The viability of slow steaming from a supply chain perspective through a break-even bunker price analysis

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Abstract

Over the years the viability of slow steaming has been researched mainly from a microeconomic perspective. In fact, the vast majority of researchers have been focused mainly on the consequences that slow steaming has to the two most affected actors of the transport supply chain, shippers/consignees and carriers. On the other hand, studies that focus on the viability of slow steaming from a macroeconomic perspective are scarce significantly. Taking this opportunity, the current research proves the viability of slow steaming nowadays from a supply chain perspective, by implementing a break-even bunker price analysis. More specifically, this research focuses on the costs and benefits of both actors of the supply chain at first, while on the later parts compares the current bunker price with the break-even point (where slow steaming's effect on carriers is equals to the effect on shippers). To implement the calculation model, we focus on five main trading routes around the world, including some not yet researched regions, such as Africa and Oceania. What is more, the main model is being implemented in a speed sample of 15 to 25 knots of sailing speed of five different vessels that differ mainly in carrying capacity of TEUs.

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1. <u>Introduction</u>

Over the years, many researchers have performed studies regarding optimal speed of container vessels in almost every sea route around the world. Reading most them, one will understand certain major topics that researchers try to focus on, are relevant mainly to cost reduction issues, environmental issues or even ethical issues. However, studies concerning fuel consumption, greenhouse gas emissions and optimal sailing speed skyrocketed during the years 2008 and 2009, due to the significant sailing speed reduction trend of container vessels, also known as slow steaming. The main idea under slow steaming, introduced by Maersk and implemented by the vast majority of the carrier companies, was the substantial reduction of bunker costs and greenhouse gas emissions, in order for the carriers to gain competitive advantage. The interesting aspect though, is the year that carriers chose to massively implement slow steaming. In fact, 2009 was the year that not only carrier companies implemented slow steaming, but also was the beginning of a rapid rise of prices in crude oil, after a significant and almost vertical fall from $750 per metric ton to $250 per metric ton (infomine.com, 2016). Consequently, in conjunction with the worldwide financial crisis, fuel costs began to have a significant impact on total costs of container vessels and their owning carrier companies. Hence, during those years, carriers were constantly trying to find a way of keeping fuel costs stable or even lower than the existing ones, without causing any important issues in the container transport supply chain. Soon enough, in 2008, several mechanical and technological breakthrough ideas came into the spotlight without any substantial effect in fuel cost reduction. Therefore, later that year, Maersk introduced slow steaming as one of the most innovative ideas around the maritime industry for fuel cost reduction, leading to significant inequities among all the other actors of the transport supply chain along with rising questions about this strategy.

The following years, up to the present, container vessels kept the same low and super low sailing speed as slow and super- slow steaming indicates. However, the more carriers are functioning under slow steaming conditions, the more issues the other actors of the container transport supply chain have. Thus, a relevant question would be whether or not such a strategy should be maintained? But, according to Maersk CEO (2013), the supply chain has already been fixed under the conditions of slow steaming and it would be painful and costly for the entire supply chain to change now. On the contrary, the current research will tackle this statement and will try to focus on the costs and benefits that slow steaming offers on the two most affected actors of the supply chain, shippers/consignees and carrier companies. To do that, a rare research method will be used, called break-even price analysis. In other words, the current research will provide an answer to the following research question.

"*Is slow steaming still viable in the container shipping market from a supply chain perspective? A break even bunker price analysis."*

To answer this question, we should firstly answer several sub-questions to introduce some basic knowledge regarding supply chain actors and slow steaming's impact on those actors and crude oil prices.

- *Which actors of the supply chain are significantly affected from slow steaming?*
- *Which is the quantified impact (benefits/costs) of slow steaming on the affected actors?*
- *In which bunker price are costs equal to benefits (break-even bunker price)?*
- *Why does slow steaming still exist?*

To achieve that, in the first part of the analysis I will quantify the impact of slow steaming in the two most affected actors of the container transport supply chain; shippers/consignees and carrier companies. More specifically, I will use several useful formulas that Notteboom, Cariou, Psaraftis, Kontovas and several other prominent professors include in some of their researches. In fact, since the current research focuses mainly on break- even bunker price in order to show the viability of slow steaming nowadays, a more thorough glimpse of fuel costs and crude oil prices over the years will be given.

Secondly, after the quantification of slow steaming's impact, I will provide the bunker price that leads to the equilibrium between carriers' net effect and shippers' net effect, by using a constructed equation. In other words, by keeping all the other data stable and having bunker price as my main variable, I will find the break- even bunker price.

Thirdly, I will compare the current bunker prices to the break- even bunker prices in order to answer the main research question, which focuses on the viability and the urgency of slow steaming. By doing that, this research will be a fruitful asset to the yet limited research that has been done on slow steaming from a supply chain perspective. In fact, one can notice that a great amount of research has been done under specific microeconomic conditions by focusing mainly on one actor of the supply chain. Hence, with the current research a more macroeconomic perspective of the whole container transport supply chain will be provided and we will see how this chain is affected by slow steaming.

To achieve all the above, one should have a concrete and stable theoretical background. This will raise interest in the aforementioned topic and offer a simple yet thorough insight of other relevant topics, so that one can construct a spherical perspective of them. So, one will be able to raise questions for further research. As a result, before the actual empirical analysis, I will proceed with a comprehensive literature review based on research of several prominent researchers around the academic world.

Moreover, concerning the literature review, I decided to provide a variety of relevant information, that is interconnected and offers both a basic knowledge on some important topics as well as specialized and extensive knowledge on some others. Therefore, in the very beginning, I will provide a short historical background for slow steaming, as well as some explanations of relevant terminology and definitions not only for slow steaming and crude oil prices, but also for the entire maritime industry, aiming at the better understanding of the current topic by readers. To continue, in the same part of the literature review, a thorough overview of the of the main inertia that led most of the carrier companies to embody slow steaming in their main sailing strategies will be given, as well as the first reactions of all the other actors of the supply chain. The main purpose of the first part is to provide the main reason that causes the disagreement between the two most affected actors of the supply chain, so as to show the urgency of our topic nowadays. For the second part of the literature review, a thorough glimpse of the container transport supply chain will be given. In this section I will provide the main links between the relevant actors, their main tasks and responsibilities, their market and industrial power, as well as the financial relationship of forwarders, shippers/consignees, carriers, terminal operators and companies which are responsible for container transportation to and from port facilities. The purpose of this part is to clarify the actors that are most affected by slow steaming, and why we are focusing mainly on carrier companies and consignees. In fact, in this section we will first meet a cost and benefit analysis of those actors in order to understand the significance that fuel costs and bunker prices nowadays have on total costs. This analysis will be useful later on my empirical analysis and model construction so as to find the break-even bunker price keeping all the other variables stable. Furthermore, in the final part of the literature review, as a start, I will provide some useful literature in order to note the aftermath of slow steaming's implementation and quantify it. Afterwards, I will provide some theoretical background of the current situation in crude oil prices and some technical information regarding preferable vessel fuel, as well as past and current trends in crude oil prices. The main purpose of this part is to give a future perspective of the topic, so as to allow readers to make several hypotheses regarding the topic and to guess what comes next. Of course, since the whole literature review is based on a break-even price analysis, I will provide several articles concerning the break- even spot, and what it actually is that.

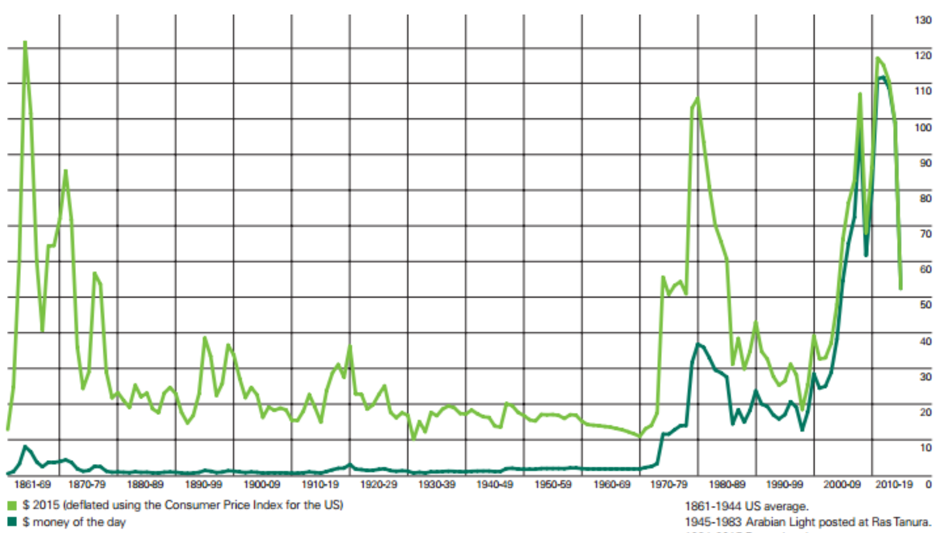
2. <u>Literature Review</u>

2.1 <u>Description of the oil market</u>

Nowadays energy sources are dominated by oil resources. Over the years, all over the shipping industry the two main issues concerning crude oil are high prices and constant price fluctuation. Historically, there were several important crises and trends that played significant roles in the formation of crude oil prices. In fact, since 1970's oil boom, there were the Asian crisis, the second gulf war, the world financial crisis and the Arab spring crisis in 2010. All of these along with several other major events, drove crude oil prices to fluctuate between 30$ per barrel and 150$ per barrel (BP, 2016).

Firstly, Notteboom and Vernimmen (2009) gave a thorough insight of bunker and oil prices in their article. In fact, they base their research in the very basic fact that bunker and oil prices are in a constant fluctuation due to two main reasons, immense market forces and the cost of crude oil. For that time and until the end of 2007, authors concluded that over that years bunker prices were substantially rising until the peak of almost \$500/ metric ton. After that era, according to infomine.com (2016) and bunkerindex.com (2016) we notice a substantial and almost vertical decrease until 2010 where oil prices again began to rise reaching a stable price of \$120/ barrel, until 2014 where the substantial decrease began and continues to the present.

To continue, as one can distinguish in the graph below, even though the whole oil industry all over the world has been through important crises and trends, in most of the past years and until 1990's, oil prices didn't have huge fluctuations. Hence one could say that oil prices had a stable tense. However, after 1990's one can notice a substantial and almost vertical change not only in oil prices, but also in the tendency of the whole industry to react violently to each historical event. Subsequently, such a significant alteration in the oil industry raised the awareness of the majority of those companies that depend on oil resources.



1. Crude oil prices 1861-2015 (BP, 2016)

When it comes to carrier companies, both high and highly fluctuated oil prices are considered as negative issues. Firstly, due to the fact that nowadays, fuel costs cover the vast majority of the total costs of a vessel trip (Notteboom, 2008). Even a minor fluctuation in crude oil prices leads to a significant change in company's operational costs. In fact, in order for carrier companies to cope with the constant fluctuations of oil prices, they have introduced several strategies that can either offer more smooth reactions in companies' fuel costs, or distribute the costs that price fluctuations cause to several actors in order to create a balance that cannot be lost by oil price fluctuations. What is more, based on Oxford Institute for Energy Studies (2010), high oil prices and a highly fluctuating oil industry can damage not only actors of the container transport supply chain, such as carrier companies, but can also harm the general growth on a global scale substantially by causing imbalances in each and every industry globally.

One of the most known moves that carrier companies made to cope with the high volatility in the oil industry is the Bunker Adjustment Factor (BAF). According to Notteboom and Vernimmen (2009), BAF is a considerable effort of carrier companies to cover some of the increased costs by passing the costs to their customers in order to avoid covering those costs by themselves. Over the years, the relationship of BAF and bunker prices has been a highly debatable issue, due to the fact that the result of the whole situation does not affect carriers at all. More specifically, carriers cover only the basic bunker costs, while bunker adjustment factor is applied mainly to changes under specific levels of trade.

Furthermore, one more move carrier companies have made in order to cope with the rough environment that oil industry offers is their intentional denial of some new types of fuel. More specifically, according to Notteboom and Vernimmen (2009) there are several famous types of fuel that vessels use commonly. However, the most common one is the Heavy Fuel Oil (HFO) which is the oldest one, while some others are Marine Diesel Oil (MDO) and Marine Gas Oil (MGO), which are considered as the most up to date ones. However, due to new regulations concerning vessels' fuel and their emissions, vessels use the new types of fuel only when they are obliged to use low Sulphur fuel in some routes, which of course is more expensive than the regular ones.

Lastly, since nowadays fuel costs have been accumulated as a significant amount of money not only in carrier companies' operational costs, but also in their total costs, almost all actors of the transport supply chain try to optimize the relationship between costs and benefits and more specifically to create a balance between all costs. However, some actors of the chain are more dependent on the gap between costs and benefits than others, basically due to their commercial character. For example, in the case of the transport supply chain, carrier companies are more dependent in the gap that they create between their benefits and costs, hence in crude oil prices than freight forwarders. Hence, even though all actors of the supply chain tried to implement some strategies in order to cope with the major changes in the oil industry, carrier companies implemented most of them due to their immediate dependence on this industry. In fact, one can notice some early efforts around 2006-2007 with some technological innovations, sail schedule alterations and new types of vessels that could reduce the fuel costs significantly, without causing any major imbalances between the actors of the supply chain. However, over the years, oil prices and oil industry's volatility led carrier companies to a critical point where they were forced to make a breakthrough move. The pressure from the oil industry along with several other major issues, led carrier companies almost to the point of decadence, led to the significant reduction of vessels' sailing speeds. This trend which stands from 2007 until nowadays is called slow steaming.

2.2 Slow steaming

Over the years, many researchers covered the trend of vessels' sailing speed reduction in container transportation industry from numerous perspectives. Hence, one can claim that nowadays slow steaming is no longer something new to container shipping industry (Liang, 2014). In fact, going back in time we will distinguish that slow steaming started around 2007 to 2008 as an effective and efficient way of lowering costs by reducing fuel consumption of vessels. In other words, almost a decade ago, Maersk introduced the reduction of vessel speed by 3-5 knots from the current vessels' design speed, as the most beneficial speed of sailing due to several reasons. Subsequently, over the years more and more companies changed their way of function by implementing slow steaming, leading to the point where almost 75% of all shipping companies not only consider slow steaming as an alternative option of their main sailing speed, but also consider it as their main way of function (Ma, 2014).

Moreover, in the first years of the implementation of slow steaming, there had been several uncertainties, as well as major controversies. At first, there was an uncertainty concerning the main inertia of carriers to proceed with the reduction of their sailing speeds. In fact, there is a common belief that carriers implemented slow steaming in order to be benefited in terms of fuel consumption and greenhouse gas emissions (Maloni, 2013). However, the significant reduction in vessels' sailing speed allowed carriers to use the excess vessels that remained idle after the financial crisis of 2008 (Liang, 2014). To cover this uncertainty, in the next few paragraphs I will present few articles that covered the main reasons that led carriers to proceed in the use of slow steaming. However, the main consequences that the sailing speed reduction created in each actor of the supply chain will be presented in the third part of the literature review.

As far as the main inertia behind slow steaming is concerned, there is a lot of research that covers a great variety of topics. On the one hand, some of them are quite innovative and try to cover a great breadth of the main reasons that led carriers to using slow steaming. On the other hand, others prefer to cover such an issue by focusing on a specific subject, covering the topic at a great depth and offering details that sometimes require specialized knowledge.

At first, Kontovas and Psaraftis (2011) gave a thorough overview regarding the main incentives of carriers to function under slow steaming conditions. As a start, in the beginning of their research they show that slow steaming is created basically for two simple reasons, fuel costs and vessels' emissions. More specifically, they show that due to fuel costs and emissions direct causality, a significant reduction of vessel speed would create a "win-win" situation among them by reducing both. Hence, from a quite general perspective, they show us that sailing slower would reduce both fuel costs and emissions. However, in the later stages of their research they elaborate the theoretical part of the main reasons of the implementation of slow steaming. In fact, they came up with six main options which, according to them, led to speed reduction. Firstly, carriers' fuel costs were constantly increasing, due to higher or extremely volatile bunker prices. On top of that, carriers' fuel preferences over the years became more expensive, increasing fuel costs even more. Especially in areas with specific environmental regulations (SECA), vessels are obliged to use environmentally friendly yet costly fuel, leading to fuel costs' skyrocketing. Furthermore, since port dues and local taxes became a substantial part of carriers operating costs, they decided to reduce their sailing speed in order to reduce various running costs components. As far as the environmental inertia is concerned, carriers decided to operate under slow steaming conditions not only to fulfil the mandatory regulations concerning vessels' emissions, but also to cover the companies that voluntarily wanted to contribute in an environmentally friendly container transport industry. Lastly, from a purely carrier perspective, slow steaming was a logical reaction to the significant reaction of freight rates.

However, as van der Lught and Streng (2012) mention in one of their articles, even from the very beginning of the implementation of the reduction of sailing speeds policy, a great controversy arose. In fact, due to the absence of a general benefit in all the supply chain's actors, slow steaming created an imbalance, mainly between carriers and shippers. Consequently, taking into account the current imbalance in the supply chain, in conjunction with the economic crisis of 2008 which led to the reduction of the worldwide demand, the authors noticed the first few reactions to this trend, which I will discuss at a later stage.

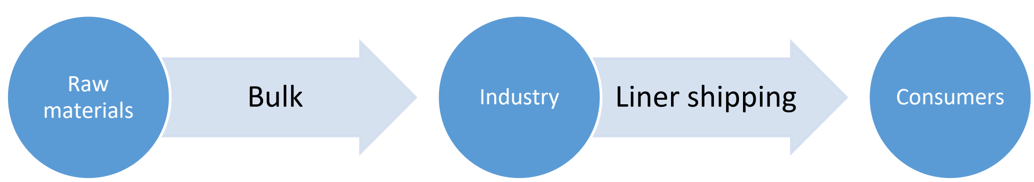
What is more, most of the researchers who deal with slow steaming have either a big or small relation to emissions, due to the fact that emissions saving nowadays is one of the most highlighted and interesting topics. At first, Corbett et al (2009) deals with the mutual causality of emissions and sailing speed, showing the effectiveness and potential costs on emissions of the container shipping, while the sailing speed constantly decreases. In fact, he concludes in an outstanding statistic that made a real contribution to the international container shipping. He found out that a vessel slowed by half of its speed can decrease its emissions by almost 70%. To continue, Psaraftis et al (2009) also focused on the emission- speed relationship, by giving a more in-depth view of it. More specifically, he showed the substantial role of the port time in the emission factor and that a speed reduction of 20% lead to a 36% emission and fuel cost reduction, while a 15% speed reduction should be followed by a 37% port time reduction in order for the voyage time to remain stable.

As one can understand, slow steaming came into the spotlight as an effective and efficient way for carriers to reduce their carbon footprint as well as their fuel costs that cover a great amount of all the carriers' costs. However, under their constant will to reduce operational costs, carriers did not think of the consequences that a substantial reduction in sailing speeds will have on the other actors of the supply chain. That was mainly due to the increased market power that carrier companies have in comparison to the other actors of the container transport supply chain (Pozdnakova, 2008). To more closely watch the relationship between all the actors of the chain, I will proceed with a presentation in the next part of this literature review.

2.3 Supply chain analysis

To continue, since the current thesis is relevant to a trend that basically affects all the parts of the transport supply chain, the analysis of the supply chain has an obligatory character. In fact, with a thorough description of the supply chain's structure, actors and the links between them, this literature review will help the readers clarify some simple yet basic things and concepts concerning the main topic. In the first few paragraphs, I will present the transport supply chain as a whole by demonstrating, through a graph, the main actors and the relationships between them. Later in this section, I will offer a thorough glimpse of each and every actor of the supply chain, as well as how they contribute to the balanced function of a container shipping supply chain.

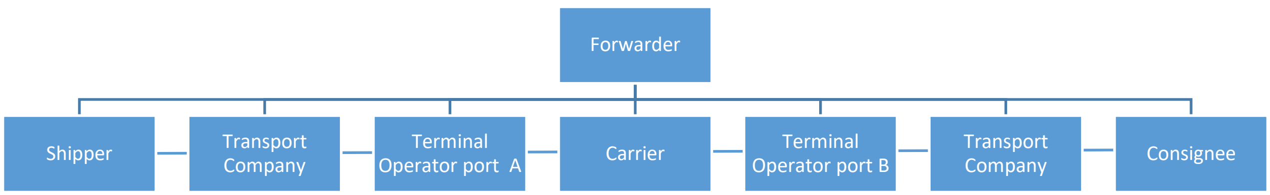
However, in order to explain the structure of the transport supply chain, we should clarify several aspects first, regarding the structure of the liner shipping industry. According to Haralambides (2007) the shipping industry consists of two main parts. Firstly, the part of bulk shipping sector which mainly involves the transportation of raw materials such as oil, coal and grains, and, secondly, the part of the liner shipping which mainly involves the transportation of final and semi-final products. In the current thesis, I will focus only on the liner shipping industry, since it is mainly focused in the provision of services between already specified ports, by following strict timetables. In addition, such services are open to everyone who has some cargo to ship somewhere. On top of that, liner shipping often provides services with global coverage, which require extensive and complex infrastructure in terms of terminals, handling facilities, ships and equipment. Also, in the current thesis, I consider the effects of slow steaming only in liner shipping and not bulk, due to the significant difference of speed between container vessels and bulk carriers. More specifically, according to the 2^{nd} GHG study of IMO (2009) bulk carriers have significantly lower average speed than container vessels. In fact, bulk carriers fluctuate their speed between 14-15 knots while container carriers sail with speeds between 25-26 knots. Hence, reducing speeds by 5 knots in container vessels could save significantly more than reducing the speeds by the same number of knots in bulk carriers.



