Panamax vessel with a capacity of 13 200 TEU and a Post-Panamax vessel, representing the ULCV class, of 18 000 TEU. The reason why we do not calculate for several ship sizes is a consequence of the scope of our research and by using the largest ship size able to transit the Panama Canal pre-expansion (~5200 TEU), post-expansion (~13 200 TEU) and the largest ship size able to transit the Suez Canal (~18 000 TEU), we will cover the most important ship sizes for our analysis.

6.6 Capital costs

The capital costs of a vessel differ from the other cost categories in the way that the other costs, such as operating and voyage costs, are necessary for the ships trade ability, while capital costs are obligations which have no direct effect on its physical trade (Stopford, 2009). When a ship is built there exist an initial purchase of the vessel and payment to the shipyard, this is followed by periodic cash payments to banks or equity investors who put up the capital to purchase the vessel, and finally, if the shipowner decides to sell the vessel, cash received from the sale (ibid.). The annual capital costs of a vessel can be calculated by using the following formula:

$$P = \frac{r(PV)}{1-(1+r)^{-n}}$$

Where P is payment, PV is present value (purchase price of the vessel), r is rate per period, and n is number of periods. This is an annuity payment formula and is used to calculate the periodic payment on an annuity. According to a research made by MAN Diesel & Turbo (2008) the lifetime of almost all container ships is higher or equal to 25 years, and only 9 % are older than 25 years. It is therefore natural to base the calculation of capital costs on a lifetime between 20 - 30 years for a vessel. It is also not improbable that a shipowner calculates for an expected sale of the vessel by the end of its lifetime.

As mentioned in Chapter 4.2, the capital cost of a vessel is considered sunk cost, and is therefore not of any particular relevance when comparing the different route alternatives. Instead, we calculate the daily contribution to capital costs from each specific route.

7 Analysis

In this chapter, we will compare the costs for the different route alternatives to assess the competitiveness of the Panama Canal. We will start by looking at scenarios using the Panama Canal before the expansion to get a picture of the current situation before we look at scenarios after the expansion. Further, we will look at different round-trip scenarios to identify the consequences related to the trade-off between time and cost. Finally, we will discuss the sensitivity of key variables that are not covered during the initial analysis.

We will perform our analysis scenarios with three different vessel sizes to cover the most important ship classes. The vessels will be *existing* vessels collected from the Clarkson SIN database presented in Table 7.

Vessel	TEU-capacity	DWT	GT	Length (m)	Beam (m)	Draft (m)	Design speed (kts)	Built (year)
Octavia	5 117	66 160	53 807	294,1	32,2	13,6	25,0	2005
MSC Paloma	13 200	165 500	153 092	365,5	51,2	15,5	23,5	2010
Majestic Maersk	18 270	194 431	194 849	399,9	59,0	14,5	23,0	2013

Table 7: Vessel overview

Octavia will represent the Panamax vessel segment, which are the largest vessels able to transit the old locks of the Panama Canal. With a TEU-capacity of 5 117 TEU it is one of the largest vessels in the Panamax register (Clarkson SIN, 2014). The Octavia does, however, have a draft that exceeds the Panama Canal restrictions, so it will not be able to transit the Canal fully laden. *MSC Paloma* will represent the Post-Panamax vessel segment, which is the ship category that will be able to fit the new locks of the Panama Canal after its expansion. With a TEU-capacity of 13 200 TEU, the MSC Paloma represent one of the largest ships expected to be able to transit the Canal after the expansion. The *Majestic Maersk* is one of the largest ships in the world, and will with its 18 270 TEU-capacity represent the ULCV segment. As of today, there are only six vessels of this size, but there are approximately 25 vessels in the orderbook with the latest order scheduled for delivery by the end of 2015. The ULCV class is able to sail all routes except through the Panama Canal.

Due to the fact that we are using existing vessels, we will use their design speed as a basis when we run the different scenarios, i.e. 25 knots for Octavia, 23 knots for MSC Paloma (rounded down from 23.5 due to information availability on fuel consumption) and 23 knots for Majestic Maersk. In addition, we will use a load factor of 80 % as a basis for all vessels in our scenarios.

All analysis scenarios will be based on key figures collected the 9th of May 2014:

- Bunker price IFO 380:
  - Shanghai: 614 USD/mt
  - Hong Kong: 600.50 USD/mt
  - New York: 613 USD/mt
- Freight rate:
  - Shanghai - USEC (Base port): 3 328 USD/FEU
  - USEC - Shanghai: 1530 USD/FEU

Thus, all voyage calculations for routes from Shanghai will be calculated with a bunker price of 614 USD/mt and routes from Hong Kong, Guangzhou and Shenzhen will be calculated with the Hong Kong bunker price of 600.50 USD/mt. The Shanghai

- USEC freight rate will be representative for all routes from Asia to the U.S. East Coast.

7.1 Before the Panama Canal expansion

To set a basis for comparing different scenarios we want to look at how the current situation is. In the following analysis we will compare the current costs of sailing the different routes. This will give us a perspective on how the competitive situation is and what the determining factors are when deciding which route to sail. We will start by performing simple analyses for single routes going from Asia to the U.S. East Coast, including a comparison of costs. Then we will examine relevant variables and their sensitivity.

7.1.1 Scenario 1. The Panamax vessel

The first analysis is based on a simple scenario where we compare the different route alternatives when assuming that the same vessel, a Panamax vessel, is used. This way, we are able to focus on the costs for a shipowner, without assuming that he has the ability to choose between different ship sizes.

The results from the scenario are presented in Table 8.

		Panama Canal	Suez Canal	Cape Horn	Good Hope	Intermodal
Shanghai - New York	Distance	10 582 nm	12 370 nm	16 746 nm	14 468 nm	5 708 nm
	TCE	$ 89 477	$ 71 700	$ 43 334	$ 62 701	$ -437 835
	Cost per TEU	$ 1 181	$ 1 248	$ 1 373	$ 1 262	$ 3 332
Hong Kong - New York	Distance	11 207 nm	11 593 nm	16 684 nm	13 686 nm	6 363 nm
	TCE	$ 51 822	$ 51 910	$ 23 065	$ 45 292	$ -445 725
	Cost per TEU	$ 1 390	$ 1 388	$ 1 543	$ 1 400	$ 3 547
Guangzhou - New York	Distance	11 290 nm	11 676 nm	16 769 nm	13 769 nm	6 446 nm
	TCE	$ 79 462	$ 79 407	$ 43 679	$ 69 585	$ -403 753
	Cost per TEU	$ 1 213	$ 1 211	$ 1 367	$ 1 223	$ 3 370
Shenzhen - New York	Distance	11 122 nm	11 508 nm	16 601 nm	13 601 nm	6 278 nm
	TCE	$ 71 983	$ 71 967	$ 37 743	$ 62 901	$ -425 819
	Cost per TEU	$ 1 267	$ 1 265	$ 1 420	$ 1 277	$ 3 424

Table 8: Scenario 1 – Overview results

Four different points of departure are presented. All voyages have New York as a destination and the shipowner has the choice between five different sailing routes. Common for all voyages, independent of point of departure, is that the intermodal choice is unrealistically expensive compared to the other alternatives. This is because it is expensive to transport cargo across the entire U.S. continent[17] and because of the

[17] Grieg Star has confirmed this. They have performed their own analysis and found it to be a non-competitive alternative.

complexity of the U.S. Intermodal System. Since our target destination for all scenarios will be the U.S. East Coast, represented by New York, we will exclude the intermodal alternative for the rest of the analysis and point our focus towards all-water routes.

For the voyage between Shanghai and New York, transiting through the Panama Canal is the most profitable and less costly alternative with a cost per TEU of $ 1 181 and a Time Charter Equivalent (TCE) of $ 89 477 (Table 8). This is mainly due to the shorter distance, which will lead to lower fuel costs for the voyage.
On the other hand, if we look at the voyage between Hong Kong and New York we can see that the distance (Table 8) is more equal for the route through the Panama Canal and the Suez Canal. In this case, the Suez Canal is the preferred alternative with a cost per TEU of $ 1 388 compared to $ 1 390 through the Panama Canal. This is interesting, because it means that most of the difference between the two canal alternatives seems to be related to the cost of transiting the canals.

If we compare Hong Kong with Guangzhou and Shenzhen, we can already see that the difference between the route alternatives is similar for the three ports:

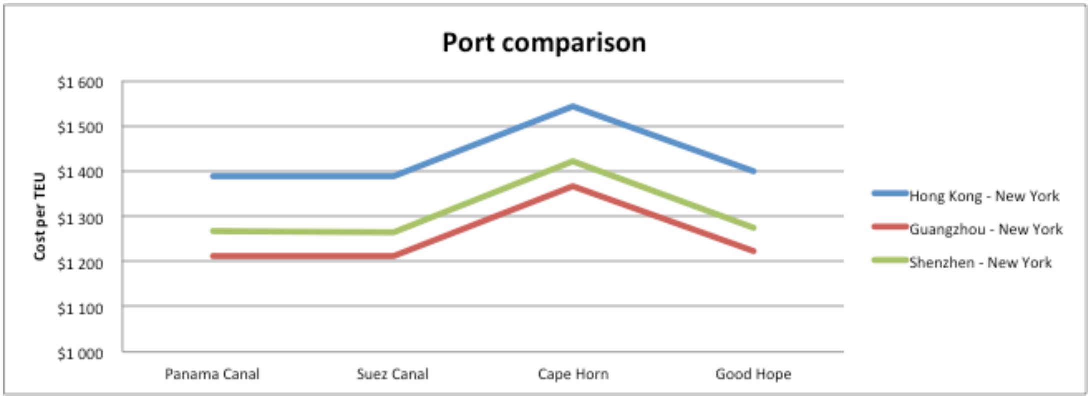


Figure 9: Port comparison

As we already know, these ports are located in close proximity to each other and the difference in cost per TEU will therefore mostly be explained by the cargo handling costs in port, which is much lower for Guangzhou and Shenzhen compared to the port of Hong Kong. Since our focus is on comparing route alternatives, finding the cheapest port alternatives is not necessarily in the scope of our research. Based on our findings in Figure 9, we can therefore carry out our further analyses with Hong Kong as a representative for the three ports.

Due to the small difference in sailing distance on the Hong Kong - New York voyage, we will be able to compare routes based on the sensitivity of key variables. Further, the Shanghai - New York voyage represents an interesting voyage for the ACP due to the advantage of shorter sailing distance on the Panama Canal voyage and the high amount of volume traded through the Port of Shanghai.

7.1.1.1 Speed sensitivity

One of the most influential variables in the total voyage cost is the speed of the vessel. We run our scenarios based on the design speed for each vessel, but in many instances the speed can be changed to optimize the voyage. In Table 9 we present the speed sensitivity for a Panamax vessel on the Shanghai - New York voyage:

	Shanghai - New York (via Panama)		**Shanghai - New York (via Suez)**	
Speed (knots):	Cost per TEU	Days at sea	Cost per TEU	Days at sea
18	$ 938	25,78	$ 966	30,14
19	$ 966	24,43	$ 998	28,55
20	$ 995	23,21	$ 1 032	27,13
21	$ 1 028	22,10	$ 1 070	25,84
22	$ 1 062	21,10	$ 1 110	24,66
23	$ 1 099	20,18	$ 1 153	23,59
24	$ 1 139	19,34	$ 1 199	22,61
25	$ 1 181	18,56	$ 1 248	21,70
	Shanghai - New York (via Cape Horn)		**Shanghai - New York (via Good Hope)**	
Speed (knots):	Cost per TEU	Days at sea	Cost per TEU	Days at sea
18	$ 993	40,80	$ 933	35,25
19	$ 1 037	38,66	$ 970	33,40
20	$ 1 083	36,72	$ 1 010	31,73
21	$ 1 133	34,97	$ 1 054	30,22
22	$ 1 187	33,39	$ 1 101	28,84
23	$ 1 246	31,93	$ 1 151	27,59
24	$ 1 307	30,60	$ 1 205	26,44
25	$ 1 373	29,38	$ 1 262	25,38

Table 9: Scenario 1 – Speed sensitivity, Shanghai – New York

What is important to notice in the speed sensitivity analysis is the relationship between the cost per TEU and the days spent at sea. For the shipowner this represents a tradeoff between spending less time at sea at the expense of a higher cost and lowering the cost at the expense of spending more time at sea. For example, in this case we see that a vessel can lower its speed to approximately 22 knots when sailing the Panama Canal route, and arrive in New York at a much lower cost within the same time window as if it sails at 25 knots through the Suez Canal.

