Bachelor Thesis

Is the reliability of liner services improved due to slow steaming?

Faculty of Economics and Business Urban, Port and Transport Economics

Jeroen Hagens

363003

Thesis supervisor: Larrissa van der Lugt

Acknowledgment

This thesis is written as part of bachelor's program of Economics offered at the Erasmus University Rotterdam. By following the major Urban, Port and Transport economics, my interest in the maritime sector became clear. Therefore, I decided to write a thesis about this segment. The decision to write a thesis about slow steaming was a logical decision. I saw potential in investigating slow steaming and its consequences, as slow steaming is a hot and trending subject in the maritime industry. Looking back at this thesis, I enjoyed analyzing the change in reliability in the shipping industry due to slow steaming.

I would like to thank the dedicated support of my family and friends. In particular, I would like to thank Larissa van der Lugt whom provided guidance and was my supervisor.

Table of Contents

Executive Summary

Due to the implementation of slow steaming in 2008, transit times for shippers increased significantly. Shipping lines claimed that due to the implementation of slow steaming, the increased transit time is compensated by increased reliability. Reliability has recently become one of the most important considerations for a shipper. In this thesis the claim of shipping lines that reliability has increased due to the implementation of slow steaming is researched.

In order to understand the concept of slow steaming, the main factors of slow steaming are discussed. These factors include bunker costs, time factor, inventory costs and CO2 reduction. Hereafter the global reliability levels of the top-20 carriers in the time period 2006-2014 are analyzed. A significant difference between the period before and after the implementation is observed. In order to get a better picture of the change of reliability due to slow steaming, a more in-depth case study on the AE10 loop of Maersk is done. This particular loop scores high reliability figures and a rising trend since the beginning of the dataset which starts in 2011. This high reliability is explained due to the fact that Maersk implements significant buffer time in this particular loop. This is possible due to the slow steaming speed which is applied on its vessels. This buffer time can be used in order to catch up on schedule and therefore ensure on-time reliability.

The conclusion of this thesis results in an acknowledgment of the claim of carriers, that reliability improved due to the implementation of slow steaming. However, it should be noted that the increased reliability isn't very high and a lot of variance in reliability between carriers and routes occur.

1. Introduction

The ongoing globalization and rise of the BRIC-countries have changed the global economy the past decades. Production is done with parts and raw materials from all over the world which comes together at one production site. Most supply chains of production sites have evaluated the past decade to just-in-time processes, with as result, a small safety stock. This is possible due to cost-effective and timely shipping services. The shipping industry which transport ninety per cent of all goods in the world have to meet the requirements of feeding its costumers tight scheduled supply chains (Wurst & Cremon, 2003).

Before 2008, shipping lines tend to speed up their vessels speed to ensure fast loading and delivery of goods with a short transit time between ports. This was done in order to offer their customers the ability to keep a small inventory which reduced inventory costs. Larger and faster ships were built in order to keep shipping service for shippers on a high service level. Lee acknowledges that huge challenges are faced by shipping lines concerning the demand of on-time delivery of its customers (Lee, 2013). A few years before 2008, the shipping industry faced another challenge as bunker prices rose significantly. As a comparison, in 2008 the average bunker prices reached a level of 700 dollars per ton which is 2 to 3 times higher compared to two years before (Bunkerindex, 2014). The shipping industry saw their operation costs rise as nearly 50% of the operation costs of a vessel consists of bunker costs (Mclean & Biles, 2008). Shipping lines were forced to use different methods and techniques in order to reduce fuel consumption.

Major shipping lines experimented with reducing the operating speed of its vessels. Rapidly it became clear that “slow steaming” referred to as decreasing vessel speed, was from an economic point of view a solution for encountering the rising prices of bunker fuel costs. Maersk which is the leading shipping line of the world implemented slow steaming in 2009 on its total fleet of container vessels (Maersk, 2012). Decreasing operating speed comes with a price, transit times between ports increases, more vessels must be deployed to maintain the same port call frequency and shippers have to redesign their supply chain.

Shippers faces serious consequences by the implementation of slow steaming by shipping lines. But what's in it for the shippers? Maersk uses an example to describe the benefits of slow steaming for shippers as follows. A journey from Hong Kong, China to Rotterdam, Netherlands had a time schedule before slow steaming of 21 days. Customers had to keep buffer inventory in the event the cargo didn't arrive on time. By the implementation of slow steaming now the trip will take 23 days, "but in exchange we offer much higher reliability" (Maersk, 2012). Maersk and other carriers justifies the longer transit time by guarantying higher reliability of the shipping schedule. According to Maersk having a stable and reliable service is equally important as transit times. Financial benefits occur because shippers don't have to spent money and/or time to reschedule their cargo and can maintain lower inventory costs.

In this thesis the claim by shipping lines that the reliability improved due to the implementation of slow steaming will be questioned and researched. Therefore the following question will be answered in this thesis: *"Is the reliability of liner services improved due to slow steaming?"*

In order to come to this research question, the set-up of this thesis will be constructive towards answering the research question. First a literature review will be done of the existing literature concerning slow steaming, liner schedule design and reliability of liner shipping. Secondly, the background and main actors of the shipping industry will be discussed in order to understand the industry. Thirdly, the main consequences of slow steaming on shippers and carriers will be discussed in order to get a good image of slow steaming and its consequences. Hereafter the design of a liner schedule is examined, reliability of a liner schedule can be influenced by the design of a liner schedule thus this will be discussed. The overall global reliability of liner shipping will be discussed next. The importance, causes, consequences and improvement of reliability will be discussed next. A case study on Maersk and on the reliability of the AE10 loop will be discussed. After these sections a conclusion will follow with acknowledgments. Recently an extensive number of publications have been written about slow steaming. However, these publications mainly focus on the bunker costs savings, CO_2 reduction and overall cost and benefits of slow steaming. Nearly any publication acknowledges the reliability factor in relation to slow steaming. However, no other publication used an integrated analysis with real figures and numbers related to the change in reliability due to slow steaming.

2. Theoretical Background

Slow steaming is quite a new way of steaming, which is used in the shipping industry since 2007/2008. Before the presence of slow steaming, a few publications described the relation between fuel costs and speed. Even in 2006 Notteboom stated “There is an obvious trend in the modern container ship designs towards higher speeds and increasing speed margin, primarily for maintaining a tight sailing schedule with good frequency and reliability” (Notteboom T. , 2006). In this same paper Notteboom comes to the conclusion by using calculations for a certain shipping route that great benefits could be gained when decreasing cruising speed a few knots. It is remarkable that at that time, when this information was available and bunker prices were raising it was not considered by shipping lines to introduce slow steaming. According to Notteboom this was a result of “primarily for maintaining a tight sailing schedule with good frequency and reliability”. When in 2007/2008 bunker costs went sky high, finally shipping lines investigated the implementation of slow steaming. Some research and papers were published quickly after the presence of slow steaming as a trend of slow steaming rose in the industry.