2. Shipping industry in the production process

Furthermore, based on Talley's (2014) article we can demonstrate the structure of the transport supply chain, as well as the relationships between its main actors. Thereupon, in order to transfer the cargo from shippers to the consignees through sea, the following chain of actions is obligatory. At first, shippers should provide their cargo to water and land transportation companies. Secondly, these companies should transfer the cargo to a port's facilities. As it follows, port should interchange shippers' cargo between water carriers and land carriers with the proper use of port's terminals. Water carriers should transfer the cargo through a specific water route to an already specified port destination in an already specified time schedule. Lastly, the destination port as well as the transport companies in the destination location should follow the same steps as the previous port/transport companies in order for the cargo to be transferred to the already specified consignee.

Moreover, Talley in his current article not only explains the aforementioned specific chain of actions in order for the shippers' cargo to be transferred to the desired consignee, but he also focuses on the availability of each actor of the supply chain. Hence, he reaches the conclusion which states that in order for all actions to be implemented properly, all actors of the transport chain should conscientiously contribute, otherwise the network does not hold.



3. Container shipping supply chain

2.3.1 Shipper/Consignee

The first major part of the container shipping supply chain is the shipper. According to businessdictionary.com (2016), shipper or consignor is "the party responsible for initiating a shipment, and who may also bear the freight cost". In our case, the shipper is also one of the two main affected parts of the supply chain by slow steaming. Interestingly enough, shippers are mainly affected in a negative way by slow steaming for various reasons, resulting in the major conflict with carriers.

More specifically, according to marineinsight.com (2016), shipper's presence, apart from its obligatory character, is also vital to the implementation of several secondary tasks, that sometimes companies tend to underestimate, such as insurance of the cargo and the fulfillment of vital documentation which is necessary for the transportation to be completed. On top of that, it is common nowadays for shippers to be responsible for the proper packaging and tagging of the cargo.

To continue, according to Tongzon (2002), there are three different types of shippers, a) the ones with long term contracts with shipping lines, b) those who prefer to outsource logistics to forwarders, and c) independent shippers who prefer to take on the transport responsibilities by themselves. In fact, the first category of shippers is mostly committed to a specific carrier, to transfer its cargo, something that the others do not prefer to include in their main functions.

Moreover, based on data collected through Kuehne + Nagel's intranet (2016) we have some practical information regarding shippers and the ways they nowadays provide to transfer their cargo. At first, we distinguish the fact that shippers can directly contact a shipping company or a broker, in order to transfer their cargo and cope with all the paper and contractual work. However, nowadays the most common way is to contact a forwarder, which is actually the agent that can take into his responsibility all the procedures and logistics that are needed to be done. In addition to that, based on the same database, we can extract various interesting practical details regarding shippers' trend to the use of freight forwarders. In fact, one can notice that the old classic definition of shippers has been significantly changed. Shippers, nowadays, despite the choice of transport mode, the amount of cargo to be shipped, the amount of cargo to be ordered and the total number of transshipment spots to be used, prefer to contact freight forwarders or third party logistics companies to cope with the whole shipment procedure. As one can understand, freight forwarders play a vital role to the transport supply chain due to the current trends. In consequence, despite the fact that the current thesis will take into account only shippers and carriers as the two most affected actors of the supply chain due to slow steaming, I will provide some useful information about them in a later stage of this section.

In any case, either with the traditional one, or through a forwarder, the final destination of the cargo and the final cornerstone of the cargo's transportation is the consignee. One can identify that plenty of researchers use consignees in the same category as shippers, time and again for various reasons. In fact, in my research, I will consider consignees in the same category as well, basically for three main reasons: Firstly, due to the fact that it is pretty common to meet the same company under the identity "shipper" and "consignee", or different departments of the same company. Secondly, due to their same cost structure as commercial companies and more important due to their same way of function, commercial character and slow steaming's affection. Thirdly due to Fries & Patterson (2008) who clearly state in their article that both shippers and consignees belong to the same level of the organizational structure of a transport supply chain.

Lastly, since shippers are one of the major parts of the sailing speed reduction trend, being the most negatively affected actor of the transport supply chain, it is important to understand and monetize slow steaming's impact. To do that, according to Rodrigue (2016) we take into account that shippers' costs are separated into two categories, direct and indirect costs. More specifically, direct costs (also called full production costs or prime costs) consist of material costs, wages costs and operational expenses, while indirect costs (also called nonproduction costs or overheads) consist of overhead costs, distribution costs and research & development costs. However, we should be aware of the fact that such kind of cost categorizing could vary due to its dependence to the company's type, structure and size. Moreover, based on the aforementioned companies' cost structure, putting slow steaming's impact on the spotlight, we will notice the substantial increase of companies' indirect costs due to distribution costs skyrocketing. The reason is quite straightforward, since slow steaming leads to longer transit times, and longer transit times lead to a significant increase of distribution costs.

2.3.2 Transport Company

At first, due to the fact that in the current research I focus only on the two mainly affected actors of the transport supply chain (shippers and carriers), I consider transportation companies as a secondary actor in the chain. Hence, even though such kind of companies play yet another important role in the supply chain, only for the purposes of the current research I do not offer substantial information on them such as cost and benefit structure, something that will be used in the empirical analysis part later on. However, since they are unambiguously one of the main parts of the chain, we should mention some important information about them.

Initially, as transport companies we consider the companies that implement the transportation of already specific cargo, towards and from the port facilities. Interestingly enough, such kind of companies, contrary to the other actors of the transport supply chain, have a broad spectrum of transportation modes. In fact, they can transport cargo towards and from port facilities not only by rail, road or barge, but also by using a combination of transport modes (intermodal transport).

Additionally, as far as road transport is concerned, there are quite low entry barriers in the market, a strong threat of substitutes such as rail and barge and a high level of internal rivalry. In fact, in 2014 there were 11.600 small and medium companies registered in the Netherlands, having the average of about 8 vehicles (van der Lught, 2016). When it comes to barge transportation, internal rivalry is high due to the fact that there are many small companies in the market. What is more, there are quite low entry barriers and there is significantly high threat of substitutes. Lastly, regarding rail freight transportation there are a few interesting topics to mention. At first, according to De Jong (2016) the cost structure of the rail industry has to do with high construction and maintenance costs of infrastructure, which the whole industry covers with excessive amounts of money from government subsidies. On top of that, the rail transportation industry has high entry barriers since train companies are mainly governmental businesses. However, there is a high rivalry between companies and a high threat of substitute modes of transport.

All in all, in this case, I consider transport companies as a secondary actor of the transport supply chain, since slow steaming does not significantly affect their costs or benefits. However, I mention once more that their role in the supply chain is quite vital and based on the aforementioned data, their market is quite intense in each and every transport mode.

2.3.3 Terminal operator/ Stevedoring

Initially, as I stated above on the "transport companies" category, for the purposes of this research, I consider terminal operators as a secondary actor of the transport supply chain. Therefore, I will present only a few basic, yet important information regarding terminal operators, in order to have a clear and spherical view of all the actors of the supply chain.

At first, based on Khan's article (2014) one can distinguish that stevedoring is not only the occupation of handling cargo operations (loading and unloading of cargoes on ships), but also includes almost all the dockside activities that are important for the proper transportation of the cargo. Stevedoring and terminal operators have a rich historical background, regarding handling gear, activities and labor workers. However, over the years, all the actors of the supply chain changed or enhanced their main activities. Consequently, terminal operators could not remain intact for many years, resulting in a substantial alternation in their activities, especially over the last years. The main reason, according to the article, seems to be the containerization of cargoes and the rapid technological evolution of the gear that terminal operators use in order to handle the cargo.

What is more, regarding their main activities nowadays, terminal operators and stevedores, in general terms, are the responsible actors of the transport supply chain for cargoes' transition from port facilities to ships and reversely. However, since the containerization of cargoes remains intact, stevedoring jobs are constantly evolving. More specifically, apart from the loading and unloading part, there are now numerous duties. At first, stevedores ensure the top-notch safety of cargoes, so they are constantly enhancing their "safety" department. What is more, inspection of cargoes for any damage is a major part of stevedores' activities, trying to ensure undamaged and intact cargoes.

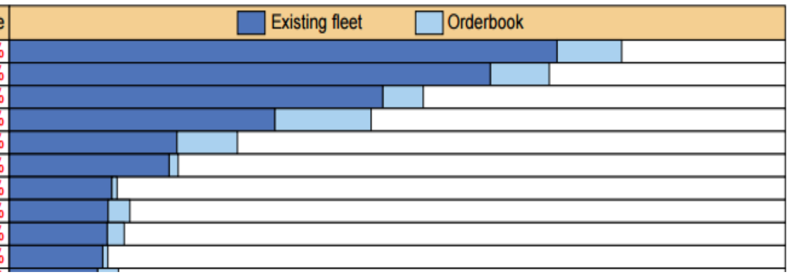
Lastly, the introduction of slow steaming in liner shipping significantly affected terminal operator companies all over global ports. In fact, those companies made serious adjustments in their structure, activities and labor, in order to be familiar with the current trend. However, in comparison with the other actors of the transport supply chain, the effects of slow steaming in terminal operation companies, especially in the long term, are negligible (Streng, 2012).

2.3.4 Carrier

One of the most important actors among all those of the container shipping supply chain are carriers. At first, carriers are basically companies that own the container vessels, which are used for cargo transportation between two or more ports as fast as possible, in the most cost effective way. According to OECD (2015) report, concerning liner shipping and carrier companies, there are several important current developments and trends that should be mentioned and discussed.

Initially, during the last decades, there is an interesting trend that takes place in the carrier market. Carrier companies tend to form liner shipping consortia and strategic alliances, causing a serious concentration in the market. In fact, approximately 55 % of the world liner fleet belongs to the top 5 operators around the world (APM- Maersk, Mediterranean Shipping Co, CMA-CGM, COSCO, Evergreen Line) (Alphaliner, 2016). The main reason of this concentration trend is the extremely high capital costs of the carrier market. According to the report, carrier companies use to follow this strategy not only to decrease the capital costs of each company, but also to afford the extreme size of investments in new vessels. On top of that, with consortia formation, the risks associated with new investments are spread among the carrier companies that are involved in the alliance. However, formation of alliances does not only have defensive motives, but also enhances carrier companies' geographic coverage. In such a way, all carrier companies can cope with the new challenges brought by globalization.

Rnk	Operator	TEU	Share
1	APM-Maersk	3,194,768	15.4%
2	Mediterranean Shg Co	2,806,101	13.5%
3	CMA CGM Group	2,178,920	10.5%
4	COSCO Container Lines	1,549,424	7.5%
5	Evergreen Line	977,562	4.7%
6	Hapag-Lloyd	932,239	4.5%
7	Hamburg Süd Group	597,886	2.9%
8	OOCL	576,270	2.8%
9	Yang Ming Marine Transport Corp.	571,723	2.8%
10	UASC	544,680	2.6%



4. Market share distribution of biggest shipping lines (Alphaliner, 2016)

Secondly, according to Stopford (2009) and Panayides (2011), the shipping industry is mainly characterized by demand volatility, freight rate instability, cargo flows imbalance and maritime assets financial commitment. Consequently, plenty of important changes took place in the specific sector during the recent years. In fact, the vast majority of the major carrier companies tried to implement low transport unit cost strategies and ordered huge number of mega-vessels. Furthermore, subsequent to the trend of "mega-vessels", the substantial growth of container vessel fleet and the global economic crisis, serious financial risks, general overcapacity risks and service-specific risks already began to bother a serious number of carrier companies.

Moreover, as widely known, the current trend of sailing speed reduction has mainly been introduced to the shipping industry by carriers to reduce vessel sailing costs. Hence, since the costs and cost structure of carrier companies are affected substantially by slow steaming, we should focus more onto these components. At first, Chen and Zhang (2008) give a thorough glimpse into the shipping costs of carrier companies. In fact, they highlight the division of the main costs into three categories a) Capital and operation costs b) fuel costs and c) port charge. More specifically, according to their article, capital and operation costs consist of the total daily expenses paid each ship use, including ownership cost, crew expenses, ship repair and maintenance and insurance costs. Furthermore, there are plenty of different approaches to calculate these main categories. They include a) daily fixed costs per TEU b) costs per TEU-mile and c) total shipping costs per TEU. However, since slow steaming significantly affected the time factor of the industry, on the one hand capital costs remained intact, while on the other hand operational costs changed significantly.

To continue, Lim (1994), Stopford (2004) gave an even deeper insight on sea carriers' cost and revenue structure. At first, Lim (1994) distinguished the costs of a container carrier into three major categories, a) Variable costs, which include cargo expenses and navigation expenses. Cargo expenses include terminal handling charges (THS), haulages and one-way short term lease costs, while navigation expenses include port charges and bunker expenses. b) Fixed costs that include crew expenses, vessel expenses, all kinds of depreciations and amortization. c) Overhead costs that include administrative costs and non-operating expenses.

However, Stopford (2004) gave a more spherical view of both costs and revenues of the liner service, on which I will base my main research. Initially, he identified six major cost categories of carrier companies: service schedule, ship costs, port charges, container operations, container costs and administration costs. More specifically, in the service schedule, he included some important decisions, such as service frequency, number of port calls and size of the ships to be used. Regarding ship costs, he included operating, capital and fuel costs, while for container costs and administration costs he included daily container costs, maintenance, repair and handling and various costs concerning management, logistics, finance and commercial purposes.

2.3.5 Forwarders

Forwarders are companies specializing in storage arrangement and shipping of cargo, on behalf of shippers (clients). They usually provide a wide range of services, that cover a great variety of client needs. More specifically, some basic services that forwarders provide are cargo tracking, preparation of shipping- including the proper documentation-, warehousing, cargo space booking, freight charge negotiation, freight consolidation and cargo insurance (Rau, 2014). The top 3 forwarding companies that cover a great percentage of the market are DHL, Kuehne + Nagel and DB Schenker. Apart from the basic tasks, the most important task of a forwarding company is information gathering. In other words, forwarding companies have to organize everything concerning the shipment of the cargo, let alone to inform their clients regarding their shipment on a regular basis, in a way that they prefer. Hence, it is quite common to meet huge IT departments in forwarding companies which handle details of shipments in their system.

Furthermore, as one can understand, freight forwarders are in a very prestigious position, handling the whole transport supply chain from the shipper to the consignee aiming to transfer the cargo as efficiently as possible. Nevertheless, with the constant terminal operators merging with transport companies,- taking the role of the freight forwarder themselves-, purely freight forwarding companies take a secondary role in the transport supply chain. However, taking into account the cost structure of a freight forwarding company, along with slow steaming's effects, one will distinguish only a small difference in their costs. More specifically, even though freight forwarders should deal with slow steaming unavoidably, they seem to have minor differences in their function and more importantly in their costs and benefits, due to their commercial character.

2.3.6 Overview

Lastly, in this section, we distinguished some interesting yet important facts of the transport supply chain: Firstly, the chain's main actors and the relationships between them, as well as their main functions and roles in the supply chain. Secondly, the effect of slow steaming on shippers/ consignees and carrier companies, due to their immediate relation in the current sailing speed trend. Thirdly, a quick glimpse in the cost structure of these two actors based on relevant literature, which will help us in the later stages of the research.

2.4 Consequences of slow steaming

2.4.1 Carriers

2.4.1.1 Fuel Efficiency

Over the years, slow steaming has been a real contribution to carrier companies regarding fuel efficiency. In fact, as Maloni (2013) states, the lower the sailing speed of a vessel, the more fuel efficient a vessel tends to be. Furthermore, Notteboom & Vernimmen (2009) showed, once more. the significance of slow steaming in fuel efficiency and its contribution to vessels' operating costs. In fact, they show that carrier companies, under slow steaming conditions, can decrease their vessels' operating costs by 50%, taking into consideration that fuel prices remained in the quite high limit of almost $700/mt (metric ton). Moreover, this consequence of slow steaming depends on the type of fuel vessels use, and the regulation of the regions that they sail through.

Furthermore, fuel efficiency is considered- by the majority of the scientists that focus on slow steaming and energy consumption optimization- as the most important consequence of sailing speed reduction. More specifically, since slow steaming is implemented by shipping lines mainly to reduce fuel consumption in an era of high oil prices, some people believe that any other consequence of slow steaming in the container transport supply chain is just a marketing trick, in order to lay down the reaction of the affected actors of the supply chain.

2.4.1.2 Greenhouse gas emissions reduction

As a consequence of the previously stated result of slow steaming, shipping companies are significantly reducing their carbon footprint in the routes that sail under slow steaming conditions. As I mentioned time and again, there is a mutual causality in vessel speed and greenhouse gas emissions. More specifically, as the sailing speed is lower, the fuel consumption is significantly reduced, which leads to lower greenhouse gas emissions (Maloni et al, 2013). In fact, according to the International Maritime Organization (IMO) in its third IMO Greenhouse Gas study 2014, for the years 2007 until 2012, the significant at-sea speed reduction in conjunction with the average reduction in everyday fuel consumption, reduced energy use and greenhouse gas emissions substantially. Of course, there are many technology-based ways to improve vessel efficiency and reduce emissions in a long term. However, speed reduction brought results faster than any other measure, by reducing CO_2 emissions by almost 70% (Corbett, 2009). One interesting fact regarding slow steaming is that it does not benefit only carrier companies, but it has a more general benefit on the whole of the transport supply chain. More specifically, shippers can also benefit from slow steaming, since they can significantly reduce their supply chain carbon footprint (Maloni, 2013).

2.4.1.3 Excess fleet capacity absorption

To continue, regarding slow steaming, it is commonly known that the motives of ocean carriers are purely financial, and partially reflect their need to find the balance forces that affect the ability to compete each other in the market. Hence, carriers face the constant need to manage their fleet size and available capacity, while reducing their fuel costs. More specifically, having in mind the economic crisis of 2008, which offered a substantial decrease of worldwide demand and increased vessel deliveries, one can understand that carrier companies would have had excess fleet capacity. Consequently, by the time of slow steaming implementation, carrier companies would need more ships to transfer almost the same amount of cargo, exploiting in such a way all of their fleet (Maloni, 2013).

2.4.1.4 *Additional Operating and Capital vessel costs*

Nevertheless, slow steaming has some negative aspects for carrier companies that should be measured, because they may cause serious loses to the company. Two major costs that increase with sailing speed reduction are operating and capital costs. Murray (2015) has done a detailed and up to date research regarding both costs. Murray's main idea is that the slower the vessels sail, the more vessels will be needed to cover the route, in order for the carrier company to sustain a stable sail schedule. Hence, even though the excess fleet capacity absorption is currently considered as a positive consequence of slow steaming to carrier companies, it also creates additional port charges, administration, store and lubrication costs, insurance costs and labor costs (Rodrigue, 2017). What is more, a great variety of researchers have measured these operating and capital costs and their increasing tense they have as long as carrier companies continue to reduce the sailing speed of their fleet. However, this caused a large deviation of the actual results, especially in the capital costs section.

More specifically, there have been several shipping companies that own a significant number of vessels. Those companies, over the years, have announced the estimated construction and selling price of various vessel categories. Moreover, according to Stopford (2009) and Murray (2015) the bigger capacity a vessel has, the more expensive it is. That is basically true, due to the fact that bigger vessels need thousands of tons of steel more than smaller ones and more labor in order to mantle them. However, since economies of scale exist in vessel's capital costs (Murray,2015) one can observe that the bigger a vessel is, the smaller is the cost per 20 ft. of container (TEU).

2.4.1.5 *Additional Container use costs*

Once more, since slow steaming increases both the roundtrip days and the vessels that are needed to keep the route schedule stable, containers that are used for transportation of cargo remain under a carrier company's possession longer. Hence, in order to have a complete image of a carrier companies' major cost categories, we should measure this cost as well. The most detailed research regarding this cost category comes for Notteboom and Verbeke (2004) and Stopford (2009) who basically quantified the hourly cost of each TEU that has been used by carrier companies over the years.

2.4.1.6 *Degradation of vessel engines*

From a purely technical point of view, a container ship working under slow steaming conditions is operating under a condition called "off- design" (Tsimplis, 2012). The immediate consequences of an "off- design" condition are mostly related to the actual degradation of the engine. More specifically, the system that recovers the heat of the engine loses its efficiency for various reasons. Secondly, vessel turbo chargers and propellers lose efficiency as well, while lubrication demand is significantly increased and several irregular vibrations may occur (Tsimplis, 2012). Furthermore, according to several marine engine manufacturers, over the next years of slow steaming's implementation, vessel engines' overall lifespan will be decreased. In fact, manufacturers are selling specialized slow steaming kits, in their effort to keep engine lifespan in normal levels, something that greatly increases scheduled investments for vessels. Moreover, now that slow steaming is not something new in the supply chain, and engine manufacturers understand that sailing speeds will keep being low, they equipped the new vessels with up to date engines which do not have the conventional mechanically controlled fuel injection pumps and exhaust valve drives. Under these conditions, the new engines increase the costs of acquirement. However, vessels and carrier companies can implement fuel cost saving strategies immaculately, in parallel with reducing maintenance costs (Santala, 2013).