For Hong Kong - New York we see that the same vessel sailing the Panama Canal would have to lower its average speed by approximately 1 knot at the account of spending more time at sea to compete with the lower cost of transiting through the Suez Canal:

	Hong Kong - New York (via Panama)		Hong Kong - New York (via Suez)	
Speed (knots):	Cost per TEU	Days at sea	Cost per TEU	Days at sea
18	$ 1 139	27,31	$ 1 129	28,25
19	$ 1 167	25,87	$ 1 158	26,76
20	$ 1 198	24,58	$ 1 190	25,42
21	$ 1 231	23,41	$ 1 224	24,21
22	$ 1 267	22,34	$ 1 261	23,11
23	$ 1 305	21,37	$ 1 301	22,11
24	$ 1 346	20,48	$ 1 343	21,19
25	$ 1 390	19,66	$ 1 388	20,34
	Hong Kong - New York (via Cape Horn)		**Hong Kong - New York (via Good Hope)**	
Speed (knots):	Cost per TEU	Days at sea	Cost per TEU	Days at sea
18	$ 1 173	40,65	$ 1 095	33,35
19	$ 1 215	38,51	$ 1 130	31,59
20	$ 1 260	36,59	$ 1 167	30,01
21	$ 1 310	34,85	$ 1 207	28,58
22	$ 1 362	33,26	$ 1 250	27,28
23	$ 1 419	31,82	$ 1 297	26,10
24	$ 1 479	30,49	$ 1 347	25,01
25	$ 1 543	29,27	$ 1 400	24,01

Table 10: Scenario 1 – Speed sensitivity, Hong Kong – New York

Another interesting observation is that the lowest cost per TEU can be achieved by sailing the Good Hope route at a slow-steam pace of 18 knots. This will, however, take more than 35 days from Shanghai and approximately 33 days from Hong Kong. The question again is how many days a shipowner is willing to let the vessel spend at sea to lower its voyage costs, when the alternative would be spending this time generating income on another voyage[18].

7.1.1.2 Sea margin

Another variable that may influence the choice of route is the sea margin. As mentioned earlier, the sea margin is related to weather conditions and other unforeseen influences. We operate with a 5 % sea margin, but this may have to be altered for the longer routes such as those rounding the Cape Horn and the Cape of Good Hope. Table 11 presents the sensitivity of sea margin for the Hong Kong - New York route, based on the cost per TEU.

[18] In addition cargo owners may be willing to pay the extra price and receive their goods faster.

Sea margin	Hong Kong - New York (via Panama)		Hong Kong - New York (via Suez)		Hong Kong - New York (via Cape Horn)		Hong Kong - New York (via Good Hope)	
0 %	$	1 363	$	1 360	$	1 503	$	1 367
1 %	$	1 368	$	1 365	$	1 511	$	1 373
2 %	$	1 373	$	1 371	$	1 519	$	1 380
3 %	$	1 379	$	1 376	$	1 527	$	1 386
4 %	$	1 384	$	1 382	$	1 535	$	1 393
5 %	$	1 390	$	1 388	$	1 543	$	1 400
6 %	$	1 396	$	1 394	$	1 552	$	1 407
7 %	$	1 401	$	1 400	$	1 561	$	1 414
8 %	$	1 407	$	1 406	$	1 569	$	1 421
9 %	$	1 413	$	1 412	$	1 579	$	1 428
10 %	$	1 420	$	1 419	$	1 588	$	1 436

Table 11: Sea margin sensitivity

Given the time of year, the weather may be harsher for the routes around Cape Horn and Good Hope, and a higher sea margin would be more realistic. For example, with a more realistic sea margin of 8 %, the route around the Cape of Good Hope becomes less attractive compared to the safer and shorter alternatives through the canals.

7.1.2 Scenario 2. Economies of scale

In this scenario, we will look at the possible advantages of sailing a larger vessel on the routes that are without any constraints. We will compare the following alternatives:

- A 5 117 TEU Panamax vessel through the Panama Canal
- A 13 200 TEU Post-Panamax vessel on all other routes
- A 18 270 TEU ULCV vessel on all other routes

This will allow us to investigate which large-scale advantages that exist, given that the shipowner has the possibility to choose between different ship sizes, and is able to exploit the cargo capacity on the larger vessels. As mentioned, we do not account for investment and capital costs in our analysis, which could present a bigger cost for larger vessels. In addition, for this and further analyses we will use a sea margin of 8 % for the two route alternatives Cape Horn and Good Hope.

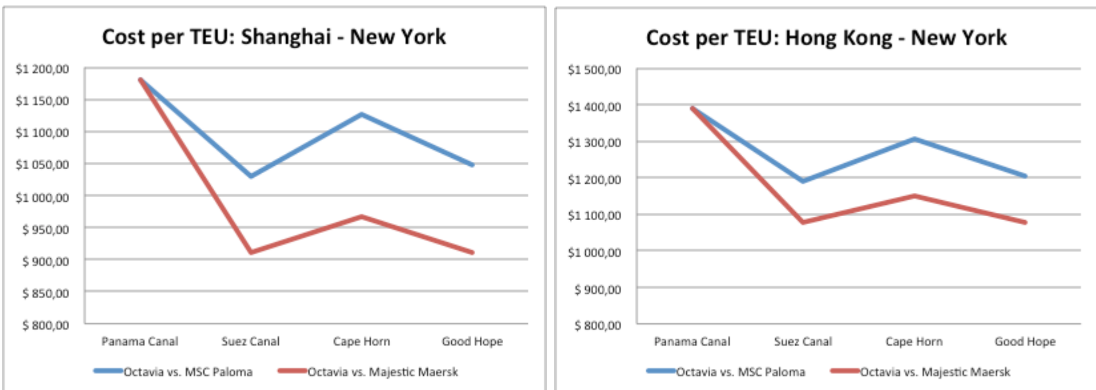


Figure 10: Scenario 2 – Cost per TEU overview

Figure 10 presents a comparison of the cost per TEU when sailing the Shanghai and Hong Kong voyage with all three ships. The cost per TEU for the Panama Canal route is for the Octavia vessel, which is the only vessel that can transit that canal, while the MSC Paloma represents the other alternatives on the blue line, and the Majestic Maersk on the red line. It is easy to see that economies of scale can be exploited by sailing larger ships on the alternative routes.

7.1.2.1 Load factor

Table 12 displays the load factor sensitivity for the Hong Kong - New York voyage:

Hong Kong - New York							
Vessel	Octavia	MSC Paloma			Majestic Maersk		
Load factor:	Panama Canal	Suez Canal	Cape Horn	Good Hope	Suez Canal	Cape Horn	Good Hope
40 %	$ 2 035	$ 1 633	$ 1 865	$ 1 664	$ 1 414	$ 1 554	$ 1 409
41 %	$ 2 004	$ 1 611	$ 1 837	$ 1 642	$ 1 397	$ 1 534	$ 1 393
42 %	$ 1 974	$ 1 590	$ 1 811	$ 1 621	$ 1 382	$ 1 515	$ 1 378
43 %	$ 1 945	$ 1 571	$ 1 786	$ 1 600	$ 1 367	$ 1 497	$ 1 363
44 %	$ 1 918	$ 1 552	$ 1 763	$ 1 581	$ 1 353	$ 1 480	$ 1 349
45 %	$ 1 892	$ 1 534	$ 1 740	$ 1 562	$ 1 339	$ 1 464	$ 1 335
46 %	$ 1 867	$ 1 517	$ 1 719	$ 1 544	$ 1 326	$ 1 448	$ 1 322
47 %	$ 1 843	$ 1 500	$ 1 698	$ 1 527	$ 1 314	$ 1 433	$ 1 310
48 %	$ 1 820	$ 1 485	$ 1 678	$ 1 511	$ 1 302	$ 1 419	$ 1 298
49 %	$ 1 798	$ 1 470	$ 1 659	$ 1 495	$ 1 291	$ 1 405	$ 1 287
50 %	$ 1 777	$ 1 455	$ 1 641	$ 1 480	$ 1 280	$ 1 392	$ 1 276
51 %	$ 1 757	$ 1 441	$ 1 623	$ 1 466	$ 1 269	$ 1 379	$ 1 266
52 %	$ 1 737	$ 1 428	$ 1 606	$ 1 452	$ 1 259	$ 1 367	$ 1 256
53 %	$ 1 719	$ 1 415	$ 1 590	$ 1 439	$ 1 250	$ 1 355	$ 1 246
54 %	$ 1 701	$ 1 402	$ 1 574	$ 1 426	$ 1 240	$ 1 344	$ 1 237
55 %	$ 1 683	$ 1 390	$ 1 559	$ 1 414	$ 1 231	$ 1 333	$ 1 228
56 %	$ 1 666	$ 1 379	$ 1 545	$ 1 402	$ 1 222	$ 1 323	$ 1 219
57 %	$ 1 650	$ 1 368	$ 1 531	$ 1 390	$ 1 214	$ 1 312	$ 1 211
58 %	$ 1 635	$ 1 357	$ 1 517	$ 1 379	$ 1 206	$ 1 303	$ 1 203
59 %	$ 1 620	$ 1 347	$ 1 504	$ 1 368	$ 1 198	$ 1 293	$ 1 195
60 %	$ 1 605	$ 1 337	$ 1 491	$ 1 358	$ 1 191	$ 1 284	$ 1 188
61 %	$ 1 591	$ 1 327	$ 1 479	$ 1 348	$ 1 183	$ 1 275	$ 1 180
62 %	$ 1 577	$ 1 318	$ 1 467	$ 1 338	$ 1 176	$ 1 267	$ 1 173
63 %	$ 1 564	$ 1 308	$ 1 456	$ 1 329	$ 1 169	$ 1 258	$ 1 167
64 %	$ 1 551	$ 1 300	$ 1 445	$ 1 319	$ 1 163	$ 1 250	$ 1 160
65 %	$ 1 539	$ 1 291	$ 1 434	$ 1 311	$ 1 156	$ 1 243	$ 1 154
66 %	$ 1 527	$ 1 283	$ 1 423	$ 1 302	$ 1 150	$ 1 235	$ 1 147
67 %	$ 1 515	$ 1 275	$ 1 413	$ 1 294	$ 1 144	$ 1 228	$ 1 141
68 %	$ 1 504	$ 1 267	$ 1 403	$ 1 286	$ 1 138	$ 1 221	$ 1 136
69 %	$ 1 493	$ 1 259	$ 1 394	$ 1 278	$ 1 132	$ 1 214	$ 1 130
70 %	$ 1 482	$ 1 252	$ 1 385	$ 1 270	$ 1 127	$ 1 207	$ 1 124
71 %	$ 1 472	$ 1 245	$ 1 376	$ 1 263	$ 1 122	$ 1 201	$ 1 119
72 %	$ 1 462	$ 1 238	$ 1 367	$ 1 256	$ 1 116	$ 1 194	$ 1 114
73 %	$ 1 452	$ 1 231	$ 1 358	$ 1 249	$ 1 111	$ 1 188	$ 1 109
74 %	$ 1 442	$ 1 225	$ 1 350	$ 1 242	$ 1 106	$ 1 182	$ 1 104
75 %	$ 1 433	$ 1 218	$ 1 342	$ 1 235	$ 1 102	$ 1 176	$ 1 099
76 %	$ 1 424	$ 1 212	$ 1 334	$ 1 229	$ 1 097	$ 1 171	$ 1 094
77 %	$ 1 415	$ 1 206	$ 1 326	$ 1 222	$ 1 092	$ 1 165	$ 1 090
78 %	$ 1 406	$ 1 200	$ 1 319	$ 1 216	$ 1 088	$ 1 160	$ 1 085
79 %	$ 1 398	$ 1 194	$ 1 312	$ 1 210	$ 1 084	$ 1 154	$ 1 081
80 %	$ 1 390	$ 1 189	$ 1 305	$ 1 205	$ 1 079	$ 1 149	$ 1 077