As mentioned above, the publication of Notteboom in 2006 mentioned a relation between reducing cruising speed and bunker costs. However in this publication the relation wasn’t investigated extensively. In 2008, Notteboom and Vernimmen published a publication called “The Impact of Fuel Costs on Liner Service Design in Container Shipping” which investigated the advantages and disadvantages of reduced cruising speed (Notteboom & Vernimmen, 2008). The publication describes three main incentives of initiatives to counter rising bunker prices. The three main initiatives are “usage of cheaper grades of bunker fuel, actions in the field of vessel design and actions with regard to the commercial speed of the fleet and the scale of the vessels”. The usage of cheaper fuels can be accomplished by using other kind of fuels with other grading’s and potential energy levels. Designing more efficient vessels can reduce fuel consumption considerably; also polishing of propeller and rudder adjustments can contribute to lower fuel consumption. Further, the paper describes that by reducing cruising speed a few knots a fair amount of fuel costs can be saved. By using a graph, it's showed that consumption rises exponentially after a certain (optimal) cruising speed. The paper mainly focuses on reducing fuel costs by managing vessel speed and vessel scale. The paper acknowledges that in 2007, CMA CGM and Maersk Line reduced speed on certain vessels on certain routes but on a small scale. As a conclusion, Notteboom & Vernimmen describes that because of reducing cruise speed, adding new ships are needed to allow more efficient scheduling. The late adaption and integration of slow steaming by liner services due to rising bunker prices has a few reasons, namely: inertia, transit time concerns, increasing costs associated with fixing schedule integrity problems and fleet management issues (Notteboom & Vernimmen, 2008).

Reducing fuel consumption because of slow steaming doesn't only have advantages for shipping lines. Reducing the fuel burn results in less pollution, in particular reducing the CO2 emissions. Numerous publications are dedicated to the CO2 reduction thanks to the presence of slow steaming. The most recent publication concerning CO2 reduction is published by Cariou, which is published in 2011 named; "Is slow steaming a sustainable means of reducing CO2 emissions from container shipping?". In this article Cariou researched the CO2 reduction, which occurred from 2008 till 2010. He came to the conclusion that slow steaming reduced CO2 pollution by 11%. Further, the paper states that if bunker prices remain considerably high, the shipping lines will be motivated to keep slow steaming. Due to the minimal adaption of new technology in the shipping industry, the ease of which slow steaming can be implied is a great advantage (Cariou, 2011).

The most recent study which is done concerning the cost and benefits of the whole picture of slow steaming including carriers as well shippers is done by Maloni & et al. in 2013, named "Slow steaming impacts on ocean carriers and shippers". It states that slow steaming "Has the potential to significantly reduce fuel costs, lower CO2 emissions, absorb excess fleet capacity and improve schedule reliability". The model, which is used in the study, clarifies the benefits and costs for stakeholders as well on environmental and financial basis. When comparing slow steaming and extra slow steaming, it seems that extra slow steaming is the best option. However, the benefits, which occur from slow steaming, should create a financial equity across carriers and shippers. This can be achieved by bunker charge reductions. Generally speaking, extra slow steaming is beneficial for the carrier as well as the shipper (Maloni, 2013).

One of the main studies concerning the importance of reliability in liner shipping is done by Vernimmen & et al. in 2007, named “Schedule Unreliability in Liner Shipping: Origins and Consequences for the Hinterland Supply Chain”. According to this study, despite fixed-day weekly schedules, the schedule reliability is relatively low with significant variations between different shipping lines and trade routes. The main factor, which causes the delay, is port congestion and therefore the difference between supply and demand of terminal (operation). This delay affects the bottom-line profits for shippers and carriers. Because of schedule unreliability seaport terminals faces berth and yard planning problems. By presenting a case study of a part manufacturer in South Africa who needs spare parts from South America, the costs from a delay are revealed. Unreliability could also be caused due to the order of port of call and different kind of loops. The literature states “by modifying sailing speed at sea, shipping lines should be able to more or less accurately maintain the ship’s expected time of arrival in the first port of call” (Vernimmen, 2007).

A more numerical study on schedule reliability is done by Chung & Chiang with their work on “The Critical Factors: An Evaluation of Schedule Reliability in Liner Shipping” which was published in 2011. This study tries to weight the importance of schedule reliability for costumers of container shipping lines. This is done by questioning the costumers and asking them to value the different factors of schedule reliability in their supply chain. Chung & Chiang came to the conclusion that schedule reliability is very important for shippers and shipping lines. Further, liner carriers should plan sufficient buffer time in their schedules in order to tackle unexpected situations such as port congestion and bad weather conditions. The paper also states that “service quality and schedule reliability might have a bigger influence on freight rate negotiates between contracting parties” (Chung & Chiang, 2011).

The most recent and only paper which discusses the delivery reliability in relation with the impact of slow steaming is published by Lee in 2013 which is named “The Impact of Slow Ocean Steaming on Delivery Reliability and Fuel Consumption”. Firstly, the different aspects of schedule reliability is discussed and the impact of slow steaming on shippers. These aspects are supported by mathematical equations and Makrov chains. Lee states that due to slow steaming, the major disadvantage is the increased transit time. According to Lee, slow steaming creates flexibility in terms of speed, which will always yield better service quality. Lee states that reliability has become the new rate war in container service line transportation. Lee concludes that slow steaming with flexible speeds improves the service quality. This publication analyses the impact of reliability in theory, but it lacks any analysis of the actual improvement in reliability which is realized in the shipping industry (Lee, 2013).