2.4.2 Shippers/consignees

2.4.2.1 Schedule reliability

As I further analyze slow steaming consequences, I will definitely meet the effect of sailing speed reduction in general schedule reliability. In fact, according to Ronen (2011) the increased transit times that slow steaming offers, provides to operators with a more flexible schedule, increasing this schedule's reliability. On top of that, Notteboom & Vernimmen (2009) claim that issues concerning vessel schedules could be partly solved under slow steaming conditions, with oil prices in a stable yet high level. Carrier companies stand on the same positive side as the aforementioned authors, stating time and again the positive contribution of slow steaming to schedule reliability. In fact, to prove their point, those companies promised enhanced schedule reliability, since slow steaming and reduced sailing speed would allow vessels to continuously adjust their speed to meet the desired schedule. However, interestingly enough, the Review of maritime transport (2010) unveiled the unpleasant truth, by providing several statistics that show the late arrival of almost 30 million vessels, as slow steaming gained more and more reputation throughout carrier companies. In fact, when the most of them reduced their sailing speeds and were under slow steaming conditions for several years, the first disruptions in shippers' production processes came into the spotlight. Based on this controversy, I will not include schedule reliability neither on benefits nor on costs for shippers. However, in the near future, when schedule reliability will be clear enough to be included in one of the two categories, it would be interesting to quantify it and include it in cost and benefit calculations.

2.4.2.2 Increased Interest costs

An important consequence of slow steaming to shippers and consignees is the increased interest costs. This cost category will be considered as one of the main cost categories on the shipper side, along with depreciation costs and insurance costs, that form the most affected cost category of shippers/consignees, distribution costs (Verbeke & Notteboom, 2004). More specifically, in interest costs, I will include pipeline inventory costs, - analyzed later on-, and the capital that could be used in any other activity of the company that does not counter the situation that slow steaming creates. For example, as Jacques Chan, general manager for Hong Kong and China with BDP international highlighted, some shippers have space issues, because they need to have bigger inventories to cover the additional days of product shipping. Hence, this could lead to substantial capital losses. Since more capital is needed to cover the urgent situation that slow steaming creates.

2.4.2.3 Increased pipeline inventory costs

Even though additional inventory costs in this research are included in the interest costs category, it will be useful to focus on the literature that covers these kinds of costs in conjunction with slow steaming, since they are the most relevant to the supply chain cost category. To continue, there is a great variety of literature from respectful authors that studied the main impact of slow steaming from a more supply chain perspective. More specifically, Eefsen (2010) studied the economic impact of sailing speed reduction of vessels, but on top of that he included the inventory cost. Some years later, Psaraftis & Kontovas (2010) studied the pipeline inventory cost of a special product category, the high value industrial one. In fact, they calculated and proved that pipeline inventory and several operational costs are equal with the positive difference in fuel costs. However, the interesting aspect of their study does not stop there. They also proved that sailing speed reduction is more attractive on the point that the CIF price of the cargo itself is lower. Hence, taking into consideration that pipeline inventory cost is proportional to the value of the cargo, shippers with higher- value cargo will undergo higher pipeline inventory cost than the ones with lower- value cargoes. Maloni et al. (2013) came into the same conclusion with a different kind of calculations. All in all, both studies concluded that longer transit times will substantially increase the pipeline inventory cost of the shipper supply chain.

2.4.2.4 Deprecation of products

One consequence of slow steaming, purely for shippers, is the substantial depreciation of their products. In other words, since products vary in time sensitivity (De Langen, 1999), -thus in transportation speed requirements-, there is a significant effect on product overall value. According to Notteboom (2006), an additional journey day creates opportunity costs that affect fixed capital, and can lower the monetary value of the specific goods. Of course, the level of depreciation depends on the type of products shippers decided to transfer. For instance, ephemeral products lose almost all of their main value if they do not reach the market on time. The same stands for types of products that are labeled as “perishable”, such as pharmaceuticals, fashion clothes and gadgets, flowers and food. Later in this research I will focus on the exact percentage of depreciation that products undergo for any additional day of travel and I will identify the exact amount of money it costs to shippers and consignees.

2.4.2.5 Increased Insurance costs

As an outcome of the previously mentioned product depreciation, there is also a significant increase in shipper insurance costs. In fact, since additional days of travel could cause irreversible damage to the shippers’ cargo, shippers and consignees should legally cover any probable damage or loss of their products. Thus, I will consider insurance costs along with deprecation costs and interest costs as the main costs that shippers have due to slow steaming.

2.4.3 Overview

In this section of the literature review I mention the major consequences of the current trend of vessel sailing speed reduction. In this case I chose the consequences that are relevant to energy and fuel consumption, as well as some that have a direct connection to costs and benefits of the two most affected actors of the supply chain, shippers and carrier companies. Hence, in the next graph, I chose to depict the consequences of slow steaming in a way that divides them into those two actors. Additionally, even though some of slow steaming's consequences are relevant to both actors, I decided to divide them on their level of importance and significance. For example, schedule reliability can also benefit carrier companies, but the significant difference from a situation without slow steaming can be more highly be noticed from the shippers' position.

	Shippers/Consignees	**Carriers**
Positive	Schedule reliability	Fuel efficiency
		GHG emissions reduction
		Excess fleet capacity absorption
Negative	Increased Interest costs	Degradation of vessel engines
	Product depreciation costs	Additional Operating and Capital costs
	Increased insurance costs	Additional Container costs

5. Slow steaming consequences divided by actor

2.5 Cost and benefit tradeoff

Finishing with the theoretical part, I will provide a short tradeoff between the costs and benefits, so as to show the contradictory character of slow steaming between carries and shippers, but mostly to show a better connection between these parts. This way I will be able to proceed to the presentation of the break-even point analysis.

To begin with, the cost and benefit trade-off between the two most affected actors of the supply chain that emerges from the use of slow steaming, is mainly based on the character and the goals of each actor. According to Woo (2014), carrier companies are mostly reliant on capital and their fixed costs are high in comparison to other actors of the supply chain. Hence, their major goal is cost minimization and operational efficiency maximization, in order to optimize their net effect. In their effort to achieve that, initially, they came up with ideas that did not cause any issue to the supply chain actors, such as Hub & Spoke, segmentation of their market and diversification of their services. However, when the situation became critical, carrier companies came up with ideas such as slow steaming, that, over the years, harmed several actors of the supply chain. On the other hand, shippers and consignees are companies that have commercial character and their basic goal is profit maximization.

So, due to their different character and structure, carrier companies and shippers\consignees have a vast cost/benefit tradeoff, not only under slow steaming conditions, but generally in every entrepreneurial move they make. Firstly, as I mentioned in the previous section, the cost/benefit tradeoff is not at all balanced. On the contrary, carriers reap most of the benefits of slow steaming, while shippers have just one benefit, and even that one is debatable. Thus, generally, one can see that fuel consumption is significantly reduced and greenhouse gas emissions minimize as well. That is a huge decrease in carrier's costs, considering that both emission costs and fuel costs comprise the majority of total costs. Additionally, on the side of carrier benefits regarding slow steaming, excess fleet capacity absorption plays a significant role, since before 2008 carrier companies ordered more and bigger container vessels that, without slow steaming, would be utterly useless. For carrier companies to have such benefits, shippers would have to cope with significant costs. More specifically, the costs shippers should tackle are mostly relevant to time. Hence, they have additional interest, depreciation and insurance costs (Verbeke & Notteboom, 2004).

Furthermore, to show the viability of slow steaming under current oil prices, I take full advantage of this cost/benefit tradeoff, in order to construct a break-even point analysis with main variable crude oil prices. In any case, if one watch closely, in this equation, crude oil prices are the main variable that reacts violently over the years, significantly changing the whole market of companies that are based on them. Additionally, I will deal with oil price, since it is one of the two basic elements -along with speed-, that affect fuel consumption costs, which -covers the greater portion of total costs. Thus, the break- even point will be found under constant alteration of the oil price variable, until shippers' net effect is equal to carriers' net effect.

Finally, since in this research I will try to find if slow steaming is viable from a supply chain perspective, using as main tool a break even bunker price analysis. It is required to provide a thorough theoretical background regarding break- even price and the break- even spot. More specifically, I should clarify the true definition of these two words in this research, since we could meet them numerous times in a great variety of sciences, but mostly in finance.

At first, according to Investopedia.com (2016) I consider the break- even point as the point in which the expenses of a company are equal to its revenues. This means that at this point, the company has neither benefit nor loss of completing a specific commercial activity. In this research, I will consider the break- even point (BEP) in an alternative way, in order to find the point in which the net effects of both shippers' and carriers are equal under slow steaming conditions.

Secondly, as far as the break-even price is concerned, normally I consider it as the amount of money that a company should sell a specific asset to cover its total costs. Hence, in this price, the seller does not have any profit or loss by selling the specific asset. In my case, when it comes to the break- even bunker price, I consider it as my main variable all over the net effects' equity equation. In other words, having the total benefits and costs of both shippers and carriers, I will fluctuate the bunker price, until the two net effects are totally equal. In that bunker price, the whole supply chain (shippers and carriers) will have neither loss nor benefit. Based on this price, I will draw the main conclusion; whether slow steaming is viable or not, taking into account bunker prices nowadays.

3. Empirical Analysis

To begin with, after a historical, as well as current detailed review of the oil market in the maritime industry, a thorough view on transport supply chain's main actors, an explanation of both slow steaming and its consequences in the two main actors (carriers and shippers/consignees) and lastly an introduction to the break-even point terminology, the part of the empirical analysis follows. The main objective of the current empirical analysis is to provide solid proof of whether or not the information that we received from the theoretical part is applicable in reality. By the end of the empirical analysis, the majority of the secondary research questions will have been answered, in a way that will lead us to the concluding section of this research. Hence, I will draw our main conclusions regarding the main research question.

Moreover, this part of the research will consist of several major parts. The first is the description of the five major routes that I chose to implement my model on, and their date-time schedules of several of their vessels. The second is the separate quantification of slow steaming's consequences to both shippers and carriers in a great variety of speeds. Thirdly, in the closing section of the empirical analysis, I will combine the already quantified consequences of slow steaming and proceed to the Break- Even Bunker Price analysis.

What is more, in order to implement the current empirical analysis, I will make some major assumptions so that my results are not biased and to allow the possibility to focus only on my major objective, which is to provide a compact and detailed break-even bunker price analysis from a macroeconomic perspective. Hence, to keep it clear enough for the reader, I will provide those assumptions in the parts they refer to. Thus, the main structure of each section will have its introductory and analysis part, assumption part and data part.

3.1 Methodology

To continue, since the current research is trying to answer its main scientific question with a quantitative approach, its backbone is the methodology part. In other words, in this part I will present a thorough summary of the main parts of my calculation model. More specifically, the model will be implemented into five (5) different trade routes, which cover a great part of the world. By selecting these routes and thus covering a great part of the world, at the end of this research I will have more possibilities to generalize the whole model on, which is one of the main purposes of the quantitative approach. All the selected trade routes are being served by one of the top carrier shipping companies in the world, on a weekly basis and by different vessels. In fact, concerning the vessels, in all the selected trade routes, the carrier companies are using only container ships which vary in their specifications. However, even though I could extract much useful information from particular vessels' specifications, I will mainly use their different capacities. To be specific, the selected vessels cover a wide spectrum of capacities, from 3500 TEU to 10600 TEU. With this kind of spectrum, I am trying to enhance the possibility of model generalization and reduce the possibility of any possible research bias.

Gathering all the vital parts of the first section, and calculating the total distance and total roundtrip days, I continue to the quantification of slow steaming's impact to the supply chain. To do that, at first, I calculate slow steaming's total impact on carrier companies, by calculating all the costs and benefits, yet omitting fuel savings, to implement the break-even bunker price analysis on a later stage of the research. Secondly, to have a spherical view of the supply chain, I quantify slow steaming's impact on shippers, by calculating the average value per container and, later, the cost of the delay that slow steaming creates to shippers. To do that, I extracted some useful data and formulas regarding the products that are being containerized and transferred into containers among the selected trade routes, mainly from EUROSTAT, as well as from several other sources of well-known researchers. Lastly, considering the fact that in the current research I will draw the conclusion after a break- even price analysis, the last part of this model consists of the calculation of the break-even bunker prices that correspond to each selected trade route and sailing speed. In fact, on the later stages of that part, there will be a comparison of the current bunker prices with the calculated (by the model) break-even bunker prices, so as to have a clear view of whether slow steaming is still viable or not in the selected trade routes and the selected speed sample. During this comparison, I will be able to draw our conclusion by following the law use by Cariou (2011). As long as the Break-Even Bunker Price is less than the current bunker price, slow steaming is still viable from a supply chain perspective.

3.2 Route Description

To continue, in this section I will present the routes that I chose to implement my model. In addition, a thorough description of them will be provided later. To be specific, after a thorough research in a great variety of sea routes among the top-notch carrier companies, I decided upon the five most representative ones for my model. The main criteria of choosing these five ones are, firstly, to cover the routes with high trading interest, as well as routes that cover areas that are not thoroughly researched for the specific topic of slow steaming. Secondly, to cover a fair amount of different vessel types, considering their capacity and design speed. Hence, the five routes that I will use for the current research are:

1. AE5 (Asia- North Europe) which belongs to the Maersk Line.
2. NEUATL1 (Transatlantic- North Europe) which is served by MSC.
3. SAMBA2 (North Europe- South America) which belongs to Maersk Line.
4. SAECS (North Europe- Africa) which is operated by Maersk Line.
5. NEWMO (New North Europe- Med Oceania) which belongs to CMA- CGM company

All of the data that is used in this research of the services mentioned above, are taken from the official websites of the companies that are responsible for these services. Thus, the time schedules, preferred ports and vessels are extracted from the official websites of Maersk line, CMA-CGM and MSC. What is more, the sail time schedules, as well as the ports that each of the companies use, differ as months pass, since some of the ports are skipped in some occasions. Hence, the vast majority of the data regarding these routes are taking part after November 2016 until the first half of 2017, which according to companies' official websites, is the time space with the least omitted ports during these years. Lastly, on a later stage, I will assume that the weight of the TEUs that will be transferred is equal to 14 tons. I will explain later what the main purpose of this assumption is. However, this assumption has a significant effect on vessel capacity. One can notice that we refer to nominal and actual capacity of the selected vessels in the selected routes. To explain that, we should focus more onto vessels' minimal stability, flexibility and load homogeneity requirements (Alphaliner, 2013). Hence, one will notice a difference of almost 40% between actual and nominal vessel capacity, due to this assumption.

3.2.1 AE5 (Asia- North Europe)

I focused on the Asia- North Europe trade route due to the fact that it is one of the most trade active and interesting sea routes of the world, connecting two of the biggest trading. In fact, the Asia- North Europe route is the second most trade active sea route (UNCTAD, 2014) as long as transported TEUs are concerned, and timelessly one of the most interesting ones. These reasons are enough to increase the already fierce competition among the top players of the shipping market, and lead them to constant action seeking for the enhancement of the specific route (WorldMaritimeNews.com, 2012). What is more, for the purposes of the current thesis, I chose to focus on Maersk's service AE5, due to the variety of ports it offers, and the stability uniqueness of coverage of the major North Europe's ports. Moreover, the vessel that will be used in this sea route is the Mette Maersk with nominal capacity of 10.150 TEUs and actual capacity 7.668 TEUs (Containership-info.com, 2014). I chose this vessel in order to include an average vessel, as far as capacity is concerned, to give a great variety of vessel capacities in my model, since I will use larger and smaller ones on the other selected routes. Lastly, as far as the sail schedule is concerned, the selected roundtrip 646W/651E begins at the Chinese port Ningbo and finishes at the same port, reaching the Danish port of Aarhus in its last European stop (Maersk, 2017).

Roundtrip	Arrival	Departure	Sea time (hrs)	Sea time (days)	Port time (hrs)	Port time (days	Distance
NINGBO		22-11-16 2:00		0		0	
SHANGHAI	22-11-16 18:00	23-11-16 18:00	16	0.7	24	1	126.47
YANTIAN	25-11-16 20:00	26-11-16 11:00	50	2.1	15	0.6	797.23
TANJUNG PELEPAS	29-11-16 19:00	01-12-16 5:00	80	3.3	34	1.4	1512.38
PORT TANGIER	16-12-16 15:00	17-12-16 13:00	370	15.4	22	0.9	6961.42
BREMERHAVEN	21-12-16 6:00	23-12-16 14:00	89	3.7	56	2.3	1538.48
GOTHENBURG	27-12-16 6:00	28-12-16 18:00	88	3.7	36	1.5	348.91
AARHUS	29-12-16 4:00	29-12-16 22:00	10	0.4	18	0.8	129.74
BREMERHAVEN	31-12-16 6:00	31-12-16 18:00	32	1.3	12	0.5	220.48
ANTWERP	02-01-17 22:00	03-01-17 22:00	52	2.2	24	1	318.06
ROTTERDAM	04-01-17 11:00	05-01-17 23:00	13	0.5	36	1.5	108.02
SINMGAPORE	27-01-17 0:01	28-01-17 10:00	505	21	34	1.4	8302.65
SHANGHAI	02-02-17 0:01	03-02-17 12:00	134	5.6	36	1.5	2161.88
XINGANG	05-02-17 15:00	06-02-17 23:00	51	2.1	32	1.3	658.49
QINGDAO	08-02-17 6:00	09-02-17 6:00	31	1.3	24	1	418.57
BUSAN	10-02-17 18:00	11-02-17 12:00	36	1.5	18	0.8	525.57
ULSAN	11-02-17 16:30	11-02-17 17:30	4.5	0.2	1	0	42.28
NINGBO	12-02-17 18:00		23.5	1		0	539.29
Total			**1585**	**66**	**422**	**17.6**	**24709.92**

6. AE5 sail schedule

To conclude, in the above table one can notice the time sail schedule as well as some useful information such as port, sea time in hours and days and distance between ports that are included in the roundtrip. The vast majority of the data regarding distances has been extracted from the official website Searates.com (2016) as well as the portworld.com (2016).

3.2.2 NEUATL1 (Transatlantic- North Europe)

To continue, the next sea route that I chose to include in my research has to do with the sea trade between Europe and North America. To be specific, over the years, the trade between these continents has been researched time and again for various reasons, especially since their trade agreements came into the spotlight and caused plenty of conflict among people. On the more practical side of NEUATL1, it is one the most famous routes of MSC, the second biggest shipping company and partner of Maersk in the 2M alliance. What is more, I chose the specific service of MSC among all others, since it is the only that offers unique roundtrip stability, as well as it services some of North Americas busiest ports (JOC.com, 2015). The vessel that implements this route in the specific time schedule is the Maersk Iowa, with the nominal capacity of 4.824 TEUs and actual capacity of 3.647 TEUs (Containership-info.com, 2014). As one will see on later stages of the research, Maersk Iowa has the smallest capacity of all the selected vessels in this model, yet it is a useful asset, since it offers a great capacity variety. Furthermore, as far the time schedule of NEUATL1 is concerned, one can see on the next table that it begins from the North European port of Bremerhaven in Germany, reaches the North American port of Miami and finishes into Bremerhaven again (MSC, 2016).

Roundtrip	Arrival	Departure	Sea time (hrs)	Sea time (days)	Port time (hrs)	Port time (days)	Distance
BREMERHAVEN		17-11-16 14:00					
NORFOLK	26-11-16 8:00	26-11-16 19:00	221	9.21	11	0.46	3623.96
CHARLESTON	28-11-16 8:00	28-11-16 18:00	37	1.54	10	0.42	413.61
MIAMI	30-11-16 8:00	30-11-16 18:00	38	1.58	10	0.42	433.62
HOUSTON	03-12-16 8:00	04-12-16 19:00	62	2.58	35	1.46	952.05
NORFOLK	08-12-16 13:00	09-12-16 7:00	90	3.75	17	0.71	1700.96
ANTWERP	18-12-16 6:00	19-12-16 2:00	215	8.96	20	0.83	3474.77
ROTTERDAM	19-12-16 15:00	20-12-16 11:00	13	0.54	20	0.83	108.02
BREMERHAVEN	21-12-16 6:00		19	0.79			245.56
Total			**695**	**28.96**	**123**	**5.125**	**10952.55**

7. NEUATL1 sail schedule

3.2.3 SAMBA2 (North Europe- South America)

Moreover, since I focused on the western side of the world, I should focus more on the SAMBA2 roundtrip, which belongs to the Maersk line, connects North Europe with South America and is the next roundtrip of my preference for this research. To be specific, SAMBA2 is not the only service that connects these two regions properly, however, it is the only one that combines so many North European and South American major ports. In fact, it goes through the three busiest European ports (EUROSTAT, 2017) and the third busiest port of Latin America (CEPAL, 2015). Hence, it gives a clear perspective of the North Europe- South America trade without causing any major discrepancies. The time schedule data has been extracted from the 638N/646S roundtrip (Maersk, 2017) and the vessel that is used for it is the Cap San Antonio with nominal capacity of 9.814 TEUs and actual capacity of 7.459 TEUs (Containership-info.com, 2014). Lastly, the distances between the included ports, as well as their total, are calculated through searates.com (2016) and portworld.com (2016).