Table 12: Scenario 2 – Load factor sensitivity

The previous results are based on an 80 % load factor. The load factor may vary depending on the vessel size, as larger vessels depend on a higher demand and cargo supply to uphold the same load factor. Consequently, a larger vessel may be forced to sail with a lower load factor than a small vessel. Given that the larger vessels are not able to sail with an 80 % load factor, this sensitivity analysis shows that a 13 200 TEU vessel needs a 55 % load factor if sailing the Suez Canal to compete on cost with the 5 117 TEU vessel sailing through the Panama Canal. Further, it will need a 70 % load factor to sail the Cape Horn route, and a 57 % load factor to sail the Good Hope route. For a 18 270 TEU vessel the load factor can be as low as 42 % through the Suez Canal and Good Hope, and 51 % for the Cape Horn route.

For the Shanghai - New York voyage we got similar results, but due to the longer sailing distance for the alternative routes, and consequently higher fuel costs, the necessary load factor will be slightly higher than for the Hong Kong - New York voyage.

7.1.3 Summary

From the pre-expansion scenarios, we see that the cost per TEU is inversely proportional with the increase in vessel size sailed on the alternative routes. This confirms our expectations for large-scale advantages, and it emphasizes the competitive disadvantage of having constraining locks in the Panama Canal. The different sensitivity analyses show us that the results are sensitive to changes in key variables. This becomes important when the shipowners decide whether or not they want to sail at a higher cost to avoid losing possible income from spending more time at sea for each voyage.

7.2 After the Panama Canal expansion

In this chapter, we will compare the costs of sailing the different routes with scenarios after the expansion of the Panama Canal. First, we will use the same tariff rates for transiting the Canal as before the expansion. Then, we will look at how much the tariffs needs to change for the Panama Canal to stay competitive. Key variables in this analysis will be equal to those used in the previous scenarios.

7.2.1 Scenario 3. The Post-Panamax vessel

In this scenario we compare the costs of sailing the MSC Paloma, a 13 200 TEU vessel, on all routes. This is based on the expectation that the MSC Paloma will represent the largest vessel able to transit the new locks of the expanded Panama Canal.

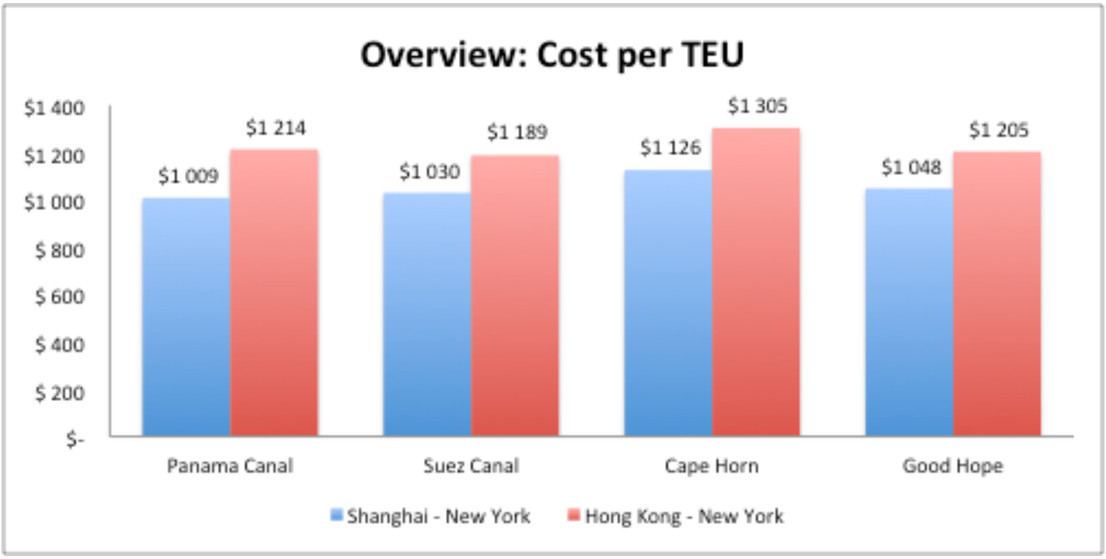
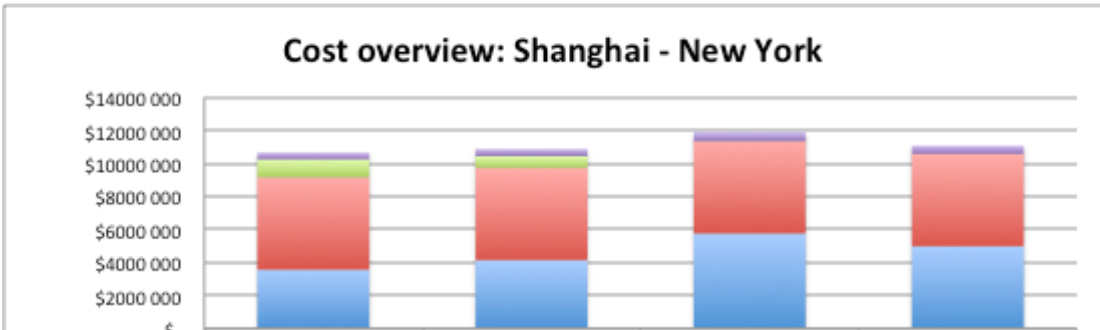


Figure 11: Scenario 3 – Cost per TEU overview

As displayed in Figure 11, we see that a vessel transiting through the Panama Canal will have a slight cost advantage on the Shanghai - New York voyage, but on the Hong Kong - New York voyage it will still be advantageous to sail the Suez Canal or around the Cape of Good Hope.



	Panama Canal	Suez Canal	Cape Horn	Good Hope
Operating costs	$404 009	$437 587	$545 040	$492 522
Canal fees	$1085 310	$695 468	$-	$-
Cargo handling	$5587 197	$5587 197	$5587 197	$5587 197
Fuel costs	$3575 700	$4154 524	$5758 906	$4991 311

Figure 12: Scenario 3 – Cost overview Shanghai – New York

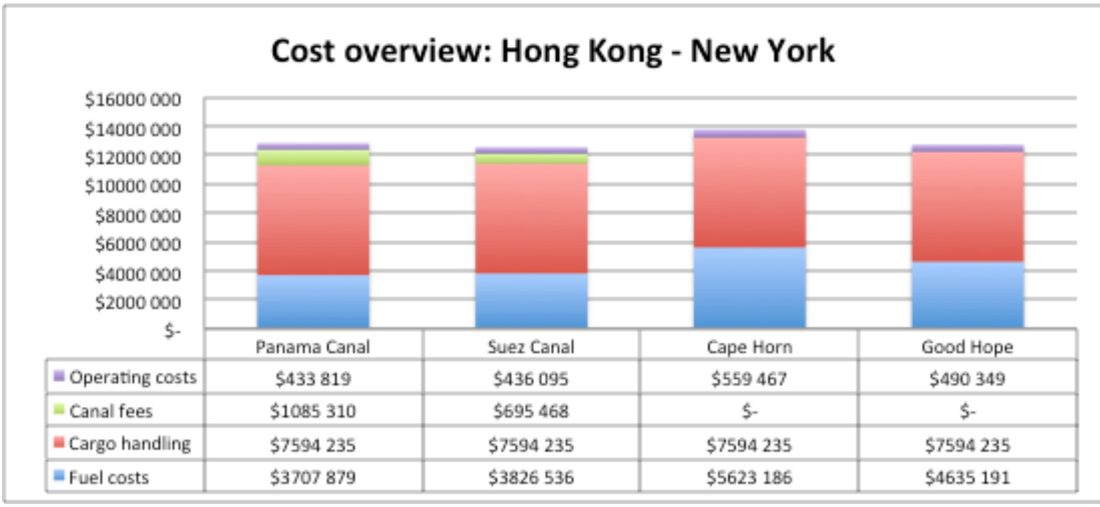


Figure 13: Scenario 3 – Cost overview Hong Kong – New York

From Figure 12 and 13, we see that the major difference in cost still can be explained by the discrepancy in canal fees. When determining if the Panama Canal is priced too high compared to the Suez Canal, we must remember that the time advantage of transiting through the Panama Canal might outplay the cost advantage of transiting the alternative routes. We will therefore perform a speed sensitivity analysis.

7.2.1.1 Speed sensitivity

Table 13 presents the speed sensitivity for the Hong Kong - New York voyage:

	Hong Kong - New York (via Panama)		Hong Kong - New York (via Suez)	
Speed (knots):	Cost per TEU	Days at sea	Cost per TEU	Days at sea
18	$ 1 068	27,31	$ 1 038	28,25
19	$ 1 093	25,87	$ 1 064	26,76
20	$ 1 120	24,58	$ 1 092	25,42
21	$ 1 149	23,41	$ 1 122	24,21
22	$ 1 181	22,34	$ 1 154	23,11
23	$ 1 214	21,37	$ 1 189	22,11
24	$ 1 250	20,48	$ 1 225	21,19
25	$ 1 288	19,66	$ 1 265	20,34
	Hong Kong - New York (via Cape Horn)		**Hong Kong - New York (via Good Hope)**	
Speed (knots):	Cost per TEU	Days at sea	Cost per TEU	Days at sea
18	$ 1 084	41,98	$ 1 022	34,44
19	$ 1 122	39,77	$ 1 053	32,62
20	$ 1 163	37,78	$ 1 087	30,99
21	$ 1 207	35,98	$ 1 124	29,52
22	$ 1 254	34,35	$ 1 163	28,17
23	$ 1 305	32,85	$ 1 205	26,95
24	$ 1 358	31,48	$ 1 249	25,83
25	$ 1 416	30,22	$ 1 296	24,79

Table 13: Scenario 3 – Speed sensitivity, Hong Kong – New York

Keeping in mind that the operating speed is 23 knots for MSC Paloma, we see that if a vessel transiting the Panama Canal lower its speed to average slightly above 22 knots, it will be able to transit at the same cost per TEU in almost the same amount of time as if the vessel transits the Suez Canal at operating speed.

For the Shanghai - New York voyage the difference in sailing time is greater. The MSC Paloma could lower its speed to an average of 20 knots and still be able to arrive in New York in approximately the same amount of days (approximately 23 days) as through the Suez Canal route. This would decrease the cost per TEU from $ 1 009 to $ 918 on the Panama Canal route, while the cost per TEU on the Suez Canal route would be $ 1 030.