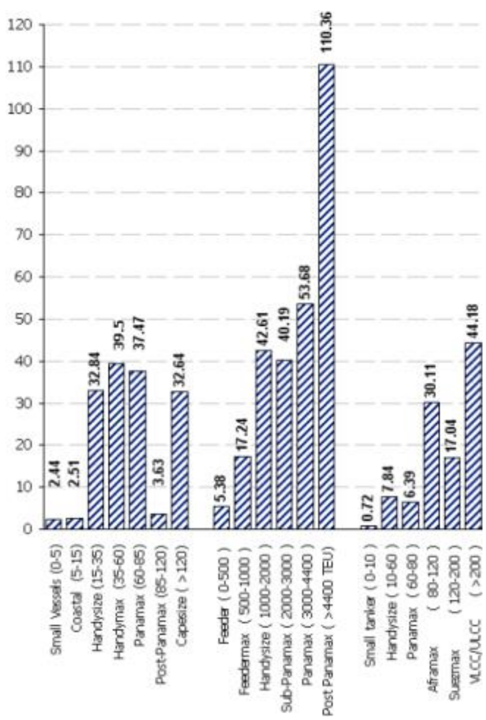
3. Industry background

Seaborne cargo transportation is by far the most used and common mode of transportation for cargo. More than 90 per cent of the global trade is carried by sea. A total of 8408 millions of tons of cargo was transported in 2010. Due to the great demand for seaborne transportation, a lot of players and segments are present in the shipping industry. The industry is divided in two main segments; the liner shipping which is involved in the transportation of the so-called “other dry cargo” and the bulk shipping, which is involved in the transportation of “main bulk”. Bulk shipping encounters 60% of seaborne transportation. Mainly due to the high oil transportation figures which encounters 32% of the total seaborne transportation (Nations, 2013). These two segments have a few market and infrastructure differences.

Liner shipping mainly transports goods, which are comparatively high-value manufactured, and semi manufactured goods with a high unit value (Parameswaran, 2004). The main market difference between liner and bulk shipping is that bulk shipping does not operate on a fixed schedule or route. Bulk shipping transports cargo direct from point A to point B. On the basis of demand for certain transportation, specific voyages are made on basis of short or long term contracts. Usually bulk shipping is located at the location where the demand is high at that moment of time on a certain location. Therefore an irregular performance of transport services and an open market characterizes the bulk shipping industry.

Besides the differences in market structures between the two main segments, different vessels which are used by these industries are also an important distinction to consider. The cargo, which is transported by liner shipping, allows different kind of ships with different characteristics. This due to the fact that liner shipping mainly transports containerized and standard dimension cargo. Vessels in the bulk shipping sector are mainly purpose-built for specific kind of cargo types (Parameswaran, 2004). Therefore the presence of niche markets, which supplies the transport of certain kind of bulk cargo, is a more common sight in bulk shipping.

In this thesis the bulk shipping won't be discussed. This thesis will only focus on liner shipping because of two main reasons: (1) The average CO2 pollution and therefore the usage of bunker fuel per tonnage is significantly lower in bulk shipping than in liner shipping (Psarafits & Kontovas, 2009) (see figure 1). Thus, much more is to be gained in terms of bunker fuel reduction in the liner shipping than in bulk shipping. This reflects in a survey, which is done by MAN in 2011, liner industry (container industry) reduces engine power significantly more than bulk shipping (MAN, 2011) (see figure 2). (2) In bulk shipping it's very difficult to determine reliability and on-time performance, as there are no (public) standard schedules. As mentioned above, the bulk shipping works on basis of short or long term contracts from point A to point B. No loops or standards port of call occurs in this industry.



	10-30%	20-40%	30-50%
Container	17.8	25.8	56.4
Bulk/Tank/others	5.9	11.9	82.2

Figure 2, typical engine load in slow steaming vessels in percentages (MAN, 2011)

Figure 1, CO2 emissions per vessel category in millions of tones (Psarafits & Kontovas, 2009)

In contrast to bulk shipping, liner shipping has standard loops and tight schedules which are publicly available. On-time performance of different shipping lines and routes are examined, so determine reliability for this industry is much easier and useful.

4. Structure and design of liner shipping

In this section a more in-depth approach into the system of liner shipping is discussed to get a view on all the actors and parties, which are involved in liner shipping. The relationships and interactions between the players will be discussed. It is important to discuss the structure of liner shipping on order to get a picture of how schedule reliability affects the different parties whom are involved in liner shipping. The implementation of slow steaming have some consequences for different actors and parties in the system of liner shipping which will be discussed later in this thesis.

4.1 Different parties in liner shipping

A publication, which is published by Ting, will be used to discuss the liner shipping system. The system starts with a demand for cargo transport by a shipper. A few options are available to ship the cargo from point A to point B. The shipper can contact directly a shipping company. This most direct way of arranging transport isn't used much in reality. Another way is through an agent. The agent acts as an intermediate between shipping line and shipper. This agent only encounters the transportation of cargo from port to port, no further transportation from/to hinterland is provided by an agent. The main tasks of an agent include obtaining all licenses, permits and approvals; Arrange container traffic and provide good customer service; Keep operation smooth and schedule punctual Collect freight (Ting, 2007).

Nevertheless, the most common used intermediate is through a freight forwarder. A freight forwarder concerns the transportation from door-to-door which is illustrated in figure 3. In the last decade a trend in vertical integration of freight forwarders occurs. This vertical integration of freight forwarders is to ensure higher reliability. On-time performance of a vessel is not enough to ensure reliability; freight forwarders are responsible for the transportation towards the costumer from/to the port. Therefore, shipping lines want to have as much influence possible on the transportation of goods which can be achieved by vertical integrating freight forwarders.

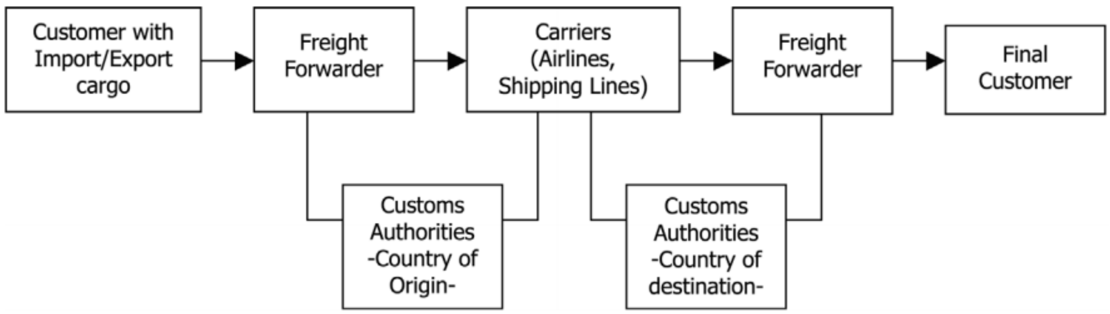


Figure 3, Structure of the freight forwarding industry (Bernal, Burr, & Johnsen, 1995)

Last but not least, a shipper could also by space from a non-vessel operating common carrier (NVOCC). A NVOCC is a cargo consolidator who buys space from a carrier and sells this space to smaller shippers.