Roundtrip	Arrival	Departure	Sea time (hrs)	Sea time (days)	Port time (hrs)	Port time (days)	Distance
HAMBURG		14-11-16 22:00					
ANTWERP	15-11-16 22:00	16-11-16 22:00	24	1	24	1	369.85
LE HAVRE	17-11-16 15:00	18-11-16 12:00	17	0.7	21	0.9	236.27
SANTOS	01-12-16 11:00	02-12-16 18:00	311	13	31	1.3	5267.87
PARANAGUA	03-12-16 5:00	04-12-16 6:00	11	0.5	25	1	166.24
RIO GRANDE	11-12-16 11:00	12-12-16 12:00	173	7.2	25	1	596
ITAPOA	13-12-16 10:00	14-12-16 6:00	22	0.9	20	0.8	434.85
PARANAGUA	15-12-16 16:00	16-12-16 17:00	34	1.4	25	1	100.74
SANTOS	17-12-16 5:00	18-12-16 18:00	12	0.5	37	1.5	166.24
PORT TANGIER	31-12-16 13:00	01-01-17 13:00	307	12.8	24	1	4393.24
ROTTERDAM	04-01-17 22:00	06-01-17 3:00	81	3.4	29	1.2	1338.99
LONDON GATEWAY	06-01-17 14:00	07-01-17 3:00	11	0.5	13	0.5	370.64
HAMBURG	08-01-17 6:00		27	1.1		0	424.59
Total			**1030**	**42.9**	**274**	**11.4**	**13784.48**

8. SAMBA2 sail schedule

3.2.4 SAECS (North Europe- Africa)

To continue, there are still several regions in the world, like Africa, that are not extensively researched. However, over the years, these regions have become more and more interesting for further research because of their immediate economic growth, as well as their huge growth is trade between other already developed regions. More specifically, I focus on the North Europe-Africa trade with the SAECS shipping service of Maersk line. More to that, SAECS is one of the most respective sea routes that properly connects some of the biggest North European ports, with the African respective ones (Arabianbusiness.com, 2008). To implement this liner service, Maersk uses one of its biggest vessels, as far as capacity is concerned, the MSC Alexandra, with nominal maximum capacity of 14.000 TEUs and actual maximum capacity of 10.640 TEUs (Containership-info.com, 2014). The capacity of MSC Alexandra not only enhances the variety of vessel capacities in my research, but also helps us understand the contribution of vessels' capacity mainly on operational costs, giving us a thorough glimpse of economies of scale in the maritime industry. In addition, SAECS's sail time schedule begins and finishes in the port of Rotterdam, passing through three major African ports.

Roundtrip	Arrival	Departure	Sea time (hrs)	Sea time (days)	Port time (hrs)	Port time (days)	Distance
ROTTERDAM		20-08-16 14:20					
BREMERHAVEN	21-08-16 12:00	22-08-16 7:55	21.4	0.9	19.05	0.8	245.56
LONDON GATEWAY	24-08-16 3:00	24-08-16 19:00	19.05	0.8	14	0.6	372.8
ALGERICAS	29-08-16 0:42	30-08-16 4:00	102.22	4.3	27.18	1.1	1315.38
CAPE TOWN	11-09-16 22:00	12-09-16 20:00	306	12.8	22	0.9	5097.65
PORT ELIZABETH	14-09-16 0:01	15-09-16 7:14	52	2.2	31.14	1.3	436.22
DURBAN	17-09-16 4:30	20-09-16 14:42	45.54	1.9	82.12	3.4	409.95
PORT ELIZABETH	22-09-16 19:30	23-09-16 9:06	53	2.2	13.36	0.6	409.95
CAPE TOWN	26-09-16 4:42	27-09-16 15:23	68.16	2.8	35	1.5	436.22
ALGERICAS	09-10-16 2:42	09-10-16 11:25	276	11.5	9.43	0.4	5097.65
ROTTERDAM	12-10-16 23:36	13-10-16 16:45	84.11	3.5	17.08	0.7	1359.71
LONDON GATEWAY	14-10-16 18:30	15-10-16 7:00	25.45	1.1	12.3	0.5	200.13
BREMERHAVEN	17-10-16 6:06	18-10-16 4:42	46.54	1.9	22.48	0.9	372.8
ROTTERDAM	18-10-16 23:42		19	0.8		0	245.56
Total			**1118.47**	**46.6**	**305.14**	**12.7**	**15999.58**

9. SAECS sail schedule

3.2.5 NEWMO (New North Europe- Med Oceania)

Lastly, I focus on a partly unknown,- from a maritime industry research perspective- , region which is Oceania. In order to focus on this region and its connection with North Europe from a sea trade perspective, I chose the CMA-CGM's NEWMO service. In fact, interestingly enough, NEWMO is the only service of the top-notch carrier companies that connects North Europe with Oceania (CMA-CGM, 2017). The vessel CMA- CGM uses to implement this service is the AEGIALI, with the nominal maximum capacity of 5928 TEUs and the actual capacity of 4394 TEUs (Vesseltracking.com, 2017). As one can observe in the sail time schedule, NEWMO is a vast and time consuming trip, covering a huge distance and passing by a great variety of ports that are not only in these two regions (North Europe-Oceania). However, since in the current research I cover all the regions that these other ports belong to, they do not cause any significant bias. More specifically, the 143NNE/ 144NNW trip begins and finishes at the port of Tilbury, passing through several ports of Europe, Middle East, and Africa, up to the ports of Sydney and Adelaide.

Roundtrip	Arrival	Departure	Sea time (hrs)	Sea time (days)	Port time (hrs)	Port time (days)	Distance
TILBURY		24-11-16 1:00		0		0	
HAMBURG	24-11-16 10:00	26-11-16 6:00	9	0.38	44	1.8	176.32
ROTTERDAM	26-11-16 20:00	27-11-16 18:00	14	0.58	22	0.9	297.35
LE HAVRE	28-11-16 11:30	29-11-16 8:00	15.5	0.65	20.5	0.9	495.81
FOS SUR MER	04-12-16 11:30	05-12-16 15:59	123.5	5.15	26.5	1.1	1856.73
GENOA	05-12-16 23:00	06-12-16 14:00	7	0.29	15	0.6	221.67
DAMIETTA	10-12-16 9:00	10-12-16 20:00	91	3.79	11	0.5	1434.68
POINTE DES GALETS	21-12-16 5:00	22-12-16 2:00	249	10.38	21	0.9	5858
FREMANTLE	31-12-16 4:30	31-12-16 15:30	218.5	9.1	11	0.5	3295
MELBOURNE	05-01-17 18:30	07-01-17 2:30	123	5.13	32	1.3	1699.53
SYDNEY	08-01-17 0:01	09-01-17 16:00	21.5	0.9	40	1.7	589.6
ADELAIDE	12-01-17 4:00	13-01-17 1:00	60	2.5	21	0.9	998.14
SINGAPORE	22-01-17 12:00	23-01-17 12:00	203	8.46	24	1	3510.12
PORT KELANG	24-01-17 2:00	24-01-17 18:00	14	0.58	16	0.7	201.39
CHENNAI	28-01-17 5:00	29-01-17 15:00	83	3.46	34	1.4	1397.84
COLOMBO	31-01-17 5:00	31-01-17 17:00	38	1.58	12	0.5	387.36
COCHIN	01-02-17 12:00	02-02-17 1:00	19	0.79	13	0.5	306.75
DAMIETTA	10-02-17 20:00	11-02-17 14:00	211	8.79	18	0.8	3285.23
MALTA	13-02-17 23:00	14-02-17 14:00	57	2.38	15	0.6	928.36
SALERNO	15-02-17 7:00	15-02-17 21:06	17	0.71	14	0.6	318.62
TILBURY	22-02-17 2:00		149	6.21		0	2288.05
Total			**1723**	**71.79**	**410**	**17.1**	**29546.55**

10. NEWMO sail schedule

3.3 <u>Carriers</u>

To continue, in the main analysis of this research, I will firstly present the monetized consequences of slow steaming separately into carriers and shippers. In later stages, I will combine them, in order to provide the combined effect of slow steaming in the supply chain and present the break- even bunker price analysis. For carriers' details, I will thoroughly analyze the calculation and monetization of the following five variables: a) Fuel consumption b) Emissions c) Operating costs d) Capital costs and e) Container usage costs.

3.3.1 <u>Fuel Consumption</u>

Regarding the consequences of fuel consumption of the vessels that carrier companies use in the aforementioned sea routes, I will provide some basic equations that Notteboom and Cariou (2009) introduced. To begin with, since each container vessel has different design speed and capacity, I should firstly determine the daily fuel consumption of their design speed (FC_{v0} from now on). That calculation will help us set a reference point for every vessel, in order to show the fluctuations that fuel consumption has under the fluctuations of the vessel speed. For the purposes of this research, the fuel consumption will be measured with metric tons of fuel (mt from now on).

$$[1]\ FC_{v0} = 3.775 \cdot e^{1.996} \cdot TEU^{1.013}$$

To continue, to determine fuel consumption's changes as the vessels' speeds fluctuate, I should use the following equation, with basic variables the fuel consumption in vessels' design speed, the actual speed of the vessel and its design speed.

$$[2]\ FC_{v1} = FC_{v0} \cdot \left(\frac{V1}{V0}\right)^{3.3}$$

The results of the implementation of the [2] equation in all the selected trade routes and in a variety of speeds can be seen in the appendix 6.

What is more, having already found the daily fuel consumption in the sample of different speeds that we want, we should proceed into the total fuel consumption calculation. To do that, firstly we should find the total roundtrip time of each route. To find that I should use an equation that Notteboom and Vernimmen (2009) firstly introduced.

$$[3]\ T_{roundtrip\ days} = \sum_{i=1}^{n} t_{port\ days} + \frac{Total\ Distance}{Vn \cdot 24}$$

In other words, the total roundtrip time is the result of the sum of the total time that vessels spent in ports and the total time that they spent in the sea. A basic assumption regarding [3] equation is that I assume that the vessels' speed remains stable for the whole roundtrip. The results are shown analytically in the appendix 14where I show the fluctuations of the total roundtrip time base on speed fluctuations. However, carrier companies specifically for the selected sea routes, want to have stability in their time schedules, allowing them to implement their services once a week by using multiple vessels. Hence, to find the number of vessels needed to enable each trip once a week, I should use the following rule.

$$[4]\ T_{roundtrip\ days} \leq \frac{NS \cdot 7}{F}$$

To explain Notteboom's and Vernimmen's (2009) equation, we should firstly be sure about the frequency of each roundtrip we want to research. In the current thesis, MSC, Maersk and CMA-CGM want to service once in a week, so the frequency (F) variable will be equal to one (1) for every route. In fact, having already explained in the literature review, sailing slower on the one hand means less fuel for each vessel, while on the other means that the carrier company should use more vessels (NS= Number of ships) to keep the weekly frequency of the route stable. What is more, in order to find how many roundtrips vessels can make in a year, we should divide the days of a year by the total roundtrip days. However, a "year" is a highly subjective topic when it comes to the maritime industry. According to several researchers, the operating days of a year do not surpass 300 days out of 365, mainly due to service and maintenance reasons (Corbett, 2004) (Endersen, 2004) Baird, 2006), (Psaraftis & Kontovas, 2008). Thus, in order to have a stable and secure option regarding the yearly operating days, I took the average number of days that these researchers proposed and I concluded to count the maritime year as 322 days out of the 365.

Lastly, having decided on the basic variables needed to calculate total yearly fuel consumption, I use them to calculate consumption at different speeds that have as a sample (15-25 knots).

What is more, having all our variables known, I can proceed to the main purpose of this section, which is the actual impact of slow steaming to the vessels' total annual fuel consumption. For that, I will use as my point of reference the vessels' fuel consumption in their design speed. Further, I will calculate the difference of each route's total fuel consumption in the sample of speeds that I chose, with their fuel consumption in the design speed. Under the same logic, I can calculate the additional roundtrip time, the additional vessels, and the difference in roundtrips that carrier companies need to cover the route and maintain their weekly frequency.

TOTAL ANNUAL FUEL CONSUMPTION DIFFERENCE (METRIC TONES)											
AE5/METTE MAERSK (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
313097	285807	256206	224252	189904	153123	113872	72115	27815	0	-19062	-68548
NEUATL1/MEARSK IOWA (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
65833	60345	54392	47966	41058	33662	25768	17370	8461	0	-966	-10918
SAMBA2/CAP SAN ANTONIO (V0=25.1)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**V0**
170201	158190	145163	131100	115984	99797	82523	64146	44650	24020	2242	0
SAECS/MSC ALEXANDRA (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
280493	256045	229526	200899	170128	137178	102015	64605	24918	0	-17077	-61410
NEWMO/AEGIALI (V0=24.1)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**V0**	**25**
212651	196376	178723	159666	139182	117247	93839	68936	42516	14560	0	-14952

11. Total annual fuel consumption difference from V0 (in metric tons)

Since fuel costs cover almost half of the vessels' expenses (Rodrigue, 2017) and a significant amount of carrier company expenses, one should focus more on fuel consumption savings that slow steaming offers. In fact, as one can see from the table above, even a minor fluctuation of a vessel's sailing speed leads to the fuel consumption either skyrocketing, or falling. Thus, we can conclude that the fuel consumption factor reacts violently under small speed changes. To give a better understanding of the table, one can notice the fuel consumption in each vessel's design speed and use it as a point of reference, along with the fuel consumption difference presented under each speed of our speed sample (15-25 knots). Therefore, one can observe any fuel savings vessels have on an annual basis, when they decide to sail slower than their design speed, as well as the fuel loses that they could have if they decided to sail faster.

3.3.2 Emissions

To continue, another significant factor of carrier companies that is being affected by slow steaming and can be quantified is the emission factor. In fact, in the current thesis, I will focus only on the CO2 emissions that vessels produce during their trips. What is more, when it comes to the emissions factor, several researchers quantified successfully not only CO2 emissions, but also other basic products of gas emission, such as Nitrous Oxide (NOx), Sulphur Oxide (SOx) and Prime Dust (PM). However, governments around the world, having already realized the significance of environmental harm that these substances cause, began to drastically and continuously tackle them (EIA, 2011) (Huggins, 2009) to evanesce them. Hence, not long after, having put extremely low limits and having tackled the whole market for these substances, they resulted in extremely low amounts of emissions of these substances in almost all the industries (EIA, 2012). So, since the issue of carbon dioxide (CO2) emissions remains, and the price does not appear to fluctuate (EEX, 2017), I will mainly focus on this.

In the main analysis of the emissions factor, I will use some basic data from a wide spectrum of researchers, in order to calculate the economic impact of slow steaming on the selected vessels' total annual emissions. To do that, firstly we should clarify the basic variable of the type of fuel that the selected vessels use. Since much of bunker fuel (almost 80%) is related to Heavy Fuel Oil (HFO) (Notteboom & Vernimmen, 2009) and it will continue to be the No1 choice of maritime fuel, even though it is being tackled down by various organizations, due to its environmental harmful character (Wang, 2014). In fact, there are plenty of options, such as Marine Diesel Oil (MDO) and Marine Gas Oil (MGO) that have the potential to be environmentally-friendly alternatives of HFO. However, since the eco-friendly alternatives are still at an early stage (Notteboom & Vernimmen, 2009) I will mainly use HFO as our basis for fuel.

Having already clarified the fuel type, I will continue to its emission factor, which is the main variable in calculating the total amount of CO2 emissions. More specifically, more and more researchers cover the topic of Green House Gas emissions, yet having small differences in their calculations, due to the emissions factor. In fact, when we refer to the emissions factor, we should say that it is the actual amount of CO2 (calculated mainly in tones) that is emitted by the vessels' fuel consumption. Each type of fuel has its own emission factor, based mainly on chemical substances. When it comes to HFO, I will take the most recent data of IMO's third GHG report (2014), which calculates the CO2 emissions factor of Heavy Fuel Oil (HFO) as 3.114 tons for every metric ton of fuel that is burnt. Respectively, Psaraftis and Kontovas (2011) calculate vessels' emissions having as a CO2 emission factor 3.17 tons per fuel metric ton and IMO's second GHG report (2009) 3.021 tons per fuel metric ton. Thus, I will calculate the emissions tones using the following equation.

$$[5]\ TE = EF \cdot TFC$$

where TE= total emissions (in tons) EF= emission factor and TFC= total fuel consumption (in metric tons)

What is more, to calculate the total cost that emissions create to the carrier company, we should multiply the price of CO2 in the Emission Allowances market by the total CO2 emissions. In fact, taking into consideration that the price of CO2 is currently at 5.05 euro per ton of emissions (EEX, 2017) and the euro to dollar ratio is currently at 1 euro= 1.07 dollar (xe.com, 2017) and using the same method that I used to calculate the total annual fuel consumption difference, I will calculate the total annual emissions cost difference, to depict slow steaming's consequences to each selected sea route.

TOTAL ANNUAL EMISSION COST DIFFERENCE ($)											
AE5/METTE MAERSK (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
974985	890002	797824	698319	591361	476826	354599	224565	86614	0	-59359	-213458
NEUATL1/MEARSK IOWA (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
205005	187915	169377	149366	127856	104822	80241	54090	26347	0	-3009	-33999
SAMBA2/CAP SAN ANTONIO (V0=25.1)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**V0**
2863883	2661790	2442587	2205960	1951608	1679241	1388579	1079353	751301	404171	37717	0
SAECS/MSC ALEXANDRA (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
4719720	4308333	3862117	3380432	2862666	2308227	1716547	1087077	419284	0	-287344	-1033308
NEWMO/AEGIALI (V0=24.1)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**V0**	**25**
3578179	3304321	3007277	2686622	2341947	1972859	1578980	1159945	715398	244999	0	-251586

12. Total annual emission cost difference from V0 (in $)

As a consequence of speed fluctuations, and keeping all the other variables constant, emissions costs will follow the same pattern. If the speed is reduced from each design speed, total fuel consumption will be reduced and the total annual emissions cost will decrease, as well. The above table depicts that statement for each selected sea route and vessel.

3.3.3 Operating Costs

Another significant factor of carrier companies that is being affected substantially by slow steaming is operating costs. More specifically, taking into account several researchers, such as Murray (2015), Greiner (2014, 2015), Murray (2015), Rodrigue (2016) and Stopford (2009), I decided not to take operating costs as a stable amount of money for each type of vessel, but to calculate them having in mind the capacity of each vessel and the operating cost per TEU that corresponds to each one of them. Hence, based on all of the aforementioned researchers, I calculated an average amount of daily operating costs per TEU for each selected vessel that can be found in appendix 8. In fact, one would notice that economies of scale indeed exist in container daily costs (Murray, 2015), thus the bigger the capacity of the vessel, the smaller its daily operating costs are.

Further on, based on variables such as vessel capacity, cost per TEU and number of vessels needed, I will calculate total annual operating costs. The basic idea of the calculation is that the slower the vessels sail, the higher the total operating costs will be. Indeed, since lower vessels' speed leads to longer trips, carrier companies should use more vessels to cover the whole roundtrip.

For the more practical details of my model of operating cost calculation, at first, I calculated the annual operating costs of each vessel using the following equation

[6] $OC_{annual} = 322 \cdot OC_{daily}$ where [7] $OC_{daily} = OC_{daily\ per\ TEU} \cdot TEU$

To continue, I calculated the total annual operating costs of all the vessels that are needed at each speed to cover the whole roundtrip with the desirable frequency (weekly in our cases).

[8] $TOC = OC_{annual} \cdot NS$

Lastly, on the following table one can notice the impact of slow steaming, by depicting the difference of the total annual operating costs of different speeds than design speed.

TOTAL ANNUAL OPERATING COST DIFFERENCE ($)											
AE5/METTE MAERSK (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
14200798	11765196	9616135	7705859	5996665	4458390	3066617	1801370	646143	0	-412814	-1387055
NEUATL1/MEARSK IOWA (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
4585286	3815705	3136663	2533070	1993013	1506962	1067201	667419	302400	0	-32200	-340032
SAMBA2/CAP SAN ANTONIO (V0=25.1)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**V0**
8987169	7591266	6359587	5264761	4285180	3403557	2605898	1880753	1218665	611750	53389	0
SAECS/MSC ALEXANDRA (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
47557737	45246554	43207274	41394581	39772697	38313002	36992326	35791711	34695497	34082361	33690635	32766161
NEWMO/AEGIALI (V0=24.1)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**V0**	**25**
13508246	11330930	9409769	7702070	6174129	4798982	3554802	2423728	1391009	444350	0	-426576

13. Total annual operating cost difference from V0 (in $)

3.3.4 Capital Costs

To continue, one of the last factors that has been affected by slow steaming is the vessels' capital costs. The interesting fact in this section is that there are substantial differences among researchers in capital cost calculations. To avoid huge deviations from the realistic results, and further discrepancies, I used construction cost data from Murray's (2015) article, who has a pretty accurate vessel sample, since it covers a great variety of vessel types and vessel capacities. The results are presented in appendix 10. What is more, for simplicity reasons, I will assume that the whole amount of construction costs will covered by carrier company's bank loan. That is not totally true, since banks, most of the times, prefer to cover a certain percentage of the total construction costs (OECD, 2007).

Furthermore, after extracting the data regarding construction costs, we can proceed to the annuity's calculation. According to Carther (2016), the basic equation for ordinary annuity calculation will be the following one.

[9] $OA = C_{construction} \cdot \left(\frac{(1+i)^{n}-1}{i}\right)$ where i= interest rate and n=number of payments

In our case, based on Stopford (2009) and Baird (2006), the interest rate will be 6.125% and the number of payments will be 20 (years).