7.2.2 Scenario 4. Economies of scale

In this scenario, we will perform the same analysis as we did in the pre-expansion chapter, where we look at the possible advantages of sailing a larger vessel on the routes that are without any constraints. Now, we will compare the following alternatives:

- A 13 200 TEU Post-Panamax vessel through the Panama Canal
- A 18 270 TEU ULCV vessel on all other routes

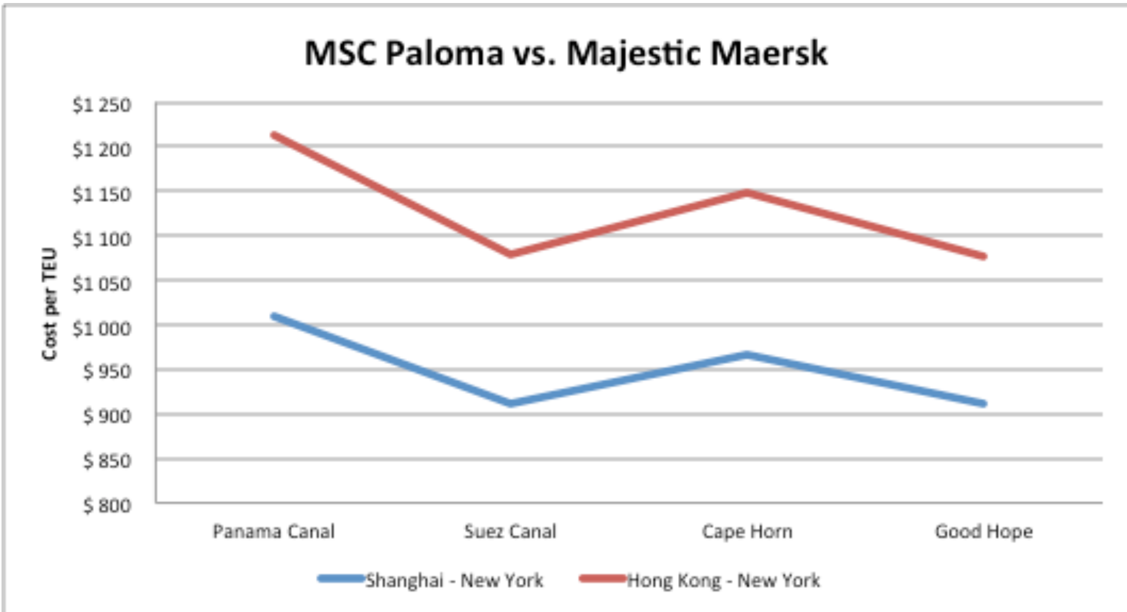


Figure 14: Scenario 4 – Cost per TEU overview

As expected, the results in Figure 14 show us that the hypothesis of large-scale advantages still holds. The MSC Paloma has a higher cost per TEU than the Majestic Maersk has on the alternative routes. This indicates that the Panama Canal will still meet competition from the ULCV segment after the expansion.

7.2.2.1 Load factor sensitivity

Table 14 presents the load factor sensitivity for the Hong Kong - New York voyage:

Hong Kong - New York								
Vessel	MSC Paloma		Majestic Maersk					
Load factor:	**Panama Canal**		**Suez Canal**		**Cape Horn**		**Good Hope**	
55 %	$	1 424	$	1 231	$	1 333	$	1 228
56 %	$	1 412	$	1 222	$	1 323	$	1 219
57 %	$	1 400	$	1 214	$	1 312	$	1 211
58 %	$	1 389	$	1 206	$	1 303	$	1 203
59 %	$	1 378	$	1 198	$	1 293	$	1 195
60 %	$	1 368	$	1 191	$	1 284	$	1 188
61 %	$	1 358	$	1 183	$	1 275	$	1 180
62 %	$	1 348	$	1 176	$	1 267	$	1 173
63 %	$	1 339	$	1 169	$	1 258	$	1 167
64 %	$	1 329	$	1 163	$	1 250	$	1 160
65 %	$	1 321	$	1 156	$	1 243	$	1 154
66 %	$	1 312	$	1 150	$	1 235	$	1 147
67 %	$	1 304	$	1 144	$	1 228	$	1 141
68 %	$	1 296	$	1 138	$	1 221	$	1 136
69 %	$	1 288	$	1 132	$	1 214	$	1 130
70 %	$	1 280	$	1 127	$	1 207	$	1 124
71 %	$	1 273	$	1 122	$	1 201	$	1 119
72 %	$	1 265	$	1 116	$	1 194	$	1 114
73 %	$	1 258	$	1 111	$	1 188	$	1 109
74 %	$	1 252	$	1 106	$	1 182	$	1 104
75 %	$	1 245	$	1 102	$	1 176	$	1 099
76 %	$	1 238	$	1 097	$	1 171	$	1 094
77 %	$	1 232	$	1 092	$	1 165	$	1 090
78 %	$	1 226	$	1 088	$	1 160	$	1 085
79 %	$	1 220	$	1 084	$	1 154	$	1 081
80 %	$	1 214	$	1 079	$	1 149	$	1 077

Table 14: Scenario 4 – Load factor sensitivity

Given that the larger vessels are not able to sail with an 80 % load factor, this sensitivity analysis shows that a 18 270 TEU vessel needs a 57 % load factor if sailing the Suez Canal to compete on cost with the 13 200 TEU vessel sailing through the Panama Canal with an 80 % load factor. Further, the 18 270 TEU vessel will need a 69 % load factor to sail the Cape Horn route, and a 57 % load factor to sail the Good Hope route.

On the Shanghai - New York voyage, the larger vessel would need a higher load factor due to the advantage of shorter sailing distance through the Panama Canal. The Majestic Maersk would need a 67 % load factor to sail the Suez Canal or the Good Hope, and a 73 % load factor to sail the Cape Horn route to compete on cost with the MSC Paloma at an 80 % load factor sailing the Panama Canal route.

7.2.3 Summary

From the post-expansion scenarios, we see that the cost per TEU still is inversely proportional with the increase in vessel size sailed on the alternative routes. We also observe that the cost per TEU when transiting the Panama Canal on the Hong Kong - New York voyage is almost equivalent to the cost per TEU of transiting through the Suez Canal if the speed is lowered when sailing the Panama Canal route.

7.3 Panama Canal tolls

Now that we have looked at basic scenarios for the competitive situation after the expansion with the current canal tariffs, it would be interesting to see how a change in the Panama Canal tariff would affect its competitiveness.

Since the sailing distance between Hong Kong - New York is fairly similar through the Panama Canal and the Suez Canal, we can use this route to isolate the transit fee from other variables that would complicate the comparison.

In the model, we use the solver-function to find the possible change in Panama Canal tariffs by setting the cost per TEU to be equal for both voyages. Given the current bunker and freight rates, the result indicates that the Panama Canal should decrease their tariffs per TEU capacity by approximately 28 %, from \$ 74 per TEU to \$ 54 to stay competitive with the Suez Canal. It is important to understand that this will still generate a much higher income for the ACP per Post-Panamax vessel transiting than the income per Panamax vessel paying the old tariffs. To compare, a Post-Panamax vessel with 80 % load factor will have to pay more than \$ 800 000 to transit, while a Panamax vessel with the same load factor will pay around \$ 400 000. So even if the tariff per TEU capacity goes down, the total income generated for the ACP per transit will still increase with the size of the vessel.

This change in tariffs is closely related to the additional fuel costs on the Suez route. In Table 15 we look at how much the Panama Canal transit cost per TEU capacity would have to change to compete with the Suez Canal route given different bunker price scenarios.

Hong Kong - New York				
Bunker price		Cost per TEU capacity		Change in percentage*
$	400,00	$	51	-32 %
$	**600,50**	**$**	**54**	**-28 %**
$	800,00	$	57	-23 %
Shanghai - New York				
Bunker price		Cost per TEU capacity		Change in percentage*
$	400,00	$	76	2 %
$	**614,00**	**$**	**91**	**23 %**
$	800,00	$	104	41 %

*Change in percentage from the original tariff rate of $ 74 per TEU capacity

Table 15: Tariff rates – Bunker price sensitivity.

We have tested for the current bunker price and two additional bunker price scenarios. By testing for significant changes in bunker price we strengthen the effect of the result. For the Shanghai - New York voyage we see that the cost per TEU capacity actually could be increased. Further, we see that the effect from a change in bunker price is much larger for the Shanghai voyage than for the Hong Kong voyage, which is an expected result due to the disparity in sailing distance between the routes on the Shanghai voyage. Note that we do not account for the relationship between speed and sailing days for the canal routes, which would further strengthen the change in cost per TEU capacity.

Given that the bunker price were to decrease, it would have a negative impact on the competitiveness of the Panama Canal. Hence, a possible solution could be to link the tariffs to the bunker price.

7.4 Round-trip

To be able to get a better perspective on the importance of the tradeoff between time and cost, we will have to look at the different alternative routes in a larger perspective than just single voyages. Thus, for the next chapter we will perform round-trip scenarios with a one-year timeframe.

Our calculations will display three different round-trip scenarios for each of the four different routes, where the difference is speed on the fronthaul and backhaul voyage. The fronthaul is the first leg of a round-trip that involves transporting goods to a targeted destination, whereas the backhaul is the returning journey after delivery. The important difference between the fronthaul and the backhaul leg on the Asia - U.S. East Coast trade route is the discrepancy in cargo volume traded back and forth. This also affects the freight rate, which is almost 50 % lower for the backhaul voyage (USEC - Shanghai: 1 530 USD/FEU). Due to the trade discrepancy, we will operate with a 40 % load factor on the backhaul[19]. Note that we have used the Hong Kong bunker price for the entire round-trip, i.e. not the New York bunker price for the backhaul. This will be a possibility in the model.

First, we will look at the annual results for each route if the speed is 23 - 23, i.e. 23 knots for the entire round-trip. Secondly, we look at the results if the vessel sails at a speed of 23 knots on the fronthaul journey while slow-steaming at a speed of 18 knots on the backhaul. Finally, we look at a scenario where the vessel sails at a slow-steam pace of 18 knots the entire round-trip.

In Table 16 we display the results from an example of a round-trip for the Hong Kong - New York voyage using the old tariffs for the Panama Canal.

[19] This is the load factor Stopford (2009) operates with in his examples.