With the implementation of slow steaming the parties who encounter the most significant and direct changes are the carriers and shippers. The carriers face lower fuel consumption and therefore lower bunker costs. The shippers face longer transit times and should reconsider their supply chain due to the changing transit times. Notteboom acknowledges that also terminal operators are important parties which are involved with the time schedules for liner shipping (Notteboom T. , 2006). Terminal operators face tight schedules that should be respected by carriers to ensure a fast and flawless operation of the terminal (Ting, 2007).

4.2 Structure of a liner service

The liner shipment which transport mainly containers, have a network that consists of nodes and links. Nodes are defined as “locations where container movement is interrupted and/or containers are handled”. Links between the nodes consists of hinterland transportation trough road, rail, inland waterway; which are supported by infrastructure such as roadway, canals, rail (Ting, 2007).

4.3 Design of a liner service

The design of liner shipping can be categorized in three main itineraries of operation. The three main itineraries are (1) End-to-end (2) Pendulum and (3) Round the world service routes. The (1) end-to-end service is a schedule of which vessels are going back and forth between two continents. (2) Pendulum service involves a schedule between three continents in which loops are used. The name of the (3) round the world service route speaks for itself; this involves a service route, which sails around the world in a particular direction. An overview of the three main itineraries is presented on figure 4. In this thesis, the reliability of loops are discussed, these loops are categorized as "Round the world service routes".

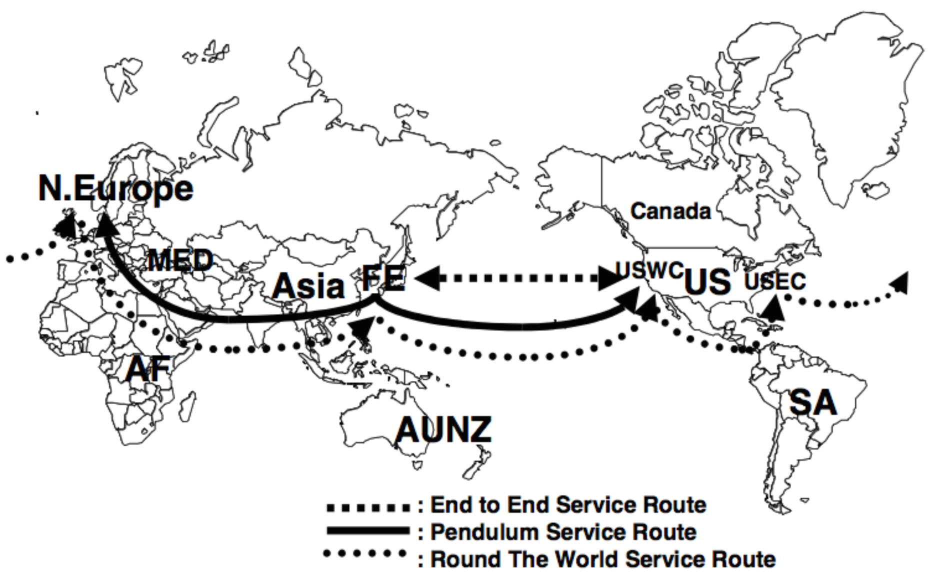


Figure 4, three types of liner service routes (Ting, 2007)

No matter which route itineraries or intermediate is used, containers will be unloaded or loaded in a certain port. Therefore a (container)terminal is needed. Terminal operators operate terminals. Carriers have contracts with terminals to load/unload their cargo. On their turn terminal operators rent land from the port(authority).

4.4 Conclusion

By discussing the structure of liner shipping it shows that schedule reliability will have the most impact on a shipper. The importance and impact of reliability on the shippers and shipping lines will be discussed further in chapter 7. As a shipper has the demand for transporting goods, this party will value its on-time delivery of goods the highest. Still, for a carrier, reliability is considered as an important factor too. It should be mentioned that besides these 2 main parties, ports are also considerably affected by schedule unreliability.

5. The effects of slow steaming

In this section of the thesis the implementation and effects of slow steaming will be discussed. This section is dived in certain sections according to the different consequences which come with slow steaming. In four different sections the effects of slow steaming will be discussed. This section will not discuss a full cost-benefit analyze of slow steaming because numerous publications already did those calculations. This section is intended to shape a picture of slow steaming and its consequences in order to look in to any change in reliability due to slow steaming later in this thesis. The following sub-question will be answered: *What are the main factors in liner shipping which are changed due to slow steaming?*

5.1 Main factor analysis of slow steaming

Firstly delimitation should be done to discuss the effects of slow steaming. As mentioned before in this thesis, only liner shipping will be discussed, as this section of the shipping industry is the most feasible in terms of slow steaming effects.

5.1.1 Time factor

The logical direct effect from slowing down is the time factor. By steaming at a slower speed, the total time it takes for a vessel to complete a journey increases. A formula for the total time that is needed for a vessel to complete a round voyage is described in a paper by Notteboom & Vernimmen, 2009.

(1) $T_R = \sum_{i=1}^{n} T_{pi} + \frac{D}{V*24}$

The following variables are used in the formula; T_r as round voyage in days, Tpi as total port time in port in i days; n as number of ports of call on a route; D as the distance of the round voyage in nautical miles (nm); V as vessel speed in knots (Notteboom & Vernimmen, 2008).

Now that a general formula for total voyage time is defined, a threshold regarding maximum trip time should be set with the following formula (Notteboom & Vernimmen, 2008).

(2) $T_r \leq \frac{S*7}{F}$

The following variables are used in the formula; S as number of ships deployed on the liner service and F as the frequency of the liner service in number of vessel calls per week in each port of call.

This formula makes clear that due to the lowering of speed, longer transit time occurs for a shipper and a decrease in frequency on a loop occurs. The consequences for both parties concerning the change in time will be discussed later in this thesis.

By using formula (1) and (2), the minimum required vessel speed needed to operate the liner service at a given frequency, number of port calls, round trip distance and number of ships can be derived.

(3) $V = \frac{D}{\left(\frac{S*7}{F} - \sum_{i=1}^{n} T_{pi}\right)*24}$

By using this formula the buffer time which is discussed earlier can be derived. By using this formula the speed on the vessel which is used on the AE10 route of Maersk can be analyzed. This is done in chapter 7.

5.1.2 Bunker costs

The main driving factor behind the implementation of slow steaming is the reduced fuel consumption. In a survey done by MAN, around 95% per cent of the carries defines fuel reduction as the most prominent reason for implementing slow steaming in its liner operation (MAN, 2011). In this section the effect of the lower bunker costs will be discussed for the carrier and shipper.