Lastly, the results of the capital cost calculations will be presented in appendix 16. However, slow steaming's impact on this factor is presented on the following table, calculating the difference of total annual capital costs in each speed with the total annual capital cost in design speed of each selected vessel.

TOTAL ANNUAL CAPITAL COST DIFFERENCE ($)											
AE5/METTE MAERSK (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
27895191	23110841	18889356	15136925	11779487	8757793	6023878	3538502	1269245	0	-810907	-2724647
NEUATL1/MEARSK IOWA (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
8494169	7068532	5810618	4692471	3692025	2791623	1976973	1236383	560192	0	-59650	-629905
SAMBA2/CAP SAN ANTONIO (V0=25.1)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**V0**
20116032	16991574	14234699	11784144	9591542	7618200	5832796	4209701	2727744	1369284	119501	0
SAECS/MSC ALEXANDRA (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
24355955	20178626	16492747	13216410	10284951	7646637	5259592	3089550	1108208	0	-708022	-2378954
NEWMO/AEGIALI (V0=24.1)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**V0**	**25**
25813552	21652815	17981576	14718253	11798438	9170604	6793040	4631618	2658146	849130	0	-815165

14. Total annual capital cost difference from V0 (in $)

3.3.5 Container Costs

Lastly, the factor that should not be skipped is the costs that are created by container use. In fact, since carrier companies are being paid by shippers through freight rates, which among all the other include the actual container that is being used for the transportation of the cargo, they are being affected by slow steaming.

More specifically, Notteboom and Verbeke (2004) and Stopford (2009) have already calculated the coefficient of the costs of container use. Hence, in the current thesis I will use an average coefficient of these two articles which is 0.81252 $ per TEU per every roundtrip day. In addition, I will multiply this coefficient with the capacity of each vessel and later I will multiply the result with the total number of days for the whole year. At last, to find the total annual container cost, I will multiply this number with the number of vessels that will be used in each speed category.

$$[10]\ CC_{annual} = 322 \cdot CC_{daily} \quad \text{where } [11]\ CC_{daily} = CC_{daily\ per\ TEU} \cdot TEU$$

$$[12]\ TCC = CC_{annual} \cdot NS$$

The results of the implementation of this equation are presented in appendix 15. However, the impact of slow steaming in container costs is being presented in the following table.

TOTAL ANNUAL CONTAINER COST DIFFERENCE ($)											
AE5/METTE MAERSK (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
7211520	5974660	4883314	3913228	3045256	2264082	1557305	914781	328128	0	-209637	-704381
NEUATL1/MEARSK IOWA (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
1552348	1291807	1061917	857571	674735	510182	361301	225955	102378	0	-10901	-115118
SAMBA2/CAP SAN ANTONIO (V0=25.1)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**V0**
4295444	3628268	3039583	2516308	2048114	1626740	1245496	898911	582464	292388	25517	0
SAECS/MSC ALEXANDRA (V0=23.6)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**V0**	**24**	**25**
6440596	5335959	4361279	3494897	2719713	2022048	1390826	816989	293050	0	-187227	-629081
NEWMO/AEGIALI (V0=24.1)											
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**V0**	**25**
5226534	4384099	3640774	2980041	2388859	1856795	1375404	937775	538201	171925	0	-165048

15. Total annual container cost difference from V0 (in $)

3.4 <u>Shippers</u>

Since in the current research I study the impact of slow steaming from a supply chain perspective, after the thorough analysis of the carriers' side, I should offer an extensive analysis from the shippers' perspective as well. To do that, I decided to use what was mentioned in the methodology part of this thesis, the "average container" or "proxy container" method. In the first part of this section I will calculate the actual value per container to and from each selected region (e.g. Europe, Africa, Oceania, Asia, North America, South America), while in the second part I will calculate the impact that slow steaming has on shippers in accordance with each value per container. After this part, there will be a sum of slow steaming's impact on the supply chain, that can be used in the break-even bunker price analysis, which is the last part of this empirical analysis.

3.4.1 <u>Value per Container & Shippers' Cost</u>

To begin with, despite the break-even bunker price analysis, value per container gives a unique character to this research. Firstly, due to the number of regions that it covers and secondly, due to the number of product categories that it takes into account in the calculation part. More specifically, since value per container is already a used method to calculate slow steaming's impact to shippers, I added some details to enhance the already existing one. To be specific, after a careful consideration and through detailed research on Kuehne + Nagel's database, I concluded that Africa and Australia nowadays are some unique options for someone to make a research, since they are currently under the shadow of some of the most famous regions, such as Asia and North America. Hence, in the current section I will use an enhanced version of an existing method, to calculate slow steaming's impact on shippers, focusing on both imports and exports of North Europe, Asia, North America, South America, Oceania and Africa.

What is more, to implement the model, we should first clarify the main thought behind every procedure that it has been made. The main idea is that we calculate the value of an average container that the selected regions trade either upon importing, exporting. The main inertia has to do that is the quantification of slow steaming's impact on shippers. Hence, by the end of this section, we will know how much an additional day/hour costs to shippers and consignees.

One basic assumption that I should make to implement our model is the product categories that I will include in the average container. To do that we should firstly distinguish the already existing product categories among all products. After detailed research, I chose to use the Combined Nomenclature (CN from now on) decided by the European Union. The CN is the systematic list of goods that constructs the international trading basis among all countries (EU, 2016). More specifically, CN is a list of categories and subcategories that include every type of commodity that it is being traded among countries. It includes twenty-one (21) main product categories and each one of them includes its own product subcategories. A detailed table of the CN is being provided in the table 16.

After detailed focus on each one of CN's product subcategories in order to decide which of them are appropriate for transfer into containers, I concluded into forty-three (43) main subcategories. To be specific, these subcategories could be merged into some bigger categories, for my sample to be more practical. However, since these categories are already strictly settled by law of the European Union, we cannot merge them, or mix them up.

One can find out the product categories on the following table. On the one side is the type of products that I selected to include in my research, while on the other is the code that represents each product category into the CN queue.

Live animals	01	Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal, and articles thereof, imitation jewelry, coin	71
Meat and edible meat offal	02	Iron and steel	72
Edible vegetables and certain roots and tubers	07	Articles of iron or steel	73
Edible fruit and nuts, peel of citrus fruit or melons	08	Copper and articles thereof	74
Coffee, tea, mate and spices	09	Nickel and articles thereof	75
Cereals	10	Aluminum and articles thereof	76
Cocoa and Cocoa preparations	18	Lead and articles thereof	78
Tobacco and manufactured tobacco substitutes	24	Zinc and articles thereof	79
Fertilizers	31	Tin and articles thereof	80
Miscellaneous chemical products	38	Other base metals, cermets, articles thereof	81
Plastics and articles thereof	39	Tools, implements, cutlery, spoons and forks, or base metal parts thereof of base metal	82
Rubber and articles thereof	40	Miscellaneous articles of base metal	83
Raw hides and skins (other than furskins) and leather	41	Nuclear reactors, boilers, machinery and mechanical appliances, parts thereof	84
Articles of leather, saddlery and harness, travel goods, handbags and similar containers, articles of animal gut (other than silkworm gut)	42	Electrical machinery and equipment and parts thereof, sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles	85
Furskins and artificial fur, manufactures thereof	43	Railway or tramway locomotives, rolling stock and parts thereof, railway or tramway track fixtures and fittings and parts thereof, mechanical (including electromechanical) traffic signaling equipment of all kinds	86
Cotton	52	Vehicles other than railway or tramway rolling stock, and parts and accessories thereof	87
Carpets and other textile floor coverings	57	Aircraft, spacecraft, and parts thereof	88
knitted or crocheted fabrics	60	Ships, boats and floating structures	89
Footwear, gaiters and the like, parts of such articles	64	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus, parts and accessories thereof	90
Headgear and parts thereof	65	Furniture, bedding, mattresses, mattress supports, cushions and	94
Umbrellas, sun-umbrellas, walking sticks, seat-sticks, whips, riding-crops and parts thereof	66	Toys, games and sports requisites, parts and accessories thereof	95
		Miscellaneous manufactured articles	96

16. Containerized product categories (EU, 2016)

Furthermore, from a more practical perspective of the model, I should explain the main idea behind the calculations that I have done to calculate the value per container. At first, I extracted import and export quantity and value data from 2015 for each of the aforementioned selected routes (AE5, NEUALT1, SAMBA2, SAECS, NEWMO) for each product subcategory from EUROSTAT (EUROSTAT, 2016). In the next step, having already calculated the total traded value and quantity of both imports and exports, I calculated the actual value per kilogram (kg) by dividing the trade value by trade quantity. Hence, in this step, one can easily notice the difference of the quality and precious products from the more common and normal ones. To continue, I divided the trade quantity of each product category by the total trade quantity among the two regions, to calculate the percentage of the distribution of one product category among the whole trade. By doing that, I could use the same percentage as the distribution percentage of the average container. In fact, by using the normal 20" container which weighs approximately 14 tons (Notteboom, 2011) (Laursen, 2015) (Alphaliner, 2013) as my model for an average container, I could see the distribution of the products inside the container, by weight. Lastly, by calculating my main variables which are the price per kg and the distribution of the products inside the container, I can proceed to the calculation of the value of each average container. By doing that, I received the values that are mentioned on the next table.

	Asia		Africa		North America		South America		Australia	
Import quantity (kg)	39,891,060,000	47%	5,789,917,000	71%	8,803,973,000	60%	12,108,873,000	29%	826,518,000	32%
Import value ($)	297,723,672,540		48,591,536,855		174,931,437,225		25,202,411,280		4,441,469,916	
Import value per container ($)	**104,488**		**46,198**		**278,174**		**29,001**		**75,232**	
Export quantity (kg)	17,556,541,000	53%	19,280,360,000	29%	19,373,948,000	40%	9,024,304,000	71%	2,011,189,000	68%
Export value ($)	145,680,749,200		65,442,698,666		254,244,675,295		47,012,880,821		22,870,046,996	
Export value per container ($)	**116,169**		**30,198**		**183,722**		**72,673**		**159,200**	
Total trade (kg)	57,447,601,000	100%	25,070,277,000	100%	28,177,921,000	100%	21,133,177,000	100%	2,837,707,000	100%
Total trade ($)	443,404,421,740.24		114,034,235,520.16		429,176,112,519.53		72,215,292,100.79		27,311,516,912.27	

17. Value per container (in $)

To explain the table above, we should focus on the quantity, value and value per container for import and export, as well as the total quantity and value of the whole trade between Europe and the selected regions. What's more, to avoid a substantial bias, I calculated the value per container in accordance to the percentage of import and export quantity with respect to the total quantity of the respective trade route.

However, the specific model has some interesting perspectives. Since the specific database that I use for the current research does not have all the required data to proceed, and because Africa in particular is one of the least researched regions regarding the worldwide trade and slow steaming, I should make some assumptions in order to implement the model properly. At first, even though EUROSTAT has summed up all the data for each continent, it does not have them for Africa. Hence, to implement the research without significant bias, I extracted the trade data of the ten (10) most trade active in both import and export for Africa. For the next steps, I summed up all the quantities and values for these regions and calculated the value per container through the normal method.

For the final part of slow steaming's impact on shippers, I should calculate the costs that each additional day/hour causes. Hence, as I already mentioned in the theoretical part of this research, the main affected costs are the insurance, interest and depreciation costs. According to Verbeke and Notteboom (2004), each of the aforementioned cost has a unique and stable annual percentage. More specifically, each additional year, the interest cost increases by 5% of the value of the cargo, depreciation cost increases by 10% and insurance cost by 0.2%. Thus, by changing these percentages into daily and hourly bases, I can quantify the actual impact of slow steaming on shippers.

	Imports														
	Asia			Africa			North America			South America			Australia		
	Per year	Per day	Per hour	Per year	Per day	Per hour	Per year	Per day	Per hour	Per year	Per day	Per hour	Per year	Per day	Per hour
Interest Cost	5,224.39	14.31	0.60	2,239.88	6.14	0.26	13,908.72	38.11	1.59	1,450.07	3.97	0.17	3,761.60	10.31	0.43
Depreciation Cost	10,448.79	28.63	1.19	4,479.75	12.27	0.51	27,817.44	76.21	3.18	2,900.15	7.95	0.33	7,523.20	20.61	0.86
Insurance Cost	208.98	0.57	0.02	89.60	0.25	0.01	556.35	1.52	0.06	58.00	0.16	0.01	150.46	0.41	0.02
Total	**15,882.15**	**43.51**	**1.81**	**6,809.23**	**18.66**	**0.78**	**42,282.51**	**115.84**	**4.83**	**4,408.22**	**12.08**	**0.50**	**11,435.26**	**31.33**	**1.31**
	Exports														
	Asia			Africa			North America			South America			Australia		
	Per year	Per day	Per hour	Per year	Per day	Per hour	Per year	Per day	Per hour	Per year	Per day	Per hour	Per year	Per day	Per hour
Interest Cost	5,808.46	15.91	0.66	1,509.90	4.14	0.17	9,186.11	25.17	1.05	3,633.64	9.96	0.41	7,959.98	21.81	0.91
Depreciation Cost	11,616.93	31.83	1.33	3,019.79	8.27	0.34	18,372.23	50.33	2.10	7,267.28	19.91	0.83	15,919.97	43.62	1.82
Insurance Cost	232.34	0.64	0.03	60.40	0.17	0.01	367.44	1.01	0.04	145.35	0.40	0.02	318.40	0.87	0.04
Total	**17,657.73**	**48.38**	**2.02**	**4,590.09**	**12.58**	**0.52**	**27,925.78**	**76.51**	**3.19**	**11,046.26**	**30.26**	**1.26**	**24,198.35**	**66.30**	**2.76**

18. Price per year/day/hour of waiting (in $)

After the calculation of the additional year\day\hour in each selected trade route for both imports and exports, I can proceed to the calculation of the total annual shipper costs and the actual impact of slow steaming. To implement such a calculation, I should firstly make several assumptions. At first, in order for the model to be realistic enough, I should calculate the empty containers that are being transferred in each selected trade route. Hence, according to Ireland (2015), New Zealand Ministry of transport (2015), Port of Los Angeles (2015), Rodrigue (2015) and ESCAP (2015) I calculated the average percentage of 78.7% of the total vessel capacity to be used for fully loaded containers, and the remaining 21.3% to be used for the transfer of empty ones.

Lastly, using the same method that I used previously to calculate slow steaming's impact on carriers, I calculated shippers' results as well. In the following table, one can observe the cost difference among the speed samples that we have. Also, one can notice the substantial decrease of costs when the sailing speed increases in each one of the selected routes.

TOTAL ANNUAL SHIPPERS' COST DIFFERENCE ($)												
AE5/METTE MAERSK (V0=23.6)												
Speed (knots)	15	16	17	18	19	20	21	22	23	V0	24	25
Import	65405853.0	52611244.3	41864024.1	32737624.2	24912300.1	18144383.1	12245417.3	7067701.6	2494081.3	0.0	-1569386.7	-5198783.5
Export	82001169.4	65960206.3	52486112.1	41044086.2	31233255.9	22748126.8	15352426.3	8860977.6	3126900.3	0.0	-1967584.6	-6517862.1
Total	147407022.4	118571450.5	94350136.3	73781710.4	56145556.0	40892509.9	27597843.5	15928679.2	5620981.6	0.0	-3536971.3	-11716645.6
NEUATL1/MAERSK IOWA (V0=23.6)												
Speed (knots)	15	16	17	18	19	20	21	22	23	V0	24	25
Import	19398270.7	15628957.9	12475128.9	9807123.4	7527978.9	5563973.8	3858220.7	2366235.2	1052811.0	0.0	-110220.6	-1145623.1
Export	8541149.6	6881503.5	5492857.8	4318122.5	3314604.5	2449843.8	1698792.7	1041864.5	463557.6	0.0	-48530.6	-504423.2
Total	27939420.3	22510461.4	17967986.7	14125245.8	10842583.4	8013817.5	5557013.3	3408099.6	1516368.7	0.0	-158751.2	-1650046.4
SAMBA2/CAP SAN ANTONIO (V0=25.1)												
Speed (knots)	15	16	17	18	19	20	21	22	23	24	25	V0
Import	3284999.1	2683288.4	2180305.7	1755198.8	1392382.2	1080012.7	808956.2	572074.0	363719.2	179376.1	15397.3	0.0
Export	20153358.6	16461883.4	13376101.9	10768085.2	8542217.8	6625841.3	4962918.9	3509654.6	2231405.0	1100466.2	94461.9	0.0
Total	23438357.7	19145171.7	15556407.6	12523284.0	9934600.0	7705853.9	5771875.1	4081728.6	2595124.2	1279842.3	109859.2	0.0
SAECS/MSC ALEXANDRA (V0=23.6)												
Speed (knots)	15	16	17	18	19	20	21	22	23	V0	24	25
Import	22601095.9	18115745.2	14367478.6	11200488.2	8498341.7	6172577.2	4154981.3	2392249.9	842225.8	0.0	-528798.1	-1748042.4
Export	6034225.8	4836690.1	3835947.2	2990398.1	2268956.9	1648005.3	1109331.0	638702.5	224864.3	0.0	-141182.8	-466706.7
Total	28635321.7	22952435.3	18203425.7	14190886.3	10767298.6	7820582.5	5264312.2	3030952.3	1067090.2	0.0	-669980.9	-2214749.1
NEWMO/AEGIALI (V0=24.1)												
Speed (knots)	15	16	17	18	19	20	21	22	23	24	V0	25
Import	23548901.5	19074998.5	15343884.2	12197690.1	9518578.3	7217120.3	5224434.4	3486754.5	1961604.7	615060.4	0.0	-580245.2
Export	105893511.5	85775490.4	68997604.1	54849957.2	42802662.7	32453582.2	23492972.9	15679061.6	8820845.1	2765772.4	0.0	-2609217.2
Total	129442412.9	104850488.9	84341488.3	67047647.3	52321241.0	39670702.5	28717407.3	19165816.0	10782449.8	3380832.7	0.0	-3189462.4

19. Total annual shippers' cost difference from V0 (in $)

To make things clear regarding the above table, firstly, one can see each of the selected trade routes, as well as the speed samples that I previously used in our quantification of slow steaming's impact on carrier companies. However, from a shippers' perspective, we have both imports and exports, so we sum up the results for both of them in order to have a total result of the annual impact of slow steaming on shippers. More specifically, to lead ourselves to this result, we should follow the next equation.

[13] $TSC = TSC_{import} + TSC_{export}$

[14] $TSC_{import} = TC \cdot \left(T_{r.days} + T_{p.days}\right) \cdot u_i \cdot tC_{import}$

[15] $TSC_{export} = TC \cdot \left(T_{r.days} + T_{p.days}\right) \cdot u_e \cdot tC_{export}$

TSC= Total shippers' costs, TC= Total containers needed, $u_{i,e}$=import/export coefficient, $tC_{import/export}$=daily additional costs

3.5 Combination

To continue, during the previous chapters I gave a detailed view of both shippers' and carriers' costs, and I quantified the annual impact of slow steaming in the selected trade routes. Hence, to give a more compact and practical overview of our results, and to link them properly with the final part of this research (the break-even bunker price analysis), we should combine and comment on our results in this section.

More specifically, on the next table, slow steaming's total annual impact on the supply chain is being presented. More specifically, since both perspectives are being examined, I decided to include them both on the same table and not separate them into smaller tables. In such a way, we can have a more complete overview of slow steaming's overall effect and we can compare and extract results more easily. What is more, as I mentioned before regarding carriers' perspective, the costs and benefits that are included in the table are: 1) Emission benefits 2) Operating costs 3) Capital costs 4) Container costs and from shippers' perspective I include 1) Import costs and 2) Export Costs. Lastly, at the bottom of each trade route, there is the total Net effect of both shippers and carriers.

Moreover, to discuss the results of the next table, one should keep in mind the results of the previous equations and tables, since in the combination section I do not calculate anew, but I demonstrate the results in a more compact way. However, if we take all the selected trade routes and analyze their results one by one, I can extract some interesting facts.