Annual results: Hong Kong - New York						
MSC Paloma - 13 200 TEU						
Route:	Panama Canal			Suez Canal		
Speed:	23 - 23	23 - 18	18 - 18	23 - 23	23 - 18	18 - 18
Round-trip distance	22 414	22 414	22 414	23 186	23 186	23 186
Voyage days	66,6	72,6	78,5	67,0	73,2	79,3
Average voyages per year	5,5	5,0	4,6	5,4	5,0	4,6
Gross revenue	**$ 118 367 131**	**$ 108 685 298**	**$ 100 467 560**	**$ 117 680 503**	**$ 107 804 035**	**$ 99 456 995**
Fuel costs	$ 40 275 110	$ 29 035 857	$ 19 335 098	$ 41 333 749	$ 29 731 903	$ 19 767 177
Cargo handling	$ 62 475 240	$ 57 365 081	$ 53 027 685	$ 62 112 831	$ 56 899 942	$ 52 494 300
Canal fees	$ 11 657 479	$ 10 703 956	$ 9 894 625	$ 7 574 190	$ 6 938 517	$ 6 401 283
Total	*$ 114 407 828*	*$ 97 104 894*	*$ 82 257 408*	*$ 111 020 770*	*$ 93 570 363*	*$ 78 662 759*
Voyage result	**$ 3 959 303**	**$ 11 580 405**	**$ 18 210 152**	**$ 6 659 733**	**$ 14 233 672**	**$ 20 794 236**
TCE	$ 10 847	$ 31 727	$ 49 891	$ 18 246	$ 38 996	$ 56 971
Operating costs	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420
Total costs	$ 118 681 248	$ 101 378 314	$ 86 530 828	$ 115 294 190	$ 97 843 783	$ 82 936 179
Contribution to capital	***$ -314 117***	***$ 7 306 985***	***$ 13 936 732***	***$ 2 386 313***	***$ 9 960 252***	***$ 16 520 816***
Route:	Cape Horn			Good Hope		
Speed:	23 - 23	23 - 18	18 - 18	23 - 23	23 - 18	18 - 18
Round-trip distance	33 368	33 368	33 368	27 372	27 372	27 372
Voyage days	86,0	94,9	103,7	74,6	81,8	89,1
Average voyages per year	4,2	3,8	3,5	4,9	4,5	4,1
Gross revenue	**$ 91 690 349**	**$ 83 148 632**	**$ 76 062 754**	**$ 105 744 769**	**$ 96 378 200**	**$ 88 535 940**
Fuel costs	$ 45 977 206	$ 32 730 449	$ 21 619 475	$ 43 661 285	$ 31 243 317	$ 20 704 260
Cargo handling	$ 48 394 994	$ 43 886 598	$ 40 146 608	$ 55 813 043	$ 50 869 284	$ 46 730 068
Canal fees	$ -	$ -	$ -	$ -	$ -	$ -
Total	*$ 94 372 200*	*$ 76 617 047*	*$ 61 766 083*	*$ 99 474 328*	*$ 82 112 601*	*$ 67 434 329*
Voyage result	**$ -2 681 851**	**$ 6 531 585**	**$ 14 296 671**	**$ 6 270 441**	**$ 14 265 599**	**$ 21 101 612**
TCE	$ -7 348	$ 17 895	$ 39 169	$ 17 179	$ 39 084	$ 57 813
Operating costs	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420
Total costs	$ 98 645 620	$ 80 890 467	$ 66 039 503	$ 103 747 748	$ 86 386 021	$ 71 707 749
Contribution to capital	***$ -6 955 271***	***$ 2 258 165***	***$ 10 023 251***	***$ 1 997 021***	***$ 9 992 179***	***$ 16 828 192***

Table 16: Post-Panamax round-trip with current Panama Canal tolls

At a higher speed, the vessel is able to average more round-trip voyages per year and generate higher annual revenue. However, with the current fuel prices, the cost of sailing at a higher speed exceeds the additional revenue gained by spending less time at sea on each voyage. This leads to a preference for slow-steaming. In the previous chapter, we suggested that the Panama Canal tariffs per TEU capacity should be lower for larger vessels after the expansion. This example verifies this recommendation. The high cost of transiting the Panama Canal makes both the Suez Canal route and the Route around Good Hope more attractive alternatives when accounting for the backhaul instead of just a single voyage.

If we look at an example with a Panamax vessel, presented in Table 17, we see that the pricing of the Panama Canal transit is more competitive.

Annual results: Hong Kong - New York						
Octavia - 5 117 TEU						
Route:	Panama Canal			Suez Canal		
Speed:	25 - 25	25 - 18	18 - 18	25 - 25	25 - 18	18 - 18
Round-trip distance	22 414	22 414	22 414	23 186	23 186	23 186
Voyage days	49,5	57,2	64,8	49,8	57,7	65,6
Average voyages per year	7,4	6,4	5,6	7,3	6,3	5,6
Gross revenue	**$ 61 767 009**	**$ 53 503 429**	**$ 47 190 047**	**$ 61 430 664**	**$ 53 007 771**	**$ 46 616 132**
Fuel costs	$ 30 209 342	$ 19 235 573	$ 10 796 095	$ 31 025 583	$ 19 681 467	$ 11 018 248
Cargo handling	$ 32 874 769	$ 28 476 575	$ 25 116 351	$ 32 695 753	$ 28 212 767	$ 24 810 891
Canal fees	$ 6 300 153	$ 5 457 279	$ 4 813 322	$ 5 268 257	$ 4 545 914	$ 3 997 771
Total	*$ 69 384 264*	*$ 53 169 426*	*$ 40 725 768*	*$ 68 989 593*	*$ 52 440 148*	*$ 39 826 910*
Voyage result	**$ -7 617 255**	**$ 334 003**	**$ 6 464 279**	**$ -7 558 929**	**$ 567 623**	**$ 6 789 221**
TCE	$ -20 869	$ 915	$ 17 710	$ -20 709	$ 1 555	$ 18 601
Operating costs	$ 3 277 335	$ 3 277 335	$ 3 277 335	$ 3 277 335	$ 3 277 335	$ 3 277 335
Total costs	$ 72 661 599	$ 56 446 761	$ 44 003 103	$ 72 266 928	$ 55 717 483	$ 43 104 245
Contribution to capital	***$ -10 894 590***	***$ -2 943 332***	***$ 3 186 944***	***$ -10 836 264***	***$ -2 709 712***	***$ 3 511 886***
Route:	Cape Horn			Good Hope		
Speed:	25 - 25	25 - 18	18 - 18	25 - 25	25 - 18	18 - 18
Round-trip distance	33 368	33 368	33 368	27 372	27 372	27 372
Voyage days	67,2	78,6	90,0	56,7	66,0	75,4
Average voyages per year	5,4	4,6	4,1	6,4	5,5	4,8
Gross revenue	**$ 45 487 477**	**$ 38 900 478**	**$ 33 979 882**	**$ 53 926 008**	**$ 46 301 520**	**$ 40 565 979**
Fuel costs	$ 32 938 911	$ 20 705 751	$ 11 527 413	$ 32 084 241	$ 20 251 143	$ 11 301 948
Cargo handling	$ 24 210 178	$ 20 704 324	$ 18 085 395	$ 28 701 488	$ 24 643 443	$ 21 590 768
Canal fees	$ -	$ -	$ -	$ -	$ -	$ -
Total	*$ 57 149 088*	*$ 41 410 076*	*$ 29 612 809*	*$ 60 785 729*	*$ 44 894 586*	*$ 32 892 716*
Voyage result	**$ -11 661 611**	**$ -2 509 598**	**$ 4 367 074**	**$ -6 859 720**	**$ 1 406 934**	**$ 7 673 263**
TCE	$ -31 950	$ -6 876	$ 11 965	$ -18 794	$ 3 855	$ 21 023
Operating costs	$ 3 277 335	$ 3 277 335	$ 3 277 335	$ 3 277 335	$ 3 277 335	$ 3 277 335
Total costs	$ 60 426 423	$ 44 687 411	$ 32 890 144	$ 64 063 064	$ 48 171 921	$ 36 170 051
Contribution to capital	***$ -14 938 946***	***$ -5 786 933***	***$ 1 089 739***	***$ -10 137 055***	***$ -1 870 401***	***$ 4 395 928***

Table 17: Panamax round-trip with current Panama Canal tolls

Even if the route through the Suez Canal and the route around Good Hope generate more earnings, we see that the Panama Canal tolls are at a competitive level. As the canal tariffs are scaled for smaller vessels like the Panamax, there might be other factors influencing the results, such as the bunker price.

In a scenario where the Panama Canal tolls are lowered to match the cost per TEU with cost of sailing the Suez Canal route, we would get the following results:

Annual results: Hong Kong - New York						
MSC Paloma - 13 200 TEU						
Route:	Panama Canal			Suez Canal		
Speed:	23 - 23	23 - 18	18 - 18	23 - 23	23 - 18	18 - 18
Round-trip distance	22 414 nm	22 414	22 414	23 186	23 186	23 186
Voyage days	66,64	72,6	78,5	67,0	73,2	79,3
Average voyages per year	5,48	5,0	4,6	5,4	5,0	4,6
Gross revenue	**$ 118 367 131,10**	**$ 108 685 298**	**$ 100 467 560**	**$ 117 680 503**	**$ 107 804 035**	**$ 99 456 995**
Fuel costs	$ 40 275 109,97	$ 29 035 857	$ 19 335 098	$ 41 333 749	$ 29 731 903	$ 19 767 177
Cargo handling	$ 62 475 239,83	$ 57 365 081	$ 53 027 685	$ 62 112 831	$ 56 899 942	$ 52 494 300
Canal fees	$ 8 711 769,46	$ 7 999 191	$ 7 394 369	$ 7 574 190	$ 6 938 517	$ 6 401 283
Total	*$ 111 462 119,26*	*$ 94 400 129*	*$ 79 757 151*	*$ 111 020 770*	*$ 93 570 363*	*$ 78 662 759*
Voyage result	**$ 6 905 011,84**	**$ 14 285 170**	**$ 20 710 409**	**$ 6 659 733**	**$ 14 233 672**	**$ 20 794 236**
TCE	$ 18 917,84	$ 39 137	$ 56 741	$ 18 246	$ 38 996	$ 56 971
Operating costs	$ 4 273 420,00	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420
Total costs	$ 115 735 539,26	$ 98 673 549	$ 84 030 571	$ 115 294 190	$ 97 843 783	$ 82 936 179
Contribution to capital	***$ 2 631 591,84***	***$ 10 011 750***	***$ 16 436 989***	***$ 2 386 313***	***$ 9 960 252***	***$ 16 520 816***
Route:	Cape Horn			Good Hope		
Speed:	23 - 23	23 - 18	18 - 18	23 - 23	23 - 18	18 - 18
Round-trip distance	33 368	33 368	33 368	27 372	27 372	27 372
Voyage days	86,0	94,9	103,7	74,6	81,8	89,1
Average voyages per year	4,2	3,8	3,5	4,9	4,5	4,1
Gross revenue	**$ 91 690 349**	**$ 83 148 632**	**$ 76 062 754**	**$ 105 744 769**	**$ 96 378 200**	**$ 88 535 940**
Fuel costs	$ 45 977 206	$ 32 730 449	$ 21 619 475	$ 43 661 285	$ 31 243 317	$ 20 704 260
Cargo handling	$ 48 394 994	$ 43 886 598	$ 40 146 608	$ 55 813 043	$ 50 869 284	$ 46 730 068
Canal fees	$ -	$ -	$ -	$ -	$ -	$ -
Total	*$ 94 372 200*	*$ 76 617 047*	*$ 61 766 083*	*$ 99 474 328*	*$ 82 112 601*	*$ 67 434 329*
Voyage result	**$ -2 681 851**	**$ 6 531 585**	**$ 14 296 671**	**$ 6 270 441**	**$ 14 265 599**	**$ 21 101 612**
TCE	$ -7 348	$ 17 895	$ 39 169	$ 17 179	$ 39 084	$ 57 813
Operating costs	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420	$ 4 273 420
Total costs	$ 98 645 620	$ 80 890 467	$ 66 039 503	$ 103 747 748	$ 86 386 021	$ 71 707 749
Contribution to capital	***$ -6 955 271***	***$ 2 258 165***	***$ 10 023 251***	***$ 1 997 021***	***$ 9 992 179***	***$ 16 828 192***

Table 18: Post-Panamax round-trip with adjusted Panama Canal tolls

With the 28 % change in tariffs, the Panama Canal route generates almost the same amount of total earnings as the route through the Suez Canal and the Good Hope, and is able to remain competitive. Due to the low bunker prices, the Good Hope route presents a competitive alternative to the canal routes.

When comparing the MSC Paloma with the Majestic Maersk on the alternative routes, we find that the Majestic Maersk is able to generate almost twice the total earnings at 18 knots sailing the Suez Canal or the Good Hope. This confirms the results from Chapter 7.2.2, which indicates a strong competition from the ULCV segment. However, it is fair to assume that the Majestic Maersk in reality, would need to spend more time in port due to a larger demand for supply of containers to reach its necessary capacity.