As the carrier pays directly for the bunker fuel, this party will benefit the most from the reduced bunker price. Steaming at full speed can be defined as an average speed of 24 knots that represents an engine capacity between 85-90 per cent (Bonney, 2012). A typical slow steaming speed is 21 knots. The potential reduced bunker cost in relation to speed reduction is highly significant. Fuel consumptions in relation to different speeds and size of vessels are highlighted in figure 1. According to Ronen, “reducing the cruising speed by 20% reduces daily bunker consumption by 50%” (Ronen, 2011). In an article by Bonney for a typical Europe-Asia service with an 8,500 TEU-vessel, the cost reduction could be 15 million dollars to 20 million dollars (Bonney & Leach, 2010).

A formula for calculating the daily fuel consumption on sea is available from a paper from Notteboom & Carriou, 2009:

$$(4)\quad {}^{FC_{mi1}}/_{at\ v_1} = {}^{FC_{mi1}}/_{at\ v_0} * (\frac{v_0}{v_1})^3$$

The following variables are used in this formula; FC as fuel consumption in tons per day; V1 as design speed; V0 as commercial speed.

In this formula it becomes clear steaming below design speed will exponentially decrease the fuel consumption of a vessel. Same goes for exceeding the design speed; this will exponentially increase the fuel consumption of a vessel.

These fuel consumption reductions are a significant cost reduction of the total ship operating costs for a vessel. According to WSC, bunker costs represents as much of 50 to 60 per cent of the total vessel operating costs (WSC, 2008). In figure 5 the relation between operation costs on a typical Europe-Asia shipping route with different vessel speeds is shown. This figure shows that a reduction of 40 to 50 per cent of bunker costs with relation to the total operation costs can be realized with a speed reduction of 12 knots. Even with an increasing number of vessels that need to be deployed to maintain the same frequency on the route that will be discussed further in this thesis, the overall operation costs decreases with 40 to 50 percent.

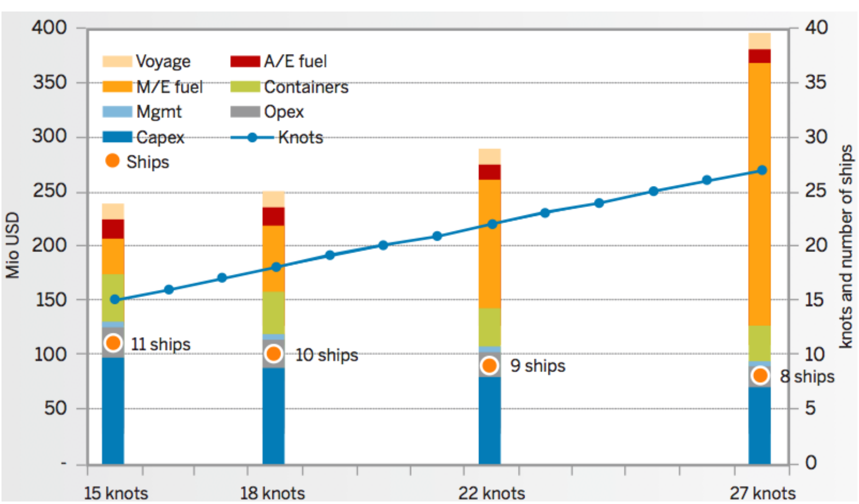


Figure 5, Total operating costs in relation with knots and number of ships for a typical Europa-Asia route (Rodrigue, 2009)

Bunker prices are quite volatile, therefore extra fuel surcharges above a standard bunker price in charged on shippers, also known as the Bunker Adjustment Factor (BAF). The BAF was introduced in 1974 after the first oil crises were bunker prices rose 500 percent. Since then the BAF is determined on liner conferences as a certain percentage of different classes of bunker prices. Since 2008 this conference is banned by the European Commission, from now on the carriers may use their own independent BAF rates, which are closely monitored by the European commission. From the web-based Maersk BAF calculator is the formula with variables can be derived (Maersk, 2014):

(5) Price * [(Vessel bunker consumption*Transit time*Imbalance factor)+(Reefer bunker consumption*Transit time)]

It appears that the BAF at Maersk is calculated on transit time and kind of container (Reefer or bunker). Notteboom & Cariou discussed the average BAF per FEU from the Port of Antwerp to another continent; this can be seen in figure 6.

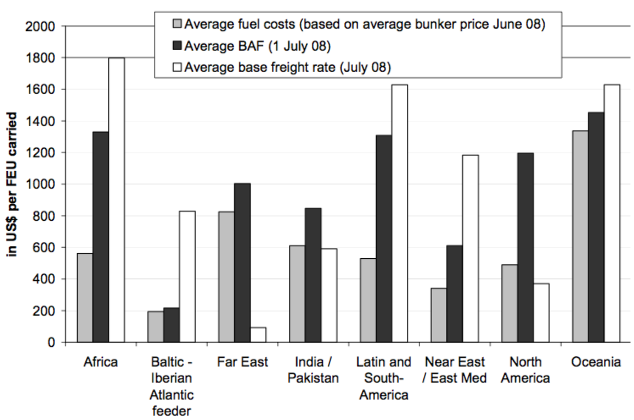


Figure 6, BAF, fuel costs and base freight rate per FEU – port-to-port relations with loading port Antwerp – figures relate to the situation in June-July 2008 (Notteboom & Carriou, 2009)

The decreasing bunker prices on a voyage of a vessel due to slow steaming are not considered to be significantly beneficial for shippers. Shippers often complained that the BAFs were nothing more than a revenue-maker for shipping lines. The BAF has become a considerable element in the price paid by the customers of carriers (Notteboom & Carriou, 2009). According to Notteboom it's not proven that carriers abuse the BAF to generate more profit.

Nevertheless, according to Notteboom “a combination of decreasing freight rates and decreasing fuel costs seems to give an incentive to shipping lines to stall the downward correction of the BAF’s” (Notteboom & Carriou, 2009).