	TOTAL ANNUAL IMPACT												
	AE5/METTE MAERSK (V0=23.6)												
	Speed (knots)	**15.0**	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**23.0**	**V0**	**24.0**	**25.0**
Shippers	Import	65405853.0	52611244.3	41864024.1	32737624.2	24912300.1	18144383.1	12245417.3	7067701.6	2494081.3	0.0	-1569386.7	-5198783.5
	Export	82001169.4	65960206.3	52486112.1	41044086.2	31233255.9	22748126.8	15352426.3	8860977.6	3126900.3	0.0	-1967584.6	-6517862.1
	Total	**147407022.4**	**118571450.5**	**94350136.3**	**73781710.4**	**56145556.0**	**40892509.9**	**27597843.5**	**15928679.2**	**5620981.6**	**0.0**	**-3536971.3**	**-11716645.6**
Carriers	Emisions	5268331.5	4809125.6	4311042.2	3773367.7	3195416.9	2576531.1	1916075.3	1213436.4	468021.3	0.0	-320744.3	-1153417.6
	Operating	14200797.5	11765195.6	9616135.1	7705859.1	5996664.8	4458389.9	3066617.4	1801369.7	646143.5	0.0	-412813.9	-1387054.6
	Container	7211520.0	5974660.5	4883313.8	3913227.9	3045256.3	2264081.9	1557305.0	914780.6	328127.8	0.0	-209637.2	-704381.0
	Capital	27895191.0	23110841.4	18889356.4	15136925.4	11779487.0	8757792.5	6023878.5	3538502.0	1269245.3	0.0	-810906.7	-2724646.6
	Total	**44039177.0**	**36041572.0**	**29077763.2**	**22982644.7**	**17625991.2**	**12903733.2**	**8731725.5**	**5041215.9**	**1775495.3**	**0.0**	**-1112613.5**	**-3662664.6**
	Net effect	**103367845.3**	**82529878.6**	**65272373.1**	**50799065.7**	**38519564.7**	**27988776.8**	**18866118.0**	**10887463.3**	**3845486.3**	**0.0**	**-2424357.9**	**-8053981.0**
	NEUATL1/MAERSK IOWA (V0=23.6)												
	Speed (knots)	**15.0**	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**23.0**	**V0**	**24.0**	**25.0**
Shippers	Import	19398270.7	15628957.9	12475128.9	9807123.4	7527978.9	5563973.8	3858220.7	2366235.2	1052811.0	0.0	-110220.6	-1145623.1
	Export	8541149.6	6881503.5	5492857.8	4318122.5	3314604.5	2449843.8	1698792.7	1041864.5	463557.6	0.0	-48530.6	-504423.2
	Total	**27939420.3**	**22510461.4**	**17967986.7**	**14125245.8**	**10842583.4**	**8013817.5**	**5557013.3**	**3408099.6**	**1516368.7**	**0.0**	**-158751.2**	**-1650046.4**
Carriers	Emisions	1107746.8	1015397.1	915228.8	807098.4	690868.2	566405.6	433583.0	292277.0	142368.5	0.0	-16258.2	-183715.0
	Operating	4585285.5	3815704.6	3136662.6	2533069.7	1993012.9	1506961.8	1067201.3	667419.0	302400.4	0.0	-32200.0	-340032.4
	Container	1552348.4	1291806.8	1061917.1	857570.8	674734.5	510181.9	361301.0	225954.7	102377.6	0.0	-10901.3	-115118.0
	Capital	8494168.6	7068532.2	5810617.7	4692471.4	3692024.8	2791622.8	1976973.4	1236383.1	560191.9	0.0	-59650.1	-629904.6
	Total	**13524055.7**	**11160646.5**	**9093968.6**	**7276013.5**	**5668904.1**	**4242361.0**	**2971892.7**	**1837479.7**	**822601.4**	**0.0**	**-86493.2**	**-901340.0**
	Net effect	**14415364.6**	**11349815.0**	**8874018.1**	**6849232.3**	**5173679.3**	**3771456.6**	**2585120.6**	**1570619.9**	**693767.3**	**0.0**	**-72258.0**	**-748706.4**
	SAMBA2/CAP SAN ANTONIO (V0=25.1)												
	Speed (knots)	**15.0**	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**23.0**	**24.0**	**25.0**	**V0**
Shippers	Import	3284999.1	2683288.4	2180305.7	1755198.8	1392382.2	1080012.7	808956.2	572074.0	363719.2	179376.1	15397.3	0.0
	Export	20153358.6	16461883.4	13376101.9	10768085.2	8542217.8	6625841.3	4962918.9	3509654.6	2231405.0	1100466.2	94461.9	0.0
	Total	**23438357.7**	**19145171.7**	**15556407.6**	**12523284.0**	**9934600.0**	**7705853.9**	**5771875.1**	**4081728.6**	**2595124.2**	**1279842.3**	**109859.2**	**0.0**
Carriers	Emisions	2863882.9	2661789.6	2442586.8	2205960.1	1951608.1	1679240.9	1388579.1	1079352.7	751300.9	404170.9	37717.4	0.0
	Operating	8987168.8	7591265.7	6359586.5	5264760.6	4285179.5	3403556.5	2605897.6	1880753.1	1218664.7	611750.4	53389.1	0.0
	Container	4295443.8	3628267.8	3039583.1	2516307.8	2048114.1	1626739.8	1245496.4	898911.5	582464.4	292387.9	25517.5	0.0
	Capital	20116031.6	16991573.7	14234699.1	11784143.9	9591541.9	7618200.1	5832795.6	4209700.6	2727744.3	1369284.3	119501.2	0.0
	Total	**30534761.3**	**25549317.6**	**21191282.0**	**17359252.3**	**13973227.4**	**10969255.5**	**8295610.5**	**5910012.5**	**3777572.5**	**1869251.7**	**160690.4**	**0.0**
	Net effect	**-7096403.5**	**-6404145.9**	**-5634874.4**	**-4835968.2**	**-4038627.4**	**-3263401.6**	**-2523735.4**	**-1828283.9**	**-1182448.3**	**-589409.4**	**-50831.3**	**0.0**
	SAECS/MSC ALEXANDRA (V0=23.6)												
	Speed (knots)	**15.0**	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**23.0**	**V0**	**24.0**	**25.0**
Shippers	Import	22601095.9	18115745.2	14367478.6	11200488.2	8498341.7	6172577.2	4154981.3	2392249.9	842225.8	0.0	-528798.1	-1748042.4
	Export	6034225.8	4836690.1	3835947.2	2990398.1	2268956.9	1648005.3	1109331.0	638702.5	224864.3	0.0	-141182.8	-466706.7
	Total	**28635321.7**	**22952435.3**	**18203425.7**	**14190886.3**	**10767298.6**	**7820582.5**	**5264312.2**	**3030952.3**	**1067090.2**	**0.0**	**-669980.9**	**-2214749.1**
Carriers	Emisions	4719719.7	4308332.6	3862116.6	3380432.2	2862665.7	2308226.9	1716546.9	1087076.5	419284.4	0.0	-287344.0	-1033307.7
	Operating	13475376.6	11164192.8	9124913.0	7312219.9	5690336.5	4230641.5	2909965.0	1709350.1	613136.4	0.0	-391726.1	-1316199.6
	Container	6440595.9	5335958.8	4361279.0	3494897.0	2719713.1	2022047.5	1390826.4	816988.9	293050.4	0.0	-187226.6	-629081.5
	Capital	24355955.5	20178625.9	16492746.9	13216409.9	10284950.6	7646637.2	5259591.7	3089550.4	1108208.3	0.0	-708022.0	-2378953.8
	Total	**39552208.2**	**32370444.9**	**26116822.2**	**20643094.5**	**15832334.4**	**11591099.3**	**7843836.2**	**4528812.9**	**1595110.7**	**0.0**	**-999630.7**	**-3290927.1**
	Net effect	**-10916886.5**	**-9418009.5**	**-7913396.5**	**-6452208.2**	**-5065035.8**	**-3770516.8**	**-2579523.9**	**-1497860.5**	**-528020.6**	**0.0**	**329649.7**	**1076177.9**
	NEWMO/AEGIALI (V0=24.1)												
	Speed (knots)	**15.0**	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**23.0**	**24.0**	**V0**	**25.0**
Shippers	Import	23548901.5	19074998.5	15343884.2	12197690.1	9518578.3	7217120.3	5224434.4	3486754.5	1961604.7	615060.4	0.0	-580245.2
	Export	105893511.5	85775490.4	68997604.1	54849957.2	42802662.7	32453582.2	23492972.9	15679061.6	8820845.1	2765772.4	0.0	-2609217.2
	Total	**129442412.9**	**104850488.9**	**84341488.3**	**67047647.3**	**52321241.0**	**39670702.5**	**28717407.3**	**19165816.0**	**10782449.8**	**3380832.7**	**0.0**	**-3189462.4**
Carriers	Emisions	3578179.4	3304320.8	3007276.8	2686621.6	2341946.7	1972859.2	1578980.4	1159944.6	715398.3	244998.9	0.0	-251586.0
	Operating	13508246.5	11330930.4	9409769.2	7702070.4	6174129.3	4798982.3	3554801.7	2423728.4	1391009.4	444350.2	0.0	-426576.2
	Container	5226533.5	4384098.9	3640774.1	2980041.1	2388858.8	1856794.8	1375403.6	937775.2	538201.4	171925.4	0.0	-165048.4
	Capital	25813551.7	21652814.7	17981576.2	14718253.1	11798437.7	9170603.9	6793039.9	4631618.1	2658146.1	849130.0	0.0	-815164.8
	Total	**40970152.3**	**34063523.2**	**28024842.8**	**22713743.0**	**18019479.2**	**13853521.8**	**10144264.8**	**6833177.1**	**3871958.5**	**1220406.8**	**0.0**	**-1155203.4**
	Net effect	**88472260.7**	**70786965.8**	**56316645.4**	**44333904.3**	**34301761.9**	**25817180.6**	**18573142.5**	**12332638.9**	**6910491.3**	**2160425.9**	**0.0**	**-2034258.9**

20. Slow steaming's Total annual impact to carriers and shippers (in $)

To begin with, focusing on the AE5 trade route, one can notice the predictable behavior of both total Net effect of the supply chain and total costs of shippers and carriers. In other words, the greater the deviation by the design speed is, the more the costs regarding both shippers and carriers are. What is more, omitting fuel savings on purpose, in order to implement the break-even bunker price analysis later, one can observe that the slower the sailing speed is, the higher the costs are. Based on the fact that carrier companies nowadays try to sail slower and slower to save fuel, having already seen the increase in any other cost from both sides, one can understand the magnitude of fuel savings without even calculating it.

To continue, one can easily observe the same behavior in the other four (NEAUATL1, NEWMO, SAECS, SAMBA2) selected routes. More specifically, even though almost all their vital details, such as vessel design speed, vessel capacity, distance, roundtrip days and additional shippers' costs are different, the costs for both shippers and carriers are still increasing, as long as the vessels keep slowing down.

However, there is a major difference between the trade routes that we should highlight which stems from their total net effect, which can be translated into the total slow steaming impact on the supply chain. One can notice that in the AE5, NEUATL1 and NEWMO trade routes, the total net effect is positive, while in the SAECS and SAMBA2 trade routes it is negative. To focus on that, I should firstly focus on the equation of the total net effect which is

$$[16] \ TNE = TSC + (-TCC) \quad \text{where } TNE\text{= Total Net Effect}$$

Hence, as one can understand, when shippers' costs (i.e. shippers' impact) are bigger than carriers' costs (i.e. carriers' impact), the total net effect (i.e. supply chains' impact) will be positive. However, when carriers' costs are bigger than shippers' costs, the total net effect will be negative. To explain that outcome, we should go back on the estimation of the value per container of each selected region. If we watch closely, in the regions that the total net effect is positive, the value per container is more than 100.000$, while in the regions that net effect is negative, the value per container is significantly lower. That makes the delay that slow steaming offers to shippers/consignees, more "expensive", and so shippers' costs significantly increase. We will discuss this effect in a more detailed way in the next section, where I will calculate the break-even bunker price of each trade route.

3.6 <u>Break-Even Bunker Price Analysis</u>

To answer the main question of this analysis, I will present a break even bunker price analysis, in which I will calculate the break-even bunker prices of all the selected trade routes, in every selected sailing speed. In other words, I will reach a conclusion by comparing the break-even bunker prices that I have calculated with the current fuel bunker price. To do that, I will follow equation 17, with its implementation being presented on the next table.

$$[17] \ |BEBP| = \frac{|TNE|}{TFC} \quad \text{where BEBP= Break Even Bunker Price}$$

BREAK EVEN BUNKER PRICE											
AE5/METTE MAERSK (V0=23.6)											
15.0	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**23.0**	**V0**	**24.0**	**25.0**
330.1	288.8	254.8	226.5	202.8	182.8	165.7	151.0	138.3	-	127.2	117.5
NEUATL1/MAERSK IOWA (V0=23.6)											
15.0	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**23.0**	**V0**	**24.0**	**25.0**
219.0	188.1	163.1	142.8	126.0	112.0	100.3	90.4	82.0	-	74.8	68.6
SAMBA2/CAP SAN ANTONIO (V0=25.1)											
15.0	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**23.0**	**24.0**	**25.0**	**V0**
55.4	54.2	52.5	50.6	48.5	46.4	44.3	42.2	40.2	38.3	36.4	-
SAECS/MSC ALEXANDRA (V0=23.6)											
15.0	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**23.0**	**V0**	**24.0**	**25.0**
38.9	36.8	34.5	32.1	29.8	27.5	25.3	23.2	21.2	-	19.3	17.5
NEWMO/AEGIALI (V0=24.1)											
15.0	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**23.0**	**24.0**	**V0**	**25.0**
416.0	360.5	315.1	277.7	246.5	220.2	197.9	178.9	162.5	148.4	-	136.1

21.Break even bunker price analysis

Furthermore, to explain the break-even bunker price table, one should keep in mind that in the last part of this research I will compare the current bunker price with all the break-even bunker prices that I calculated, to show the viability of slow steaming from a supply chain perspective. Therefore, I follow the same table format that I used previously, where I split the selected trade routes into five (5) major categories, and I calculate the break-even bunker price (in $) that corresponds to each sailing speed from our speed sample (in knots).

To begin with, the trade route between Asia and North Europe (AE5) shows some interesting results. Firstly, one can notice that the break-even bunker price is constantly decreasing when sailing speed increases. That is the expected result of the calculations, since the total impact of slow steaming is constantly getting lower when vessels sail faster. Secondly, as one can observe, the result spectrum that I conclude in consists of prices ranging from 330.1$ per metric ton of fuel (in 15 knots) to 117.5$ per metric ton of fuel (in 25 knots). That means that a slight change in vessels' sailing speed could result into a significant increase or decrease of the break-even bunker price. In fact, calculating the actual price difference between the different sailing speeds in the AE5 trade route, one will find that changing the vessels' sailing speed by one (1) knot will result to a price change of almost 15%, on average.

To continue, focusing on the trade route between North America and North Europe (NEUATL1), one will notice the same price behavior as in AE5. However, one will also notice that the break-even bunker price spectrum not only becomes narrower, but also the prices are significantly lower. That mainly has to do with the vessel's specifications and with the value per container. To explain, if we compare the Asia- Europe value per container with the one of North America-Europe, one will notice that the second one is significantly higher. That makes slow steaming's delay more expensive from the one of Asia-Europe, thus shippers' costs increase more abruptly at the slightest change of the traded quantity between North America and Europe. In addition to that, vessel's specifications (Maersk Iowa) do not allow carrier companies to save money from operating and capital costs, since this vessel has small capacity compared to the others used, and thus high operating and capital costs per TEU (Murray, 2015). All of the above lead us to the conclusion that, having excluded fuel savings from our calculations in the previous parts (shippers' impact, carriers' impact, total Net effect), we come up with a considerably lower total impact of slow steaming (Net Effect) than the AE5's one, and eventually, a lower break-even bunker price.

This interesting phenomenon, adding a major difference, stands for the next two selected trade routes, the SAMBA2 (South America-Europe) and the SAECS (Africa- Europe). In fact, one can easily notice that even though the break-even bunker price is increasing, if the vessels sail slower, the price sample decreases dramatically. To explain that, we should recall the table with the calculated value per container and the specifications of the vessels that have been selected to operate in these routes by their carrier companies (Cap San Antonio, MSC Alexandra). At first, regarding the value per container section, if we go back to the table where one can see the calculations of the average value per container, one will notice that in Africa, as well as in South America, the value of each container traded is significantly lower than any other selected trade route. More specifically, in SAECS, one can see that the import value per container is 46.198$ and that results into 18.66$ shippers' cost per day of delay, while the export value per container is 30.198$ which results into 12.58$ shippers' cost per day of delay. In addition to that, in the SAMBA2 trade route, the import value per container and shippers' costs is 29.001$ and 12.08$ accordingly, and the export ones are 72.673$ per container and 30.26$ per day, accordingly. As far as the vessels' specifications are concerned, both vessels result in considerably high capital and average operating costs. This results in a considerably low Net effect, and a low break-even bunker price. In other words, since shippers' costs tend to be equal to carriers' costs, the total impact is low (small Net Effect), which gives us the lowest break-even bunker prices of table 20.

Lastly, in the NEWMO trade route, one can, on the one hand, see the usual behavior of its break-even bunker price (sail speed increasing- break even bunker price decreasing), while on the other hand one finds the highest break-even bunker prices of all the five selected trade routes. As I mentioned time and again, this fact has to do with the value per container and vessels' specifications. More specifically, in NEWMO we found out that the import value per container is 75.232$ which results into 31.33$ shipper costs per day, while the export one is 159.200$ per container, which leads to 66.30$ shipper costs per day. Adding the specifications of the vessel called Aegiali into our calculations, I come up with one of the highest Net effects, which leads to high break-even bunker prices.

To conclude, the break-even bunker price section showed us the different break-even price spectrums among the selected trade routes. All of them show the expected behavior, increasing when the sailing speed decreases, while only two of them show some interesting deviations from the expected price spectrums. However, based on relevant facts that come from accurate sources, we can build a reliable model that can cover and explain some unexpected results.

3.6.1 Comparison

To answer the main research question, I should compare the current fuel bunker price with each of the break-even bunker prices of our model. For the purposes of this research, I will use the IFO380 which is one of the most common fuels in maritime industry (marquard-bahls.com, 2015). One basic assumption at this point is that, since the selected trade routes cover different regions around the world, we should compare the break-even bunker prices of each trade route with the bunker price that corresponds to each region.

Hence, taking into consideration the aforementioned assumptions, as well as the bunker prices taken from Ship&Bunker.com (2017), Bunkerworld.com (2017) and BunkerIndex.com (2017), we conclude with the following table, which includes eleven (11) major bunker ports.

Ports	**Price ($/mt)**
Singapore	328.50
Rotterdam	301.00
Houston	307.00
Fujairah	329.50
LA/ Long Beach	346.50
Hong Kong	342.00
Instanbul	337.00
New York	317.00
Rio de Janeiro	324.50
Piraeus	323.00
Gibraltar	318.00

22. Current bunker prices in major ports

To continue, focusing on our five (5) main trade routes, one will get some interesting results. The depiction of these results is presented in appendix 12. Firstly, as far as the AE5 route is concerned, since this route connects China with North Europe, I will use the average bunker price between Hong Kong and Rotterdam as a point of reference. Thus, comparing the break-even bunker prices of our model to our point of reference, which is 321.5$ per metric ton of fuel, one will notice that slow steaming is viable only under 16 knots. Secondly, going to the NEUATL1 trade route, which connects North America with North Europe, we should take into consideration that the point of reference (current bunker price) will be the average price among Rotterdam, New York, LA/ Long Beach and Houston. By doing this I find the average price of 317.8$ per metric ton, which is higher than all the model's break-even bunker prices. Hence, slow steaming is still viable, even if vessels' speed is reduced to 15 knots. To continue, focusing on the next two trade routes, the SAMBA2 and the SAECS, I get the same results as in the NEUATL1 route. In other words, even though our point of reference decreases in both cases (314.5$/mt for SAMBA2 and 309.5$/mt for SAECS), slow steaming is still viable from a supply chain perspective. Lastly, regarding the NEWMO trade route, which connects North Europe with Oceania, I find out that slow steaming is not viable at 15 and 16 knots. More specifically, since the current bunker price is being settled to 320.5$/mt from the bunker prices of ports of Rotterdam, Singapore, Piraeus and Fujairah and the model's break-even bunker prices are lower that this, at 17 knots, we can draw the conclusion regarding slow steaming in the NEWMO route.

3.6.2 Larger vessels approach

Even though I tried to cover a great variety of vessel capacity to have more realistic results, we notice that, over the years, vessels become bigger, in an effort to transfer more and more TEUs all over the world. Thus, one can easily notice that in the current research, I did not cover the vessels that have the highest capacities in the selected trade routes. What is more, as everything shows that the future of container shipping is vessels with capacity up to 13000 TEUs, we should focus on that, and consider it as a significant factor for research. So, in this section, keeping all the sailing schedule details the same, I will try to implement the same model, increasing the capacity of each vessel, and considering all the required factors as well (increased capital costs, different operating costs, etc.).

At first, for the trading route between Asia and North Europe, I will pick one of the biggest container vessels of Maersk Liner, Emma Maersk (Marinetraffic.com, 2017). Considering that currently (Feb-2017), Emma Maersk serves the trade route of Asia- Europe (Maersk, 2017), I can assume that the schedule will not have a substantial difference from the AE5 one. However, since in all the other selected routes I already selected vessels with slightly increased capacity from the standard ones, I will approach the "larger vessels" topic from a more theoretical perspective. In fact, I will use Emma Maersk in all the routes, to observe the effect of the increased vessel capacity into the break-even bunker price analysis.

As far as vessel's details are concerned, for vessel capacity I will take 11000 TEUs, which is one of the biggest capacities in container ships (14t TEU) (Containership-info, 2014). Consequently, I will amend the variables that are mainly based on vessel size, such as Operating, Capital costs and fuel consumption. More specifically, I will use the same equations to calculate all the aforementioned variables used previously on the empirical analysis. The result of variables' calculation and model's implementation are being presented in appendix 13.

Lastly, after the model's implementation into all the selected trade routes, under the increased vessel capacity, I conclude in some interesting results. As one can see in the graphs' appendix 13, at first, in AE5, the break-even bunker price analysis shows that slow steaming still has the same behavior as in the normal model. In other words, since the break- even bunker price is higher than the current bunker price only in 15 knots of sailing speed, we can conclude that slow steaming is still viable in all the other sailing speeds, apart from 15 knots. As far as NEUATL1, SAMBA2 and SAECS are concerned, the results are almost the same as the ones of the normal model, due to the previous explanation. As long as the value per container remains still small, the net effect of both actors will be small, leading to a lower than expected break-even bunker price. However, the situation is different when it comes to the NEWMO trade route. As one can observe from the results and the graph in the "normal capacity" model, slow steaming is not viable at until 17 knots of sailing speed. In the "large capacity" model, slow steaming, according to the results, is viable from 18 knots and on. In these kinds of routes, that cover distances of almost 30.000 nautical miles, one (1) knot could make a significant difference in the sailing schedule of the carrier company, and, also, in the carrier companies' strategic approach for the specific trade route.