When running the Shanghai – New York round-trip for the MSC Paloma on all routes without adjusting for new canal tolls, we confirm our previous results on this voyage – the Panama Canal is the most profitable alternative on this voyage. However, when comparing with the Majestic Maersk on the other routes we see that the Panama

Canal is the least preferred alternative – with the Majestic Maersk on the Suez Canal route able to generate earnings more than 40 % higher than the MSC Paloma on Panama Canal route.

7.5 Bunker price and Freight rates

Freight rates and bunker prices are expected to have a great influence on a shipowners decisions when choosing which route to sail. If the bunker prices are high, the shipowner have to expect higher fuel costs and will therefore prefer to sail shorter distances. If the freight rate is low, the gross revenue will be lower, and the shipowner will be forced to cut costs by for example sailing at a lower speed. The low freight rate could indicate that there is an oversupply of vessels in the market, which would make slow-steaming a preference to be able to have more ships operative at the same time. If the bunker price were low, the shipowners would be less worried about costs, which would favor the longer routes such as the Good Hope route. Lastly, if freight rates increase, the shipowner would want to increase profits by sailing shorter routes to be able to average a higher amount of voyages per year.

By looking at the sensitivity of bunker prices, we can find the bunker price where the preference for one route changes to another. The following sensitivity analysis does not take into account a possible correlation between bunker price and freight rate, i.e. the freight rate is held constant. In addition, this is built on the previous scenario where the Panama Canal tariffs have been decreased by approximately 28 % to match the competition from the Suez Canal for larger vessels on the Hong Kong - New York voyage with the MSC Paloma. Note that the results are based on a single-voyage scenario.

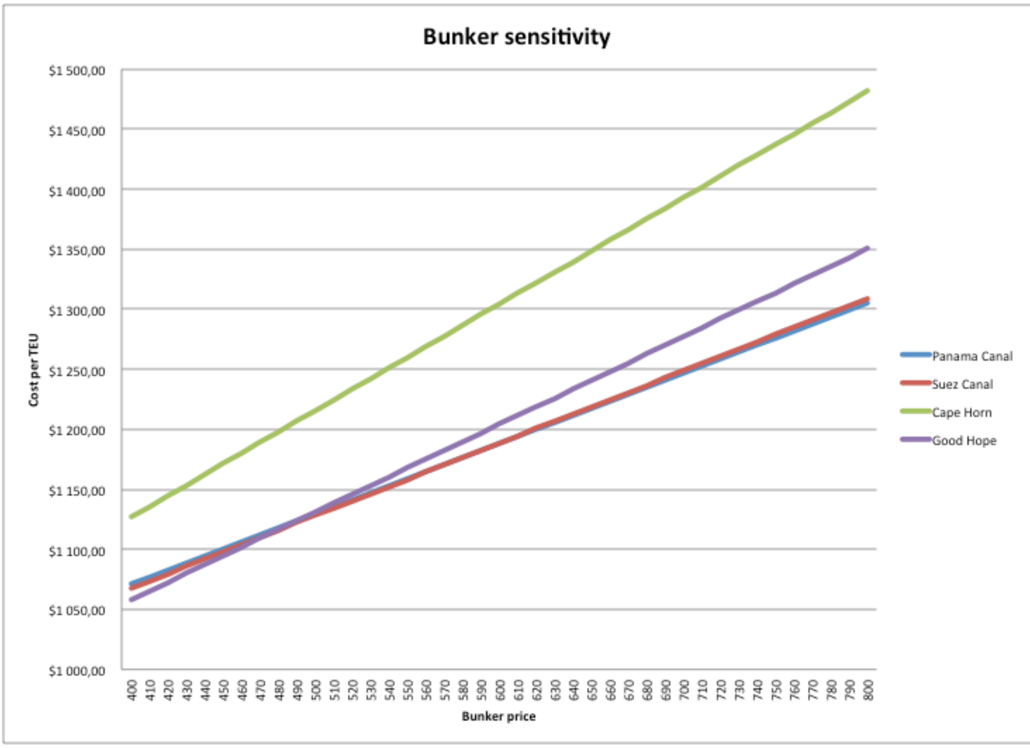


Figure 15: Bunker sensitivity

From Figure 15 we see that when the bunker price goes below $ 600 the Suez Canal becomes the preferred route alternative. This is obvious, since the tariff was decreased to match the Suez Canal at a bunker of $ 600.50. A more interesting observation is that if the bunker price goes below $ 500 it becomes less expensive to sail the Good Hope route. This confirms the assumption that if the bunker gets low enough, the longer routes will become more attractive.

On the other hand, if we look at the sensitivity for the freight rate, we see that this is much less sensitive to changes given that the bunker price is held constant:

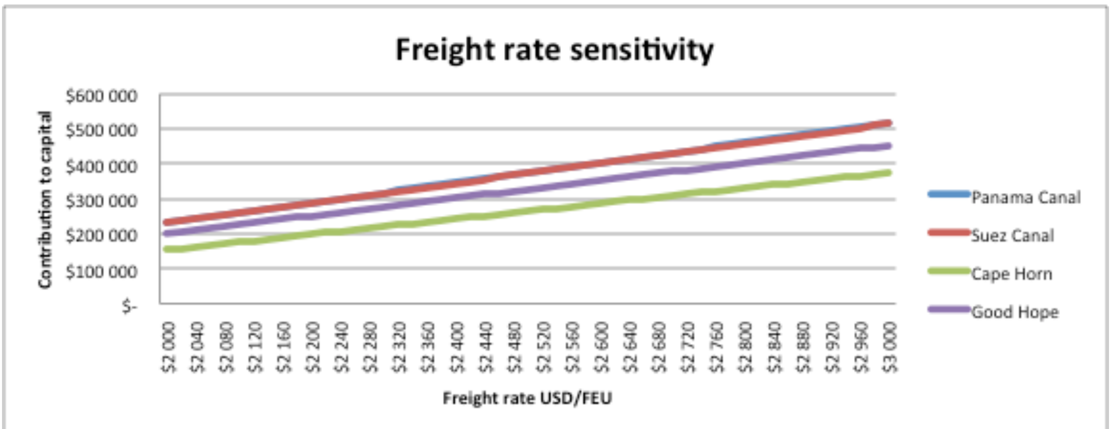


Figure 16: Freight rate sensitivity

8 Discussions

Dr. Theo Notteboom and Dr. Jean-Paul Rodrigue (2011b) argue that global freight distribution, supply chain management, and the strategies for maritime shipping companies and terminal operators have become so complex and interrelated that the effects of the expansion and the consequences are unclear for most of the parties involved. Academics find it difficult to assess the potential impacts, as the possible consequences are multidimensional and prone to feedback effects[20] (ibid.). As the world shipping market still adjusts after the financial crisis in 2008, the expansion comes at an interesting point in time. There are still uncertainties regarding main trade drivers, such as import-based U.S. consumption, and new trade relations are emerging as the rise in Chinese labor costs force companies to shift their production to other countries such as Bangladesh and Vietnam (Financial Times, 2011). China´s comparative advantage is eroding because of the redistribution of parts of the manufacturing to South and Southeast Asia (Notteboom & Rodrigue, 2011b). The re-location of manufacturing could be both positive and negative for the Panama Canal, depending on the new locations. While Bangladesh is located closer to the Suez Canal, Taiwan would favor sailing through the Panama Canal. However, it is expected that countries closer to the Suez Canal are preferred, mostly due to a relatively low income per-capita in countries like Bangladesh, Burma and Cambodia. This could be advantageous for the Suez Canal, as larger parts of trade would move closer to the Canal.

For overall world trade, the new Panama Canal will have a positive impact, as the capacity for the well-travelled route increases. The expansion will reduce per-unit shipping costs for vessels transiting the Canal and calling U.S. ports (Notteboom & Rodrigue, 2011b). According to a presentation given by DNB Markets on the widening of the Panama Canal (2014) there are uncertainties about who is going to be the main beneficiary from the expanded Panama Canal. If the impact is more tradable volume and increased traffic in the Canal, both the ACP and shipowners should be able to capture more profit. On the contrary, if the existing trade gets re-routed with no increase in volume, it is difficult to see who will profit.

[20] Feedback effects: The market adjusts to changes/feedback in order to establish a new equilibrium

As the Panama Canal offers a unique route in an important trade lane, it is fair to assume that the ACP will reap benefits no matter how trade develops. If the container shipping industry ends up using shorter routes with no increase in volume, the consequence might be that another link in the supply chain or the consumers reaps the benefit. This could in turn make the container segment less profitable, which could affect the Panama Canal as their largest customer's solvency decreases.

8.1 Trade lane effects

As supply chains have become more sensitive to demand and disruptions, the expansion of the Panama Canal gives incentives for companies to explore using Gulf Coast ports on the Asia - U.S. trade (Inbound Logistics, 2013). In addition, single-source strategies on exclusive East and West Coast ports are less common (ibid.). A possible effect could be that companies would want to pull products closer to demand centers and reduce overland drays.

The U.S. Southeast is one of the fastest growing population areas in the country, situated within rail reach to Ohio Valley and the population center in the U.S. (ibid.). Rob O`Brian, president of the Joplin Mo Chamber of Commerce, argues that shipowners might change shipping patterns towards Gulf Coast ports and their rail connections. By doing so, they could better reach the U.S. inlands. Consequently, the West Coast ports perceive the expansion as a threat to their market share in the Midwest (Notteboom & Rodrigue, 2011b). This is in line with the arguments that all-water routes would better serve the mid-inlands of the U.S. after the expansion. If the shift of ports materializes, the Panama Canal would have an advantage by bearing shorter routes when serving the Gulf ports, and could possibly capture market shares from both the Suez Canal and the U.S. Intermodal System.

New trade patterns might become a self-fulfilling prophecy, as ports in both North and South America have started extensive work to accommodate Post-Panamax vessels. In order for these projects not to fail, stakeholders will most likely try to influence shipowners to choose routes that involve their port facilities. Shipowners would probably want to use the new port facilities, as these are expected to be better equipped (which could lead to shorter berth time) and have better access (which would limit the need for tugs).

A major concern, and a possible game changer in regards of new trade patterns, is the possibility for backhaul cargo transfer, or lack of such. The imbalance in cargo flows makes it difficult for shipowners to make good use of the return trip when sailing the Asia - U.S. trade route. If flows were more even, the cost of shipping to the East Coast would be lower, as more income could be captured on the return trip. The predicted increase in large-scale advantages that comes from the expansion will also apply on the return trip. The possibility for a new trade triangle is therefore interesting: Consumer goods from Asia to the East Coast, high-end consumer goods and pharmaceuticals from North America to South America, and coal and iron ore from Columbia, Venezuela and Brazil to China (Forbes, 2013). Exporting liquefied natural gas (LNG) to Asia could also become a part of this trade triangle in the future. Involving these Latin American countries would also favor Panama over Suez, as they are situated in close proximity to Panama. All these possibilities do not necessary involve container cargo today, but are used as an example of new trade possibilities[21].

Our research has focused on the Panama Canal and the Suez Canal as competitors. However, after the expansion, a relative capacity parity exists for the first time between the two canals (Rodrigue, 2010). Container shipping companies may use this new cohesion as a basis for establishing round-the-world equatorial routes in both directions – using container vessels close to the limit of 13 200 TEU. These round-the-world routes were in fact abandoned by shipping lines in the mid-1990 because of the size restrictions in the Panama Canal (Notteboom & Rodrigue, 2011a). This high frequency travel route could support a significant share of global East-West freight in a cost effective matter. Several round-the-world configurations are possibly depending on what marked each carrier serves. This service would not necessary be homogeneous as several port-calls are possible, especially if the liner service adds some nautical deviations to the route (Rodrigue, 2010).