5.1.3 CO2 reduction

Global climate change due to CO_2 emissions is a trend that the world discovered a few decades ago. However, before the usage of slow steaming as a standard, nearly any progress regarding reduction of CO_2 emissions was realized in the shipping industry. Fortunately due to the implementation of slow steaming, fuel consumption decreased. Therefore a significant CO_2 reduction is realized due to slow steaming. Mainly containerships are big CO_2 emitters in the shipping industry compared to their marginally presence of 4% of the total worldwide vessels. Due to their relatively high speeds and high engine loads the containership industry emit 230 mega metric tons (Mmt) of CO_2, this equals 22% of the total emissions from the shipping industry (Buhaug & al., 2009). A few publications about the amount of CO_2 emission in relation to fuel burned; Corbett states that the amount of CO_2 emitted per ton of (bunker)fuel lies around 3.17 kg of CO_2. Cariou calculated the total CO_2 reduction from the implementation of slow steaming from 2008 till 2010, a total of 11.2% of CO_2 reduction was realized with an average of 42.9% of ships that were slow steaming (Cariou, 2011). As mention before in this thesis, fuel consumption is exponentially related to the vessel’s speed. Therefore the CO_2 emissions are also exponentially related to cruising speed. In figure 7, the CO_2 emissions for different speeds are shown. Still due to increasing volume TEU estimations the CO_2 emissions will rise further compared to 2010. The different kinds of slow steaming are defined as: full steaming (24 knots), slow steaming (21 knots), extra slow steaming (18 knots) and super slow steaming (15 knots). From this figure it seems that a decrease of 43.3 per cent of CO_2 emissions can be realized by a reduction of speed from full speed to extra slow steaming (Maloni, 2013).

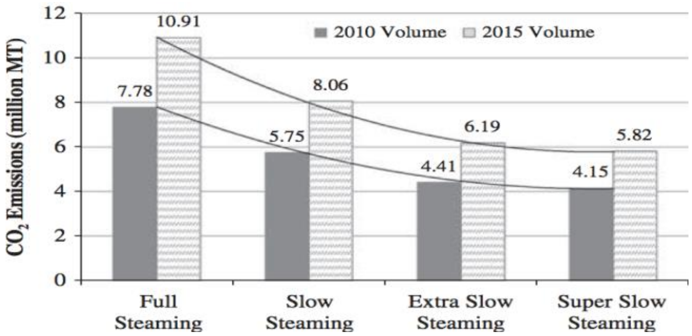


Figure 7, Annual CO_2 emissions (million MT) from vessels (2010 and 2015 volume) (Maloni, 2013)

Co2 emissions can considered as an external cost for carriers and shippers. However, Maloni attempted to create a model for establishing costs and benefits for carriers and shippers in relation to CO2 reduction. Maloni sets a cost of 50 dollars per ton CO2 for carriers. Concerning shippers, Maloni stated that shippers have an opportunity costs of 34.23 per ton CO2 concerning slow steaming (Maloni, 2013). This means that slow steaming is cheaper than every other project to reduce the carbon footprint which amounts more than 34.23 per ton CO2. The outcome of this model can be seen in figure 8.

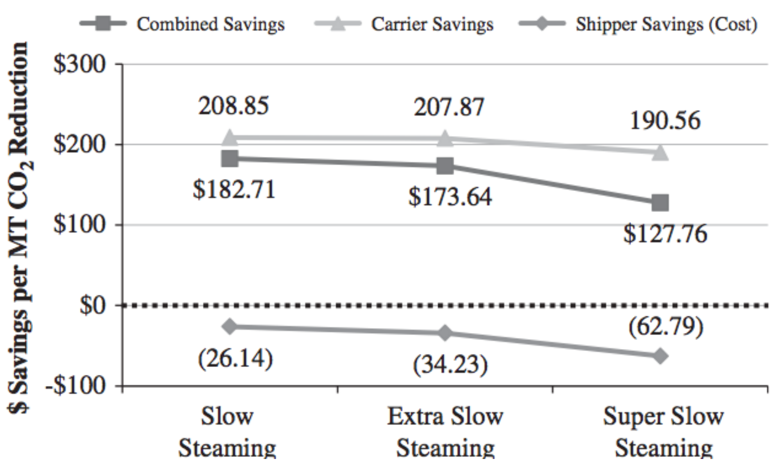


Figure 8, $US savings per metric ton of reduced CO_2 emissions (2010 volume; $700/MT fuel price) (Maloni, 2013)

5.1.4 Inventory Costs

Inventories exist at every phase of a supply chain as either raw material, semi-finished or finished goods. Inventory costs includes capital costs of a good, as well the (safety) stock which is held at the final destination in order to cope up with any variations in arrival time of the goods (Hummels, 2007). According to Shukla, the inventory costs for a certain good lies between 20-40% of their total value (Shukla, 2009). Therefore inventory costs are one of the main concerns for a shipper when shipping their cargo. Because of steaming at a slower speed inventory costs are a cost factor which should be considered for shippers. According to Notteboom the costs of an extra day of a TEU on sea consists of two costs: Opportunity costs which amounts 3-4,5 euro per day and economic depreciation which amount 10-30% per year for consumer goods. Notteboom has calculated the average value of goods per fully-laden TEU for Belgian-Asia import and export which amounts 40,000 euro for import goods and 15,000 euro for export goods (Notteboom T. , 2006). Although this data isn't very recent, other studies claim an average value of 21,000 dollars per TEU on a loop between Europe and Asia (Cowie, 2007). Therefore the inventory costs for each shipper is different as the inventory costs depends on the value of the shipped goods. A survey which is conducted by Centrx, BDP and St. Joseph's university states that 52% of the costumers of shipping lines acknowledge that due to the implementation of slow steaming their inventory costs are significantly affected (CENTRX, International, & University, 2013). Due to longer transit time which is caused by slow steaming, consignees need to maintain a higher (safety) stock in order to maintain a steady supply chain. According to Ganeshan & Harrison, a trade-off between inventory costs and transportation costs should be done in order to choose the best option for transporting goods (Ganeshan & Harrison, 1995).

6. Design of a liner service

In this section the design of a liner service will be discussed. This is done in order to understand and highlight the different aspects which a shipping line considers in order to provide certain reliability and service. Due to the implementation of slow steaming, different aspects of the design of a liner service have to change in order to keep a certain service level. In container liner shipping the scheduled basis of their operation is one of the key characterizing aspects. Numerous different factors are considered by a shipping line in order to design a liner service. Frequently changes are made to schedules, amount of vessels to deployed, ports of call, etc. due to a change in the markets or other external factors. In this section only the so called "line-bundling" (Round the World service route) type will be discussed. According to Notteboom, the line bundling type is the most used for liner shipping (Notteboom T. , 2006). Line bundling consists of a number of roundtrips which are operated by a number of vessels with a similar calling pattern of port calls and time intervals between two consecutive port calls. One round-trip is referred to as a loop.

The main design factors of a shipping route which are considered by a shipping line will be discussed. Container shipping routes are characterized and designed to have low operating costs, high frequencies, fast transit times and tight and reliable voyage schedules. To achieve this, the main design factors consist of:

- The service frequency. Most loops consist of a weekly service frequency. In other words, each port on a loop is served once a week by one vessel. The frequency of a route is determined by a trade-off between frequency and volume on the designated shipping route.