4. Conclusion

4.1 Conclusion

To conclude, firstly, we should highlight the fact that, even though slow steaming was introduced almost a decade ago and researched from several perspectives, it still raises the interest of researchers. More specifically, from the very beginning of slow steaming's implementation by carrier companies, more and more researchers focused on its consequences to each actor of the supply chain involved, offering more and more data in the already existed literature. However, by focusing on the actors of the supply chain separately, and by observing slow steaming from a microeconomic perspective, there is a lack of scientific research from a macroeconomic perspective, focusing on the supply chain as an entity and not as smaller separate parts. To enhance the yet developing research concerning this perspective, this research answers to the question: "Is slow steaming still viable in the container shipping market from a supply chain perspective?"

To answer the research question, I chose to use a break-even bunker price analysis. However, to reach the point of break-even bunker price analysis, there are several steps that were followed. One major step is the quantification of the impact of slow steaming on the supply chain. To do that, I firstly distinguished the most affected actors of the supply chain, and focused on them separately. Concluding to the fact that the most affected ones are carrier companies and shippers/consignees, I implemented three sub-models, which helped me calculate slow steaming's impact on the actors, combine them, and calculate the break- even bunker prices of five (5) different trade routes, from a speed sample of 15 to 25 knots of sailing speed. The second and final major part is the comparison of the break-even bunker prices to the current bunker prices in eleven (11) major bunker ports of the world.

By following this analysis, we lead ourselves into some interesting results, some of them already predicted. To be specific, we reach the fact that slow steaming is still viable in most of the selected trade routes from a supply chain perspective. In fact, even though it increases shippers' and carriers' costs significantly, it still increases fuel and emission savings that make slow steaming viable macro-economically. What is more, if we focus on the constructed model, before the break-even bunker price model, we will notice that the most significant factor that prove the viability of slow steaming in all the selected trade routes are the value of imports and exports of each region. In other words, ceteris paribus, we can see that even a slight fluctuation in the total value per container, offers a substantial increase or decrease into shippers' costs during the delay that slow steaming offers. This leads us to the answer of whether slow steaming is still viable. Taking all the needed data regarding imports and exports from Eurostat, we notice that some regions have significantly lower value per container than others. That, in conjunction with the costs that are related to the selected vessel, gives us most of the total costs of the supply chain. Going back to the break -even bunker price analysis, which is the actual outcome of the main model, we can say that the simplest scenario to prove if slow steaming is not viable anymore, is to increase the gap between shippers' and carriers' effects from slow steaming. To succeed in that, we should either increase one of the two actors' net effect and decrease other one's, or have the one have bigger rate of increase than the other. In that way, we would have a high enough break-even bunker price that would probably be higher than the current bunker prices.

What is more, when it comes to the break -even bunker price analysis result, we should clarify the concept behind the outcome. After the main model's implementation, we conclude to five different samples of break-even bunker prices that correspond to each sailing speed and trade route. Comparing these prices with the current bunker price we can see when break-even bunker prices are higher or lower than the current bunker price. In that way, we can easily conclude to the same results as Cariou used in his research, "when the break-even bunker price of our model is lower than the current bunker price, slow steaming is still viable" and vice versa.

To finish, considering all the previous details, we can say that, for the time being, slow steaming remains viable and will remain as such if no extreme changes occur. It might not be as financially viable as it was back in 2009, when oil prices skyrocketed. But it is still one very simple yet successful strategy of carriers to decrease their main costs. That does not automatically mean that it is a healthy strategy for all the others actors of the supply chain. However, considering the market power of carriers, we could say that they lead the supply chain, driving sometimes the actors of it in making choices that they would not make under normal situations.

4.2 Limitations

Throughout this research, several assumptions have been made, to make the research model able be implemented and easily generalized. To start, to cover a great variety of trading routes, I decided to cover all the continents around the world by connecting each one of them with Europe. However, to do that realistically, we should have used all the trade routes that carrier companies use to cover the selected areas. In fact, to achieve that better, we should have created many different pairs of selected areas and not combine all of them with Europe. What is more, regarding trade routes, if we watch closely, we focus only on the Northern part of Europe as starting and finishing points of our roundtrips. For more precision, we should have also covered the Mediterranean Europe, since it is one of the biggest trade regions around the world. However, by doing that, we would increase the number of selected trade routes, perplexing the actual purpose of this research.

What is more, to cover the selected routes, I chose to include some specific types of vessels in my model, to increase the variability of vessels' capacity. However, vessels' capacities are different from route to route, and from carrier company to carrier company, creating an average capacity of TEUs transferred in these trade routes that may not correspond to the ones that I used in my model. That may have caused some bias in my research regarding particular routes, but this bias vanishes when we see the model as a whole.

One important assumption that I have used to make this research happen, concerns the type of fuel that vessels use, and the type of fuel that I used in the break- even bunker price analysis. As I previously stated, vessels' fuel has already been affected by technological breakthroughs, and considering the latest facts, more and more vessels use eco-friendly fuel. However, in this research, we assume that all the selected vessels use IFO380 in all of their selected traded routes. However, as we previously mentioned, even though it would be a good extension to the already existing research, it would easily mix the answer to the basic research question. Lastly, one important limitation regarding bunker prices is that I used the average bunker price of 11 major ports of the world, concluding in a price that is probably slightly different from the real average one. However, a slight change in bunker prices would not change considerably the outcome of the existing model.

4.3 Recommendations

This research proved the viability of slow steaming from a supply chain perspective today, using a break-even bunker price analysis. The outcome of this research showed us that, even though slow steaming creates some significant costs to both shippers and carriers, it is still viable from a supply chain perspective. However, since this research focused on some developing regions among all the others, it could be interesting to see the outcome of a future research that would be focused on those developing regions, after some years -when they may be already developed-. In such a way, their value per container would be significantly increased, leading to substantial costs for shippers and consignees in those regions.

What is more, by focusing on the total vessel capacity that I used for this research, we could find several interesting outcomes in a research that would focus on the same topic, but with higher vessel capacities. More specifically, since in this research I use the actual vessel capacity using only 14 ton containers, it would be interesting if, in the near future, the maximum vessels' capacity was used in a similar research. That could lead into substantial alterations in the viability of slow steaming, since several main variables would change, for the model to be properly implemented.

Lastly, by focusing on some used variables in the model, we would notice that some of them have changed time and again, over the years. More specifically, on the one hand are the ones that can change daily, such as oil prices, while some others change slowly and steadily, such as the percentage of full containers transferred from and to major ports. These variables could lead into a significant fluctuation in the revenues and expenses for both carriers and shippers/consignees, probably leading to a different outcome regarding the viability of slow steaming.

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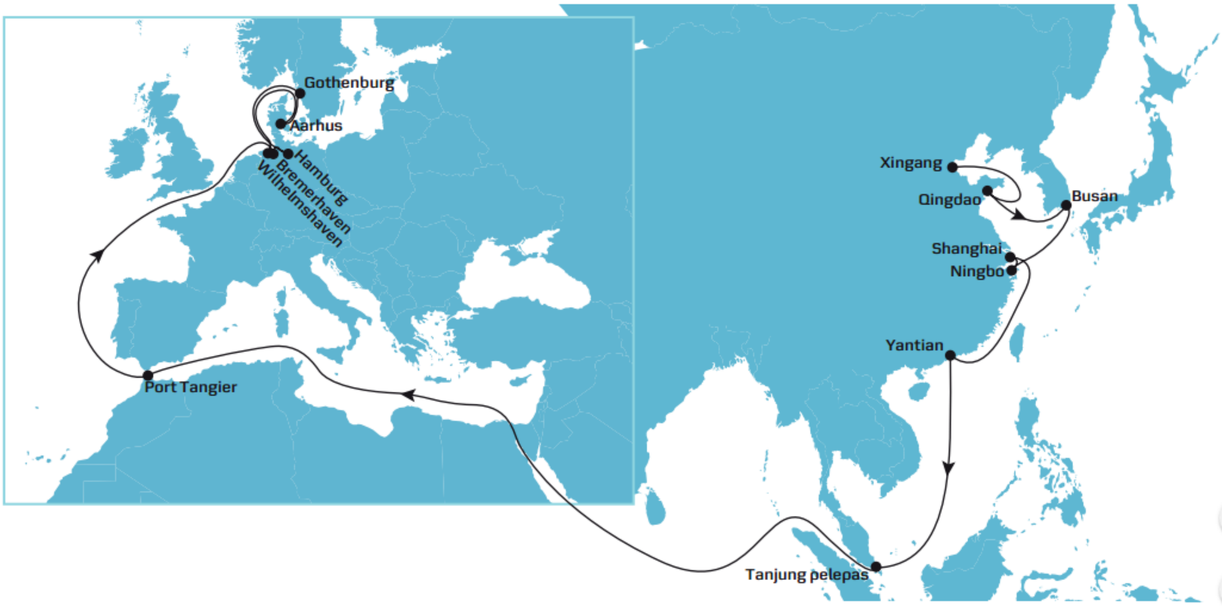
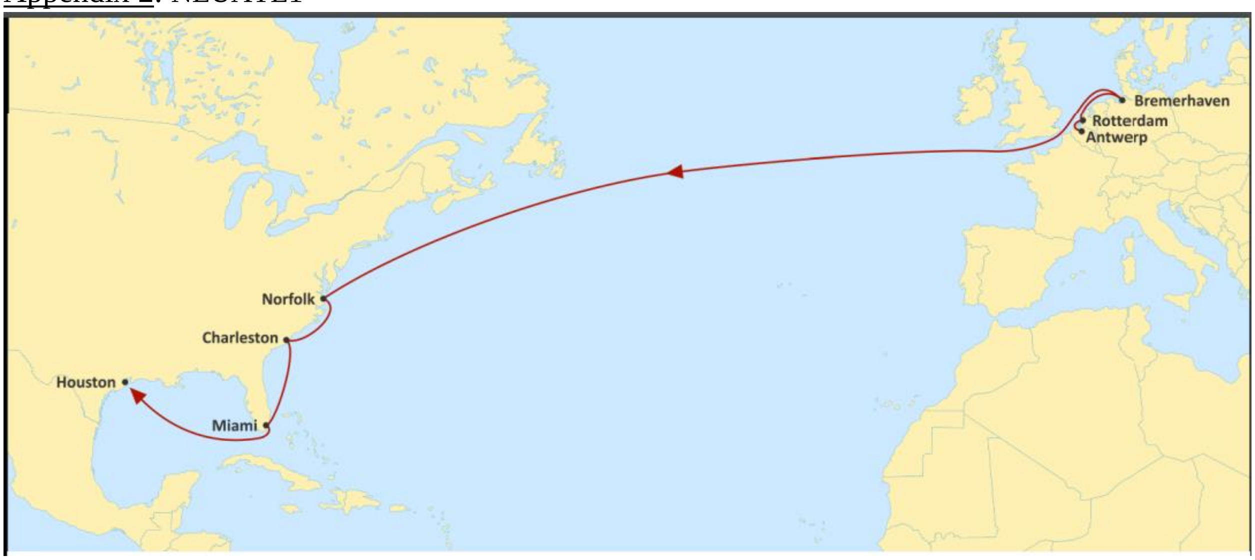
6. Appendix

Appendix 1: AE5 route



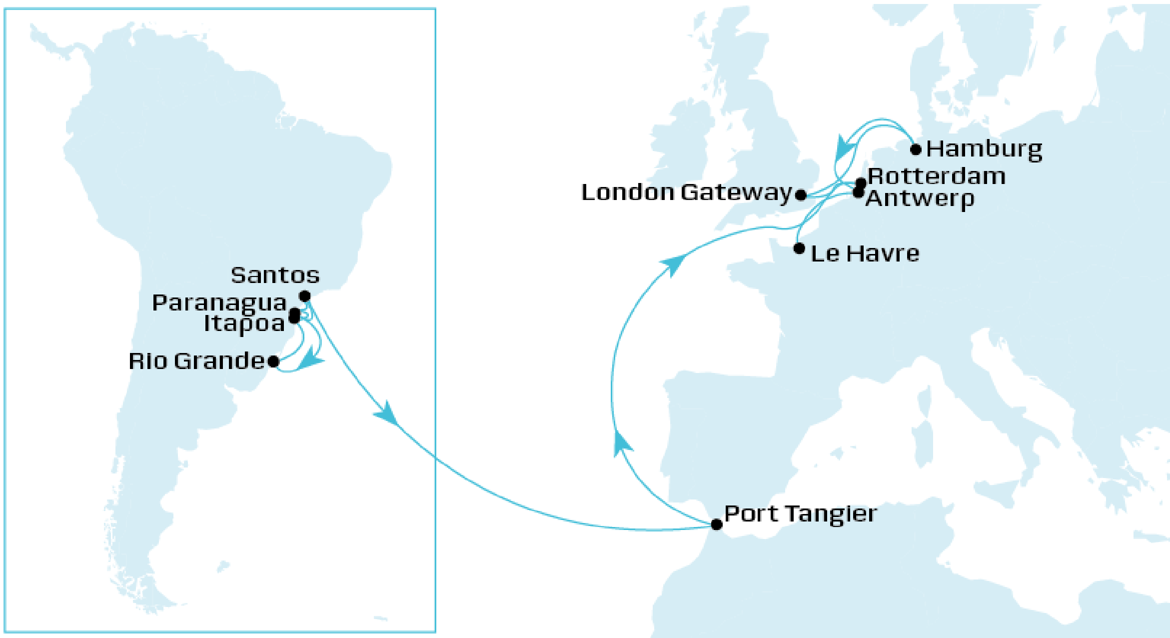
Appendix 2: NEUATL1



Appendix 3: SAECS

Appendix 4: NEWMO

Appendix 5: SAMBA2



Appendix 6: Daily fuel consumption of each vessel at V0

Vessel	***FCv0***
Mette Maersk	241
Maersk Iowa	114
Cap san Antonio	233
MSC Alexandra	333
Aegiali	136
Emma Maersk	335

Appendix 7: CO_2 price

Appendix 8: Daily operating costs per TEU

Vessel	***OC_{daily} ($/TEU)***
Mette Maersk	1.6
Maersk Iowa	2.4
Cap san Antonio	2.1
MSC Alexandra	1.7
Aegiali	2.0
Emma Maersk	1.5

Appendix 9: Construction cost per TEU (Murray, 2015)

Size	**Cost/TEU**
0-999	$ 23,065.11
1000-1499	$ 20,606.62
1500-1999	$ 19,215.59

2000-2999	$ 16,436.43
3000-3999	$ 16,255.45
4000-5099	$ 14,672.54
5100-7499	$ 13,912.16
7500-9999	$ 11,491.36
10000-13299	$ 11,234.63
13300+	$ 9,298.82

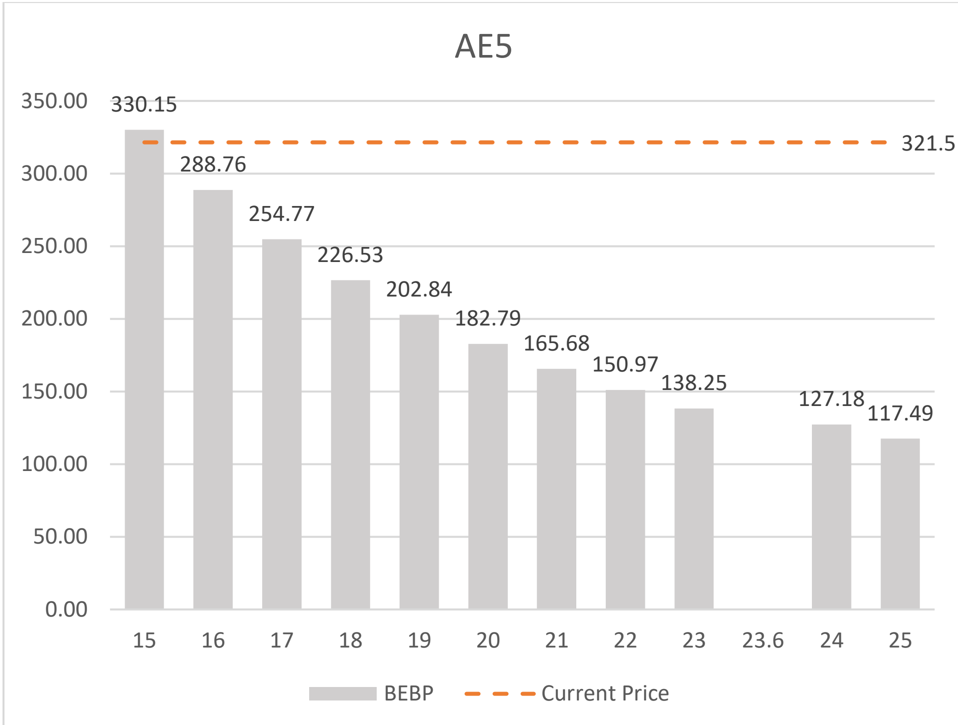
Appendix 10: Construction costs

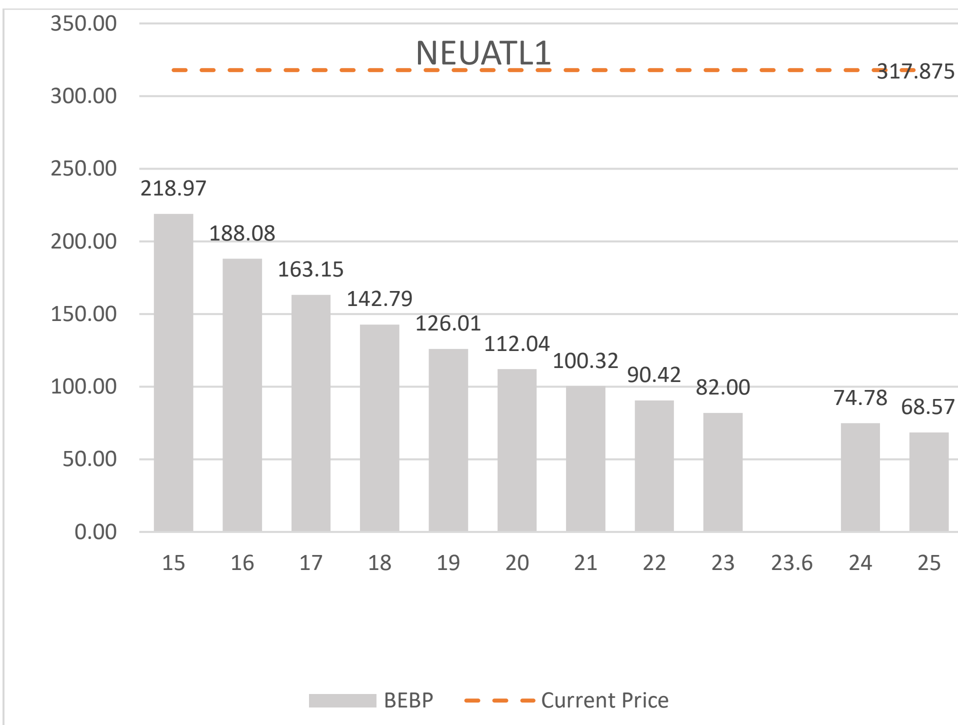
Vessel	**Construction cost ($)**
Mette Maersk	88641574
Maersk Iowa	59590830
Cap san Antonio	103769608
MSC Alexandra	119529760
Aegiali	64468768
Emma Maersk	123574000

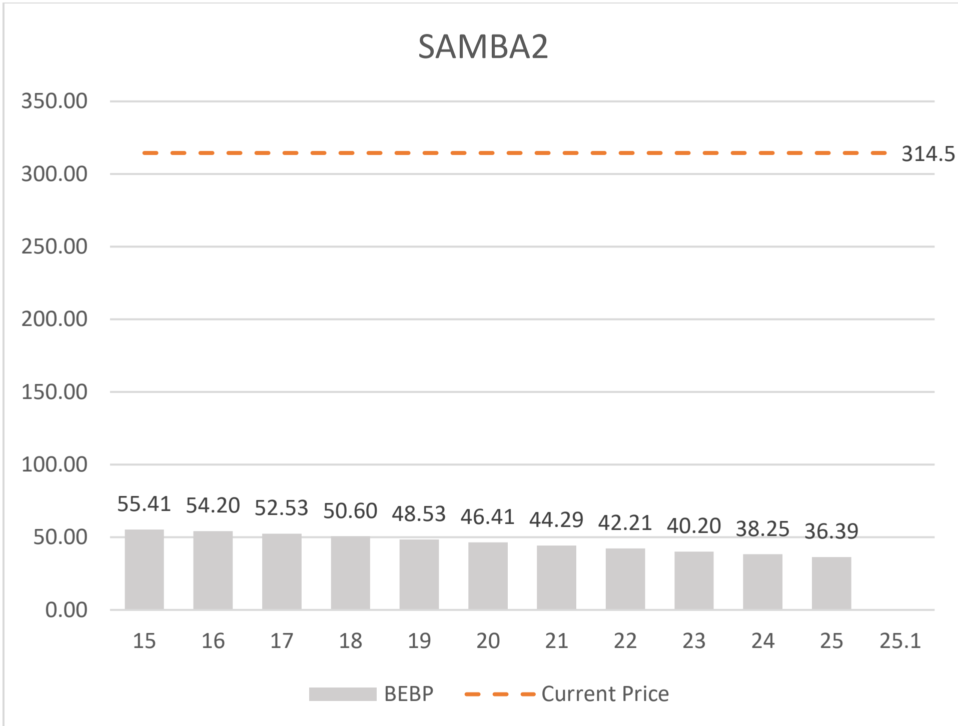
Appendix 11: Shippers' costs coefficients