8.2 Pricing effects

Canal pricing has been an issue in the past and, as we have illustrated in our analysis, will still be an issue when shipowners choose routes. Nothing official has been announced from the ACP about what changes they will make to the transit booking

[21] Grieg Star is experiencing an increase in cargo moved from bulk to containers in a measure to simplify on- and offloading.

system when the expanded Panama Canal opens. They are, however, in close dialogue with The World Shipping Council and The International Chamber of Shipping regarding the possible changes in toll structure and procedures for the expanded canal. The general understanding is that the current system, procedures and pricing for vessels using the old locks will stay the same, while changes are expected for the new locks.

In a presentation given by the CEO of ACP, Jorge L. Quijano, during an INTERCARGO meeting in London on February 7th 2013, long term forecasts and new toll structures were discussed. The ACP wants to use the new toll structure to facilitate economies of scale for large vessels using the new locks, while maintaining and improving the benefits for those using the existing locks. They will also address economies of scale in both fully and partially loaded vessels taking draft restricted conditions into account, and further recognize the role of ballast transits in some trades. They argue that this would move the Canal closer to industry standard ($/Ton), encourage traffic volume growth and create greater cost/price transparency. They have, amongst other, suggested the following changes:

- Changing from PC/UMS to DWT to measure vessels for toll assessment and include a variable portion on actual cargo being carried
- Differentiate different commodity types – grains, coal, iron ore, other dry bulks and ballast. By doing this, they will relate tolls to the cargo value in order to provide more competitive pricing. This would also mean an introduction of specific cargo loading options such as topping-off after transiting the Canal
- Having one part of the variable cost depend on fuel prices. This would lead to higher transit costs when the fuel price rises, and lower transit costs when the fuel price is low.

Rob Lomas, Secretary General at Intercargo, has confirmed to Grieg Star that existing Panamax vessels will keep using the old locks after the expansion, with the new locks reserved for the larger Post-Panamax vessels. Exceptions will be made when the ACP decides otherwise for operational reasons. The ACP has confirmed that there will be no financial disadvantage for the shipowners in this arrangement.

The ACP raised the price per TEU capacity from $ 40 in 2006 to $ 72 in 2009, an 80 percent increase in just three years (Notteboom & Rodrigue, 2011b). The toll is $ 74 per TEU capacity today, having seemingly stabilized since 2009. It has been said that the toll increase already has captured 40 percent of the potential cost savings from the expansion, which in turn has mitigated a significant share of the expected gains (ibid.). This could further implicate that the price for transiting the new locks will not be significantly higher than the current price.

The Suez Canal transit fees are also under pressure from shipowners. In 2009 several shipowners started boycotting the Suez Canal as a reaction to the high transit fees. Maersk Line and the Grand Alliance are examples of companies that re-routed many of their vessels around the Cape of Good Hope. After this incident, the SCA imposed a transit fee freeze as a result of global downturn and an increase in piracy activity. The fees have, however, increased since 2009. The transit rates saw an increase of 3 percent in 2012, 3 to 5 percent in 2013 and the SCA has announced an increase of between 2 - 2.6 percent come 1th of May 2014 (The Lone Star, 2014). The raise in 2013 started a debate on the subject, as freight rates were low and bunker prices high, making the increase harder to accept.

Canal rates are a sensitive issue for shipowners, and both the Panama Canal and the Suez Canal show signs of taking customers into account when deciding their prices. They also pursue the possibility of increased profits in all segments. What is certain is that the two canals will have to take each other's pricing into account when reviewing own rates, as they are the main competitors on the Asia - North America trade route. Higher rates, increased popularity towards extra-slow steaming and excess vessel supply combined with an uncertain macroeconomic environment may increase the popularity of the Cape of Good Hope route. Opting for a longer route may also be a mean to counter the excess supply, as sailing longer routes will increase the need for vessels. Regardless of route, slow steaming can add three to seven days in transit time, which will require the addition of two to three vessels to the pendulum service to maintain the frequency of port calls (Notteboom & Rodrigue, 2011b). Lower bunker prices would also make shipowners less concerned about nautical miles, putting pressure on the canals by making the Good Hope route more affordable.

A substantial risk to the Panama Canal is that the Suez Canal Authorities may use the improvement of East Coast ports to their advantage. To meet the new competition the

SCA could possibly offer a discount to shipowners in the period after the completion of the new locks. By making it more profitable to sail the Suez route, they could hinder the establishment of new trade lanes. It is reasonable to assume that the ACP has to meet several obligations after the $ 5 billion expansion, making them less able to compete on price. Today, the SCA has an arrangement where they grant rebates if shipowners are able to prove that their voyage cost through the Suez Canal is more expensive than proceeding through an alternative route (Notteboom & Rodrigue, 2011a). In such a scenario the SCA could take advantage of the expanded port facilities by being the preferred option for the largest container vessels on long-haul routes to North America.

8.3 The P3 Alliance

An emerging deal that could affect the Panama Canal and its position is the proposed P3 Alliance between Maersk Line, MSC and CMA CGM. Already approved by U.S. regulators, they now await green light from the European Commission and Chinese regulators, hoping to start in mid-2014 (Reuters, 2014). Representing the three largest container carriers in the world, an alliance could have implications for the canal authorities. On the ACP customer-ranking (2014e) MSC is ranked as number two, Maersk Line as number five and CMA CGM as number eight – clearly important customers to the Panama Canal. Having suffered from excess capacity since the financial crisis, the alliance is a measure taken to control the capacity and rates on container routes between Asia, North America and Europe. In order to cut costs they have agreed to pool approximately 250 vessels on three trade lanes: Asia - Europe, trans-Pacific and trans-Atlantic. This will allow for the companies to sail bigger and more fuel-efficient ships with a higher load factor. Analysts from the investment bank Alm forecasts that Maersk would be able to cut costs by 6 percent if the alliance is approved (Reuters, 2014). Both cargo owners and shippers criticize the proposed alliance. They fear the alliance will dominate the key routes in a way that could drive prices up and push smaller carriers out of the market.

A reason why this alliance should be monitored is the fact that they have vessels available that might force them to exclude the Panama Canal. The alliance is based on adjusting demand and supply to allow freight rates to cover their costs, and it is fair to assume that sailing the largest ships with a higher load factor could contribute in achieving this. This could make Suez a preferred option when sailing the Asia - North

America trade route. One option for the ACP is to compensate for the stated 6 percent cost reduction by reducing the cost of transit if such a situation should arise. Another possibility is a proactive approach touting the alliance as to what is a bearable price and practice. This would be a more sensible market approach. It is also possible that the container segment is large enough to cover the capacity in the Panama Canal even with the alliance favoring the Suez Canal.

The shipping industry is experiencing a surplus of Panamax vessels, which is likely to become larger after the new locks open in 2015 (Drewry CIW, 2014). When the new locks open it is assumed that more Panamax vessels becomes redundant as shipowners upgrades to larger vessels. Given the availability of Panamax vessels, the demand for the old locks should still be met, even if the alliance re-routes ships to the Suez Canal. The average age of the Panamax fleet is 8.5 years and 73 percent of the fleet is under 11 years, making scrapping unlikely. As Panamax vessels usually are depreciated over more than 20 years, their book value will be of such size that destruction will mean a big shareholder loss and is therefore improbable. A possible scenario is that the ACP allows Panamax vessels to transit through the new locks in the event of high demand for transiting vessels of Panamax size.

8.4 Orderbook implications

The container-shipping segment is characterized by economies of scale, which has led to a relentless upsizing of vessels. An overview of the container ship orderbook for the last seven years is presented in Figure 17.

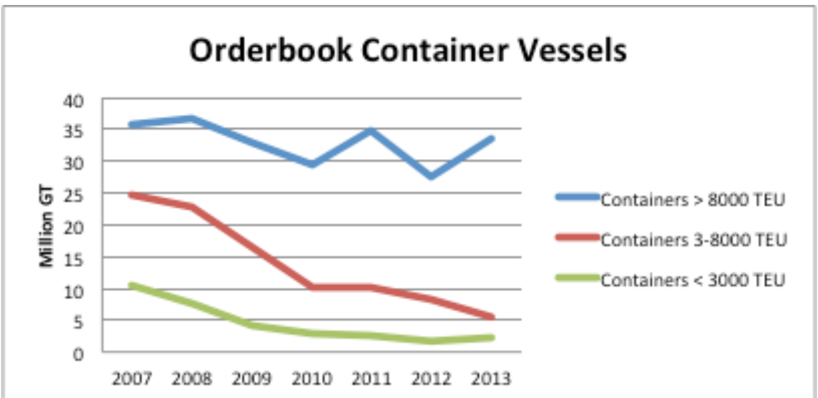


Figure 17: Orderbook trend 2007-2013 (Clarkson SIN, 2014)

After the expansion proposal was announced and passed in 2006, the orderbook for container vessels has seen a significant change. Container vessels with a capacity of less than 3 000 TEU and vessels ranging from 3 000 to 8 000 TEU have had a constant decline in orders since 2007. This decrease might not be solely explained by the plans to expand the Panama Canal, but it is fair to assume that the plans have made it easier to justify investing in larger container vessels. The increased flexibility and re-sale value of vessels up to 13 200 TEU should make the increasing need for financing easier to obtain. Today there are twenty-five 18 000 TEU vessels on order with planned delivery in 2015 (Clarkson SIN, 2014). Alphaliner (2014) forecasts that the total TEU capacity of vessels outsizing the expanded Panama Canal will account for approximately 11 percent of the total TEU capacity of the container world fleet by the end of 2015.

Another effect of the expansion might be an overall decrease in demand for vessels, regardless of size. When bigger vessels are able to make shorter trips, shipowners and shippers will ultimately be able to move more cargo on each voyage. It is thinkable that this could lead to a decrease in demand for vessels in the long run. A consequence could be a smaller world container fleet containing larger vessels that operates the market. Further, this could lead to an extensive turn-around for container shipping, as shipowners has to adjust the supply of vessels. A period of low freight rates would be inevitable, unless shareholders accept losses in order to scrap unused vessels. Based on this hypothesis, it is fair to assume that the effects of the Panama expansion not necessarily only have positive implications for shipowners.

8.5 The U.S. Intermodal System

Early analysis revealed that the cost of using intermodal container freight from Asia to New York was too high compared to the other routes. This was an expected result, as intermodal freight in the U.S. involves more parties than the other options. The other routes only differ in costs by either using more fuel or transiting a canal, whereas the cost of intermodal through the United States is more complex, making in very difficult to compare to the all-water routes to New York. Numerous rail and truck companies are involved in order to move cargo from west to east and these parties derive more costs and risk. Intermodal risk stems from e.g. delays caused by harsh weather, congestion, maintenance, and labor conflicts. Even if the intermodal alternative was dropped from the cost analysis due to its complexity, this routing option is highly relevant for the Panama Canal. Goods originated outside the U.S. with endpoint inlands will have to use intermodal transport when arriving to the U.S. coastline. From the ACP expansion proposal (2006) we know that the ACP considers this mode as a complementary option, while Stopford (2009) on the other hand argues that they are competitors.

The time factor still favors the West Coast intermodal mode when the final destination is U.S. inlands. This water-land bridge connects Shanghai with Chicago in 18 to 20 days. The same route could take up to four weeks choosing an all-water way (Inbound Logistics, 2013). Despite the difference in time, shipowners are still opting for slow steaming and an all-water way. Offering less risk and a better sustainability, supply chains have adopted better up- and down-stream visibility in order to manage longer lead times.