- Vessels deployed, vessel size and fleet mix. The size of containerships stills grows due to the worldwide economic growth and globalization. The average vessel size of the top-200 vessels have increased with 10,000 TEU over the past 20 years (Murphy, 2014). According to Cullinane & Khanna, the biggest vessels are deployed on the longest loops because economies of scale are more significant than on short routes (Cullinane & Khanna, 1999). The optimal number of vessels which need to be deployed to maintain a weekly frequency depends on the trade-off between speed and bunker costs. Generally the size of vessels on a loop is not homogenous. Different sizes of ships occur on a loop due to the slow and complex implementation of new vessels on a certain loop. However, it must be noted that mostly the variation in ship size on a loop is not significantly high. The number of vessels which should be deployed on a certain loop for a certain frequency and total days of loop time can be calculated by formula by Notteboom (Notteboom T. , 2006):

(6) $S = \frac{T_r * F}{7}$

With S as number of ships deployed on the liner service; T_r as round voyage in days, F as frequency of the liner service in vessel calls per week in each port of call.

- Number of port calls. The number of ports factor can be considered as the most important factor in the liner service design process. A logical relation between number of ports and number of days needed to complete a loop can be derived. By limiting the number of ports of call, fewer days are needed to complete a loop. On the other hand, by limiting the number of port calls on a loop, less accessibility is available for cargo shipments of shippers. However, according to Notteboom, high-order service networks will have fewer ports of call and bigger vessels than lower order networks. According to Notteboom & Carriou, congestion and/or port access are one of the main drivers of schedule unreliability. Therefore, high number of port calls probably means a higher probability of schedule unreliability (Notteboom & Carriou, 2009). The order of ports is also a consideration which is made by shipping lines. The order of ports of call is influenced by certain determinants such as cargo generation, distribution of hinterland, berth allocation profile and maritime access (Notteboom T. , 2006).

- Buffer time. This design factor is the most important factor concerning the reliability of a shipping line. Buffer time can easily be implemented on a shipping route by a shipping line with low costs and significant results. Using a high buffer time window for a shipping route allows the vessels to cope up with delays and disruptions without major schedule unreliability. According to Notteboom, “customers of shipping lines will accept inferior transit times in exchange for improved schedule integrity, resulting from additional buffer allowance” (Notteboom T. , 2006). It should be stated that increasing buffer time will result in longer transit time and can cause some delay at terminals because of early arrival at the berth.

Concluding concerning the design of a liner service it may be stated that carriers are constantly trading-off the different design factors in order to provide their customers the best services in terms of frequency, accessibility, transit times and reliability. Reliability of a shipping line will be affected by each of these factors. Therefore, by changing design factors, shipping lines will have to consider the effect on the reliability and should make a trade-off between reliability and its costs to ensure reliability.

7. Change in reliability due to slow steaming

In this section service line reliability will be discussed and investigated. This will be done by analyzing the global service line reliability. Firstly a definition of reliability will be stated. Thereafter the importance of schedule reliability for carries and shippers will be discussed. Next the different ways to tackle service unreliability will be discussed. Then the global liner shipping reliability will be discussed and measured before and after the implementation of slow steaming. Then the causes of schedule unreliability will be discussed. A conclusion concerning any changes in reliability due to slow steaming will be stated.

7.1 Definition

According to Notteboom reliability of a liner service network can be defined as “the probability that one or more of its links does not fail to function, according to a set standard operating variables” (Notteboom T. , 2006). This means that reliability not only depends on historic events but also concerns future actions and certainty of these actions. In this thesis service line reliability will be considered to be the same as schedule reliability (on-time performance of a vessel). In reality schedule reliability is just a part of service line reliability because more parties are involved in getting a container from point A to point B. Also terminal operators or hinterland transportation can cause disruptions which will result in unreliability of a liner service network even with an on-time performance of a vessel. Therefore schedule reliability will be used to measure the effects of slow steaming on shipping line reliability because schedule reliability can be measured by analyzing on-time performance of vessels and can be influenced by shipping lines.

7.2 Importance of reliability

Transit time and reliability are the most important factors concerning freight transport (Fowkes, 2004). Notteboom acknowledges increasing pressure on supply chains due to the implementation of just-in-time inventories. Shippers consider reliability as an important decision factor concerning which shipping line is best for their transportation of goods (Notteboom T. , 2006). Page stated that in recent negotiations, the priorities set by shippers towards carries are: service, reliability and price, in that order (Page, 2010). Therefore shipping lines are guarantying more on-time delivery and making firmer commitments towards shippers (Lee, 2013). Delay in delivery of goods will increase inventory costs for shippers because a safety stock should be held in order to operate their supply chain (Lee, 2013). However, schedule reliability is also important for carriers. Carriers who face delays on shipping routes might miss their berthing window in a terminal, which will cause extra delay. Also additional costs such as fixed daily ship costs, rescheduling cargo across vessels or ports, increasing speed and therefore bunker costs to make up for lost time (Notteboom T. , 2006). Also non-financial consequences can occur due to schedule unreliability, long term bad on-time performance can damage the image and reputation of a shipping line. It may be concluded that reliability of liner shipping is both important for shippers as well for carriers.

7.3 How to tackle service line unreliability

In this section different options to deal with service line unreliability form a shipping line perspective will be discussed. Numerous options are available for shipping lines in order to encounter service line unreliability. Notteboom discusses these options in his publication about the time factor in liner shipping (Notteboom T. , 2006). These different options for dealing with delays come with certain costs and consequences for shippers as well as carriers.

- Reshuffling the order of ports of call

  Notteboom acknowledges that reshuffling the order of ports of calls is common practice in the liner industry. This might coincides with discharging more import cargo at the first port of call or reshuffle cargo by hinterland transportation to a port of call which will be called later in a loop. This option isn't a very expensive manner to cope with schedule disruptions and can be very effective and efficient.

- Cancelation of port of call

  A shipping line can cancel a certain port of call to cut the total port time and to regain time to get back on schedule. Although this action can be very effective to get a vessel back on schedule, it has considerable consequences on the customer satisfaction which uses the canceled port of call. As a port of call is canceled, import and export cargo should be transported by intra-port transportation which should be paid by the shipping line. This option to increase schedule reliability can be considered as an expensive manner and with considerable consequences for shipper and carrier. Nevertheless, canceling ports of calls becomes more a rule instead of an exception according to Notteboom (Notteboom T. , 2006).