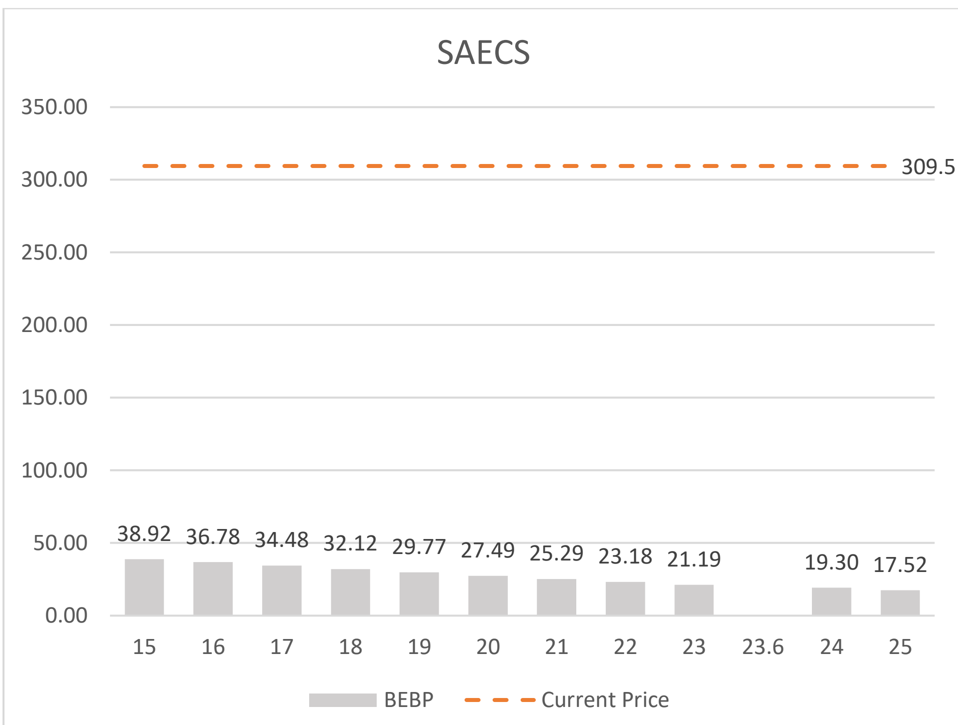
	Per year	**Per day**	**Per hour**
Interest Cost	0.05	0.00013698630	0.00000570776
Depreciation Cost	0.10	0.00027397260	0.00001141553
Insurance Cost	0.002	0.00000547945	0.00000022831

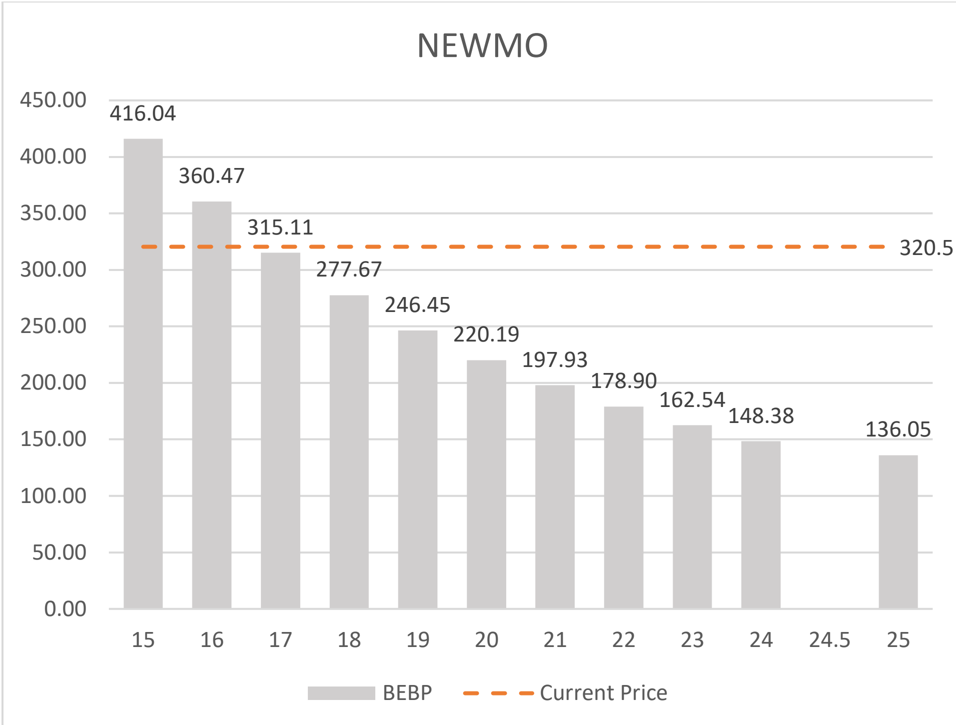
Appendix 12: Break even bunker price analysis (normal)



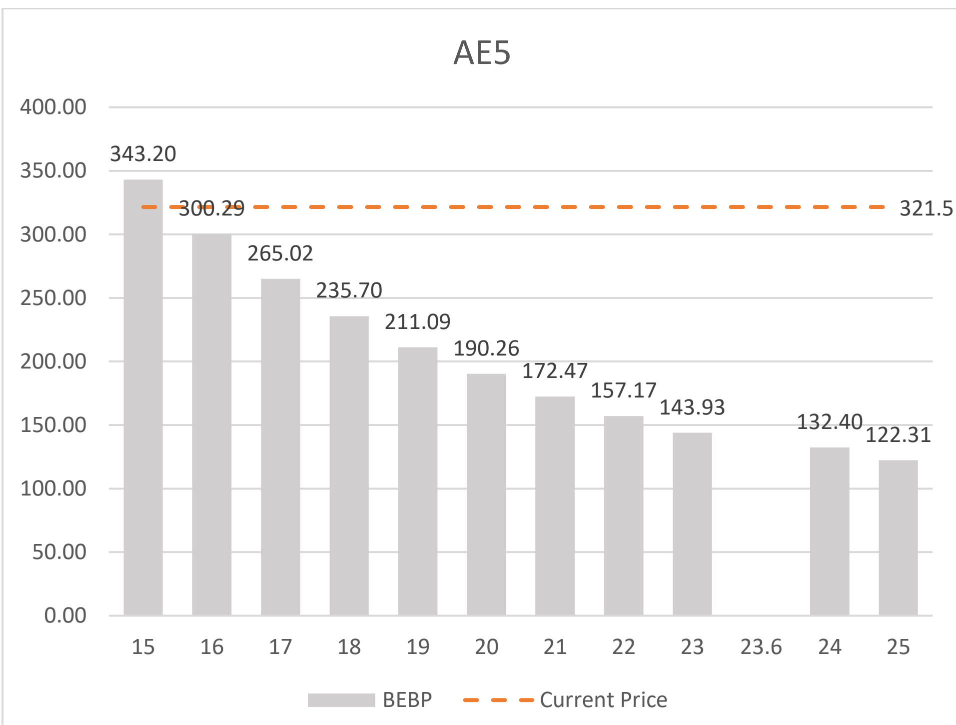


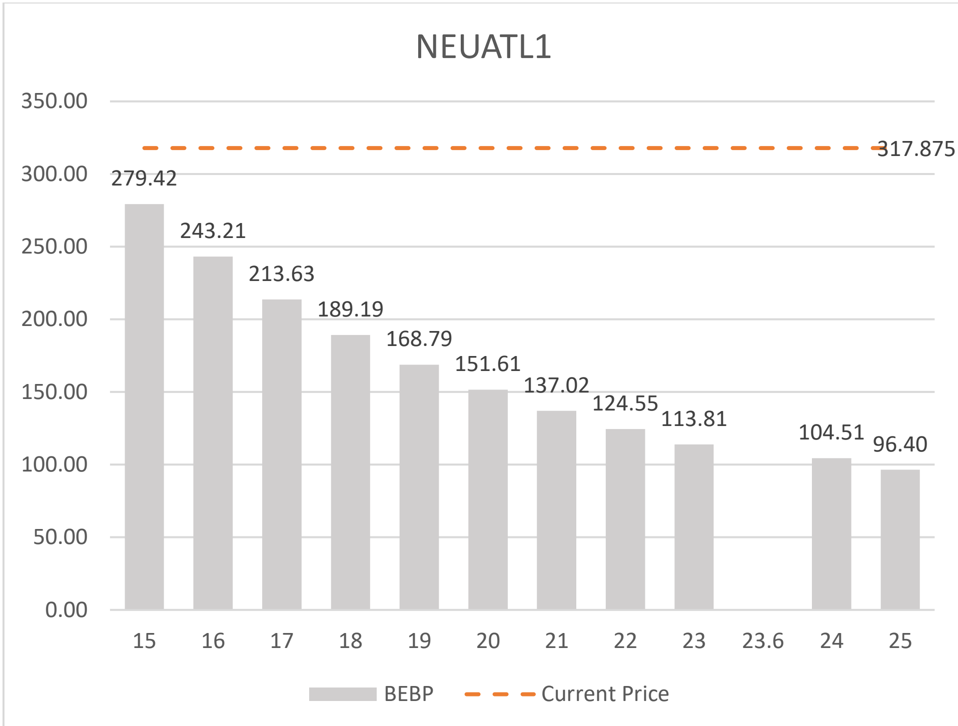

SAMBA2
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
314.5
55.41 54.20 52.53 50.60 48.53 46.41 44.29 42.21 40.20 38.25 36.39
15 16 17 18 19 20 21 22 23 24 25 25.1
BEBP
Current Price

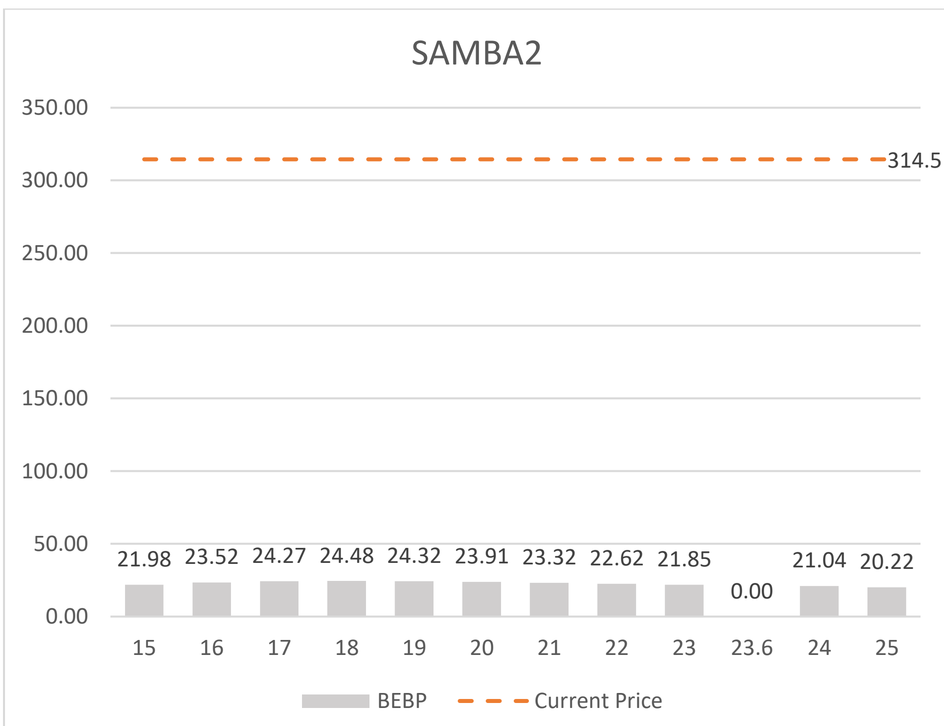

SAECS
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
309.5
38.92 36.78 34.48 32.12 29.77 27.49 25.29 23.18 21.19 19.30 17.52
15 16 17 18 19 20 21 22 23 23.6 24 25
BEBP
Current Price

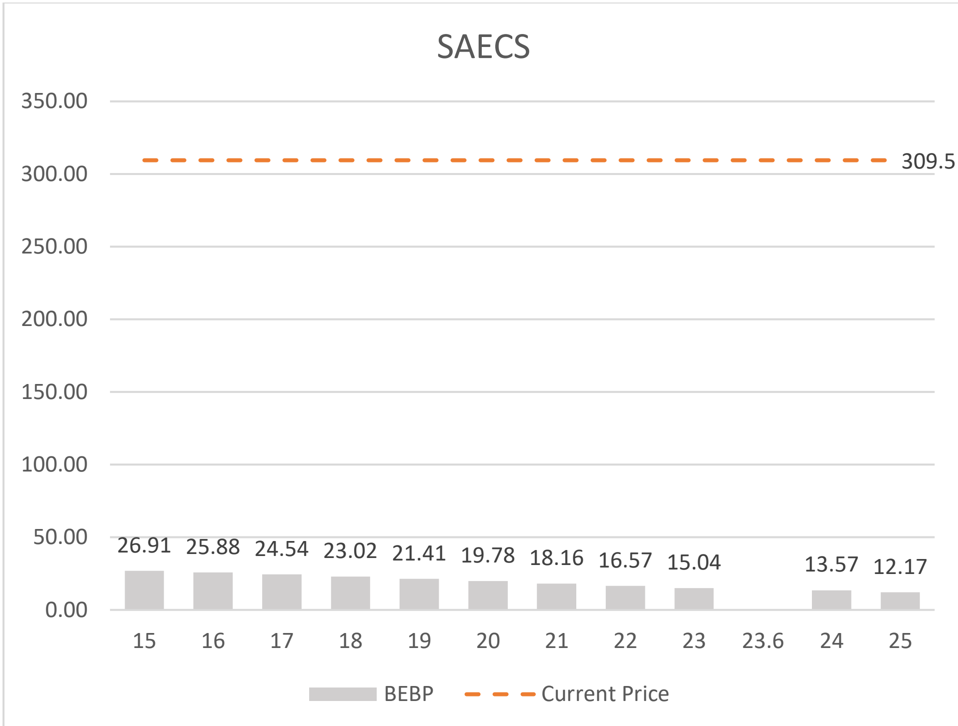


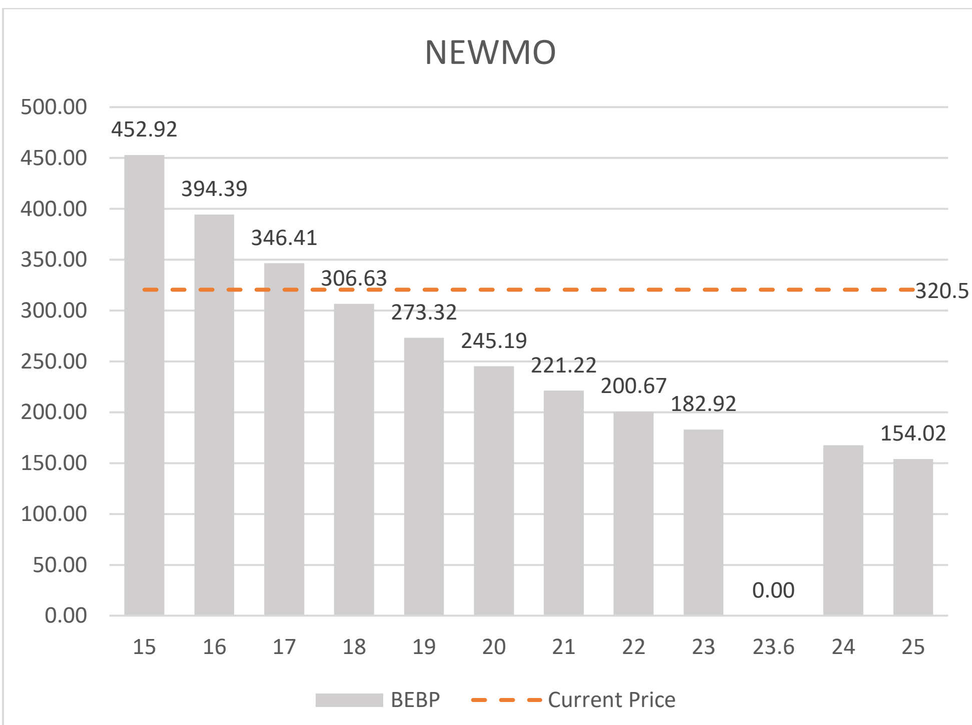
Appendix 13: Break even bunker price analysis (Emma Maersk)




NEUATL1
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
317.875
279.42
243.21
213.63
189.19
168.79
151.61
137.02
124.55
113.81
104.51
96.40
15
16
17
18
19
20
21
22
23
23.6
24
25
BEBP
Current Price


SAMBA2
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
314.5
21.98
23.52
24.27
24.48
24.32
23.91
23.32
22.62
21.85
0.00
21.04
20.22
15
16
17
18
19
20
21
22
23
23.6
24
25
BEBP
Current Price


SAECS
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
309.5
26.91
25.88
24.54
23.02
21.41
19.78
18.16
16.57
15.04
13.57
12.17
15
16
17
18
19
20
21
22
23
23.6
24
25
BEBP
Current Price


NEWMO
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
452.92
394.39
346.41
306.63
273.32
245.19
221.22
200.67
182.92
0.00
154.02
320.5
15
16
17
18
19
20
21
22
23
23.6
24
25
BEBP
Current Price

Appendix 14: Number of roundtrip days in different sailing speeds

ROUNDTRIP DAYS											
AE5/METTE MAERSK (V0=23.6)											
15	16	17	18	19	20	21	22	23	V0	24	25
69	64	61	57	54	51	49	47	45	44	43	41
NEUATL1/MAERSK IOWA (V0=23.6)											
15	16	17	18	19	20	21	22	23	V0	24	25
30	29	27	25	24	23	22	21	20	19	19	18
AMBA2/CAP SAN ANTONIO (V0=25.1											
15	16	17	18	19	20	21	22	23	24	25	V0
38	36	34	32	30	29	27	26	25	24	23	23
SAECS/MSC ALEXANDRA (V0=23.6)											
15	16	17	18	19	20	21	22	23	V0	24	25
44	42	39	37	35	33	32	30	29	28	28	27
NEWMO/AEGIALI (V0=24.1)											
15	16	17	18	19	20	21	22	23	24	V0	25
82	77	72	68	65	62	59	56	54	51	50	49

Appendix 15: Container costs in different sailing speeds

CONTAINER COSTS											
AE5/METTE MAERSK (V0=23.6)											
15	16	17	18	19	20	21	22	23	23.6	24	25
24859341	23622482	22531135	21561049	20693078	19911903	19205126	18562602	17975949	17647821	17438184	16943440
NEUATL1/MAERSK IOWA (V0=23.6)											
15	16	17	18	19	20	21	22	23	23.9	24	25
4870894	4610352	4380463	4176116	3993280	3828728	3679847	3544500	3420923	3318546	3307644	3203428
SAMBA2/CAP SAN ANTONIO (V0=25.1)											
15	16	17	18	19	20	21	22	23	24	25	25.1
13857634	13190458	12601773	12078498	11610304	11188930	10807686	10461102	10144654	9854578	9587708	9562190
SAECS/MSC ALEXANDRA (V0=23.6)											
15	16	17	18	19	20	21	22	23	23.6	24	25
22730360	21625723	20651044	19784662	19009478	18311812	17680591	17106753	16582815	16289765	16102538	15660683
NEWMO/AEGIALI (V0=24.1)											
15	16	17	18	19	20	21	22	23	24	24.5	25
16284547	15442113	14698788	14038055	13446872	12914808	12433417	11995789	11596215	11229939	11058014	10892965

Appendix 16: Capital costs in different sailing speeds

CAPITAL COSTS											
AE5/METTE MAERSK (V0=23.6)											
15	16	17	18	19	20	21	22	23	23.6	24	25
96159489	91375139	87153654	83401223	80043785	77022090	74288176	71802800	69533543	68264298	67453391	65539651
NEUATL1/MAERSK IOWA (V0=23.6)											
15	16	17	18	19	20	21	22	23	23.9	24	25
26652648	25227011	23969097	22850951	21850504	20950102	20135453	19394862	18718671	18158479	18098829	17528575
SAMBA2/CAP SAN ANTONIO (V0=25.1)											
15	16	17	18	19	20	21	22	23	24	25	25.1
64896810	61772352	59015478	56564923	54372321	52398979	50613574	48990479	47508523	46150063	44900280	44780779
SAECS/MSC ALEXANDRA (V0=23.6)											
15	16	17	18	19	20	21	22	23	23.6	24	25
85957830	81780501	78094622	74818285	71886825	69248512	66861466	64691425	62710083	61601875	60893853	59222921
NEWMO/AEGIALI (V0=24.1)											
15	16	17	18	19	20	21	22	23	24	24.5	25
80428452	76267715	72596476	69333153	66413338	63785504	61407940	59246518	57273046	55464030	54614900	53799735