8.6 Environmental effects

One of the possible effects of the expansion may be the reduction of carbon footprint in shipping. In their article, Stott and Wright (2012) refer to the International Maritime Organization´s (IMO) predictions that shipping will be responsible for between 12 and 18 percent of global carbon dioxide emissions by 2050 unless the industry improves significantly. Further, they refer to figures from Clarkson, and estimates that bunkers accounted for 28 percent of the daily voyage cost in the 1990s, compared to 78 percent in January 2012. However, the bunker prices have decreased in proportion to total costs in 2014, as prices are lower than the high levels of early 2012. Sailing larger vessels leads to a smaller CO_2 footprint per container or per metric cargo ton. In addition, newer vessels are assumed to be more fuel-efficient. This could be an important factor for both shipowners and shippers, and adds to the series of incentives to upsize container vessels. If we only look at CO_2 emissions, an 18 000 TEU vessel should be preferred to a 13 200 TEU vessel, and thereby favor the Suez route. However, a shorter route through the Panama Canal should lead to less pollution.

9 Concluding remarks

From our pre-expansion analysis we have found that the Panama Canal provides a competitive alternative in the Panamax segment. However, we also found that by exploiting economies of scale, shipowners are able to lower their voyage costs significantly. The cost per TEU and the size of vessels can be considered inversely proportional. This has played in favor of the alternative routes such as the Suez Canal and the Cape of Good Hope, where larger vessels require a much lower load factor to stay competitive with the current Panama Canal.

The post-expansion analysis uncovered a discrepancy between the current Panama Canal tariffs and sailing time on the Hong Kong - New York voyage when sailing with a Post-Panamax vessel. With the current tariff based on cost per TEU capacity, the new Panama Canal will not be able to stay competitive and shipowners may continue to use alterative routes for their Post-Panamax vessels. It will be decisive that the new toll system facilitates for economies of scale by lowering the cost per TEU capacity transited through the Panama Canal. The ACP has proposed several solutions for the new toll structure, and we think that a good option would be to have a diminishing cost per TEU capacity transited. This would make the Panama Canal competitive with the Suez Canal that has based their tolls on diminishing cost per tonne. In addition, a solution would be to link the tariff to the bunker price. By lowering the cost of transit proportionally with the bunker price, the Panama Canal would be able to stay competitive with the longer routes that are more relevant when bunker prices are low. If this solution were to be introduced, a ceiling would be recommended to avoid the cost of transit becoming too high if the bunker price increases.

The round-trip scenarios strengthen the findings from the initial analysis. An interesting observation is that at the current freight rate and bunker price, our results suggests that slow-steaming is the best alternative to maintain profits. This coincides with the current situation, where vessels are slow-steaming due to an imbalance in supply and demand. Our bunker price and freight rate analysis shows that bunker prices are more sensitive than freight rates. A higher bunker price will increase the willingness to pay for transiting the canals to avoid longer sailing distances. Further, we found that the difference in sailing time between the Panama Canal, the Suez Canal and the Cape of Good Hope route is close to irrelevant in today's market. This indicates that there are no annual gains from sailing a shorter route at a higher speed given the current bunker price. Consequently, there are incentives for shipowners to prioritize cutting costs at the expense of fewer annual round-trips.

We believe that the expansion of the Panama Canal will have a positive effect on the world trade. However, it is difficult to predict the effect on container shipping. If the expansion leads to an increase in tradable volume, this should have a positive effect for container shipping. But if the expansion only leads to a shift for existing trade, the increase in cargo shipped by fewer ships on the shorter route through the Panama Canal could have a negative effect for shipowners.

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Appendix 1 – Model guide

This is a guide developed to help users of the model. The results displayed in the model are described in Chapter 5, *Model description*. An explanation to the data used in the model can be found in Chapter 6, *Data*. The model is found in a CD attached with the document.

1. Opening the model

When opening the excel-file, it is important that macros are activated. You will be asked if you want to disable macros before opening the file.

Click *Enable macros*.

2. Front page

The front page displays two options for the model:

- Single Voyage Cost Comparison
- Round-Trip Calculation

Choose the preferred alternative by *clicking one of the options*.

Based on your choice you will be sent to one of the following pages:

3. Single Voyage Cost Comparison

This model gives you the possibility to calculate the cost and results for *four* specific voyages or route alternatives and compare the results.

3.1. Input values

The cells marked in red are the input cells. This is where you can choose your input values for the calculation.

3.1.1. Additional information:

Freight rate per FEU is equipped with an explanation box. The freight rate for the model calculations needs to be in $/FEU. Freight rates on the routes between Asia and the U.S. are usually provided in $/FEU but if the freight rate is found in $/TEU, this must be converted by multiplying the $/TEU by 2.

Route is equipped with a scroll-down menu where you are presented with the available route alternatives to choose from.

> For more information about each *Route* you can go to the table where all the data is stored. The table can be found in the sheet named *Route information*.

Name is equipped with a scroll-down menu where you are presented with the available vessel name alternatives to choose from.

> For more information about each *Name* (i.e. vessel information) you can go to the tables where all the data are stored. The tables can be found in the sheets named *Panamax Container Register* or *Post-Panamax Container Register*, depending on which ship category you want to compare.
>
> Note that the name list is directly linked to the ship category. When you change the ship category from e.g. Panamax to PostPanamax, the vessel name will not automatically change and the model will not be able to calculate and all calculations will display N/A (Not available). Therefore, you need to change the name of the vessel after changing ship category for the model to calculate.

Operating speed is equipped with a scroll-down menu where you are presented with the available speed alternatives to choose from.

> Note that the model only allow for integer values between 18 - 25 knots. It is also important to notice that the design speed of the vessel is mentioned under 2. *Ship information* in the calculation sheet.
>
> If the operating speed chosen is higher that the design speed of the vessel, the model will not calculate fuel costs. In this case, the cost per TEU result will display as *not available.*

The input cells without a scroll-down menu are equipped with a short explanation box that provides information regarding value restrictions.

3.2. Calculation

The model will calculate the costs and results automatically when input values are inserted in the input cells.

3.3. Export of results and sensitivity analysis

The model provides the possibility to export the results to a new workbook or run sensitivity analysis for key components. These options are presented on the right side of the calculations. For sensitivity analysis, click the preferred sensitivity option, and the model will calculate the scenario automatically and export the results to a new workbook.

4. Round-Trip Calculation

This model gives you the possibility to calculate a round-trip voyage. It will also calculate the annual result for the chosen round-trip.

4.1. Input values

The cells marked in red are the input cells. This is where you can choose your input values for the calculation. The design is similar to the single voyage cost comparison model. However, this model only calculates for one voyage. It distinguish between the fronthaul and backhaul leg of the voyage, i.e. the back and forth journey of the trip.

Note that the fuel unit cost, freight rate and load factor usually are different for the backhaul journey in the round-trip.

4.1.1. Additional information

This is similar to the information presented under additional information for the single voyage cost comparison model.

4.2. Calculation

The model will calculate the costs and results automatically when input values are inserted in the input cells.

4.3. Export of results

The model provides the possibility to export the results to a new workbook. This option is presented on the right side of the calculations.

5. Other important information

5.1. Hidden sheets and calculations

Some of the calculation sheets are hidden. To show them, right click on one of the sheets in the bottom navigation line and click *Unhide.*

In addition some of the results for the sensitivity analyses are calculated in the calculation sheet before they are exported to a new workbook. These calculations are hidden below the main calculations.

5.2. Navigation

Each calculation sheet is equipped with a *Back*-button, which will take you back to the front page.

When exporting the results or performing sensitivity analysis, the results are displayed in a new worksheet that automatically opens. For Mac-users this workbook opens in a new window. For Windows-users this workbook may open in the same window. To get back to the main workbook, the other workbook may have to be minimized depending on your default settings.

5.3. Data tables

All the information used for calculating the costs and results in the model are available in separate sheets in the Excel-workbook. If you want to view the information presented in these sheets, the easiest way to navigate between them is to use the navigation line on the bottom of the page.

5.4. Locked workbook and cells

The entire workbook will be locked for structural changes. In addition, all sheets except the calculation sheets will be locked for editing. The locked sheets are not restricted by password, and can be unlocked if the user wish to make changes.

Cells that perform calculations will not be locked for editing because some of the sensitivity calculations depend on the calculation sheet to be unlocked. It is not recommended to edit these cells, as they depend on intricate formulas calculated in other, hidden sheets.

Appendix 2 – Port settlement

Estimates for a Houston Port settlement for a Grieg Star vessel*:

Port Dues (per day)	$ 5 000
Pilot	$ 7 500
Towage	$ 8 200
Lines	$ 1 000
Agency Charges	$ 8 500

* These are rough estimates for one of their largest vessels. The costs will vary with the size of the vessel. Handling costs will come in addition.

Appendix 3 – Invoice Panama Canal

AUTORIDAD DEL CANAL DE PANAMA

FACTURA - INVOICE

PANAMÁ

Facturar a / Bill to:	Fecha / Date	Tipo de Transacción / Transaction Type	Número / Number	Página / Page
CITIBANK N A APARTADO POSTAL 0834-0555 Republica de Panama	08-JAN-2014	Invoice	5468296	1 de/of 1
	Agente / Agent	BOYD STEAMSHIP CORPORATION		

Remitir por correo a / Remit by mail to:

Dentro de la República de Panamá. From within the Republic of Panama	Fuera de la República de Panamá. From outside the Republic of Panama.
Autoridad del Canal de Panamá División de Contabilidad Sección de Cuentas por Cobrar y Pagar (FACO) Balboa, Ancón República de Panamá	Autoridad del Canal de Panamá División de Contabilidad Sección de Cuentas por Cobrar y Pagar (FACO) P.O. Box 526725 Miami, FL 33152-6725

Fecha de vencimiento / Due Date	Para mayores informes, sírvase comunicarse con: / For questions regarding this form, please contact:	Preparado por / Prepared by	No. de Teléfono / Telephone No.
	01-BILLING-ADMEASUREMENT UNIT	ADMEASUREMENT UNIT	272-4530

Descripción de la Transacción / Transaction Description	Cantidad / Quantity	UDM / UOM	Tarifa / Rate	Importe / Amount
SHIP NUMBER 6008223 — ARRIVAL DATE 04-Jan-2014 1620 SHIP NAME STAR LOFOTEN — TRANSIT DATE 07-Jan-2014 0620 LENGTH 670.6 — TRANSIT DIRECT NORTH BEAM 106.0 — BATCH NUMBER 108				
TOLLS (LADEN) PANAMA CANAL TEU - 10 TEU - (GENERAL CARGO)	10.00	TEU	$ 82.00	$ 820.00
TOLLS (LADEN) PANAMA CANAL NET - 30,982 PC/UMS - (GENERAL CARGO)	1.00			$ 154,821.62
FIRST 10,000 TONS @ $5.10 — $51,000.00 NEXT 10,000 TONS @ $4.99 — $49,900.00 REMAINING 10,982 TONS @ $4.91 — $53,921.62				
TUG SERVICE CHARGE (FIXED FEE)	1.00	UNIT	$ 11,445.00	$ 11,445.00
WIRE HANDLING SERVICE CHARGE	1.00	UNIT	$ 4,745.00	$ 4,745.00
TRANSITING VESSEL INSPECTION	1.00	UNIT	$ 118.00	$ 118.00
LOCOMOTIVE SERVICE CHARGE (6 X 12)	12.00	WIRE	$ 300.00	$ 3,600.00
PANAMA CANAL SECURITY CHARGE	1.00	UNIT	$ 1,000.00	$ 1,000.00

PAGADO
10 ENE 2014
Depto. de ... Citibank, N.A.
Sucursal Panamá