- Cut and run

  The cut and run principle implies that the loading off a vessel is stopped abruptly so that the vessel can leave the berth on time. By using this principle it means that certain cargo which should be loaded is left behind. This cargo will have to wait for the next vessel which arrives or is transported to another port which can load the cargo. This principle is mainly applied at port with limited maritime access such as the port of Antwerp or Hamburg were tidal windows should be respected. When a vessels doesn't depart on time in order to leave the port with respect to maritime access it will experience even more delay.

- Faster turnaround time in port

  A shipping line might try to achieve a faster turnaround time in a port of call. Notteboom states that certain ports/terminals are known for their efficient and fast turnaround times of a vessel. Shipping lines consider these ports/terminals as a certain "safe havens" were lost time can be recovered by increasing turnaround time of a vessel. This option comes at a low cost and doesn't include any consequences for shipper or carrier.

- Increasing vessel speed

  By increasing vessel speed, shipping lines can catch up time in order to regain the vessel schedule. This option has become the most applicable since the implementation of slow steaming. Because of slow steaming, a great buffer came available for shipping lines to increase speed and regain time on the vessel's schedule. As mentioned before, this option comes with significant bunker costs. These costs are borne by a shipping line. According to Notteboom, increasing vessel speed is only beneficial for a shipping line when the additional bunker costs are counterbalanced by savings in time costs. This option in order to regain schedule reliability may be considered as costly for a shipper but effective due to the larger buffer time which occurs due to the implementation of slow steaming.

7.4 Reliability in liner shipping

Measuring and analyzing the global reliability of liner shipping is not as convenient as it might look. As there are many variations of carriers and routes to consider. According to SeaIntel, the global schedule reliability in 2011 accounts for 62% of the delayed containers worldwide (SeaIntel, 2012). As mentioned before in this thesis, schedule reliability is an important factor in consideration in choosing the right shipping line. Large deviations between liner services occur regarding schedule reliability. Shipping lines value schedule integrity differently and therefore the shipping lines anticipate differently on solving any disruptions or delays. Schedule reliability is one of the factors which determine the price which is paid by costumers of shipping lines. For example, Maersk is one of the most reliable shipping lines in contrast to low-cost carrier MSC. This difference in reliability comes with a price; rates of Maersk are substantially higher than MSC (Notteboom T. , 2006).

7.4.1 Global liner reliability before implementation of slow steaming

Drewry and SeaIntel provide the data which will be used to analyze the global liner reliability before and after the implementation of slow steaming. In order to understand interpret the data on a good manner, the data collection and usage should be discussed. Drewry obtains and interprets its figures by measuring the deviation between published vessel arrivals at a single destination port against the actual arrivals. A vessel is considered to be “on time” if it arrives on the scheduled day of arrival or on the day immediately before the scheduled day of arrival. So, not on-time means a delay of minimal 24 hours after the scheduled arrival.

The data concerning global reliability in liner shipping before the implementation of slow steaming is obtained from Drewry. This data ranges from the 3th quarter of 2007 till the 2th quarter of 2009. The first implementation of slow steaming is considered to be in 2008. As this implementation of slow steaming was only done by a few shipping lines, the period till the second quarter of 2009 which is analyzed, is considered to be before the implementation of slow steaming. In figure 9 the schedule reliability in percentages is showed for this period. It shows that the reliability is relatively low before the implementation of slow steaming. The average global reliability in liner shipping amounts 44,5%[1]. This means that more than 50% of liner shipping lines arrive one day or more behind the published schedule.

[1] Based on own calculations

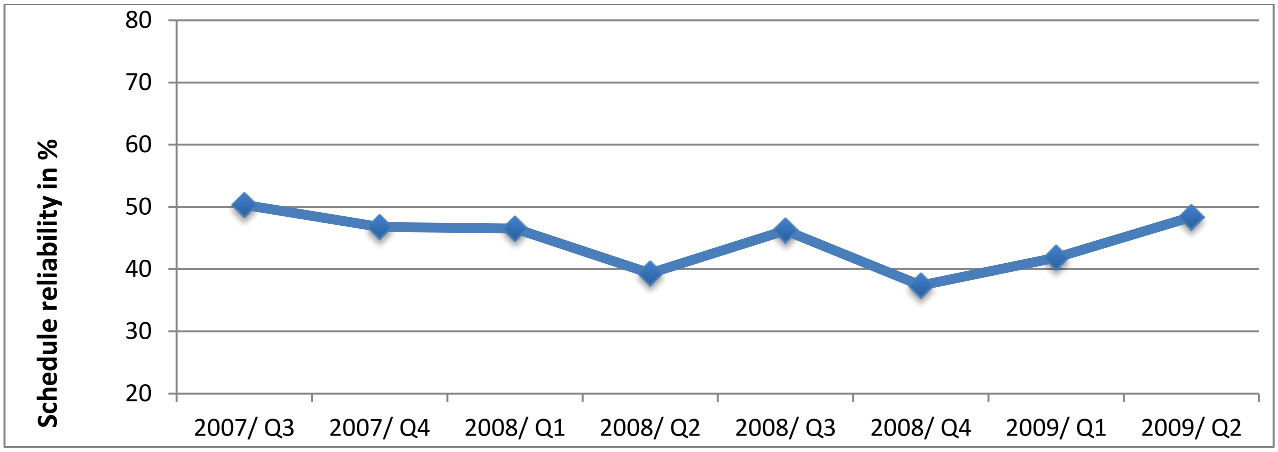


figure 9, Schedule reliability before slow steaming from 2007 till 2009 (Drewry, Carrier Performance Insight, 2010)

7.4.2 Global liner reliability after implementation of slow steaming

For analyzing the global liner reliability after implementation of slow steaming, data from SeaIntel is used. Same as the methodology of Drewry, SeaIntel defines on time as an arrival according to schedule on the scheduled day or one day before. SeaIntel measures the global liner reliability on the basis of all vessels arrivals recorded in SeaIntel's global liner Performance database compared to their published scheduled arrivals. Each vessel arrival is only counted once in the global performance, irrespective of the number of container carriers that may be onboard a given services (SeaIntel, 2014)

The period of the analysis ranges from the third quarter of 2011 and ends in the first quarter of 2014. This period can be considered as a period in which the global implementation of slow steaming of the top-20 liner carriers occurred. In figure 10 the different reliability levels of each quarter is shown. Relatively high schedule reliability can be observed. A global average of nearly 80%[2] is achieved by shipping lines. By analyzing this data it may be stated that the global schedule reliability of carriers after the implementation of slow steaming may be regarded as high.

[2] Based on own calculations of data provided by SeaIntel

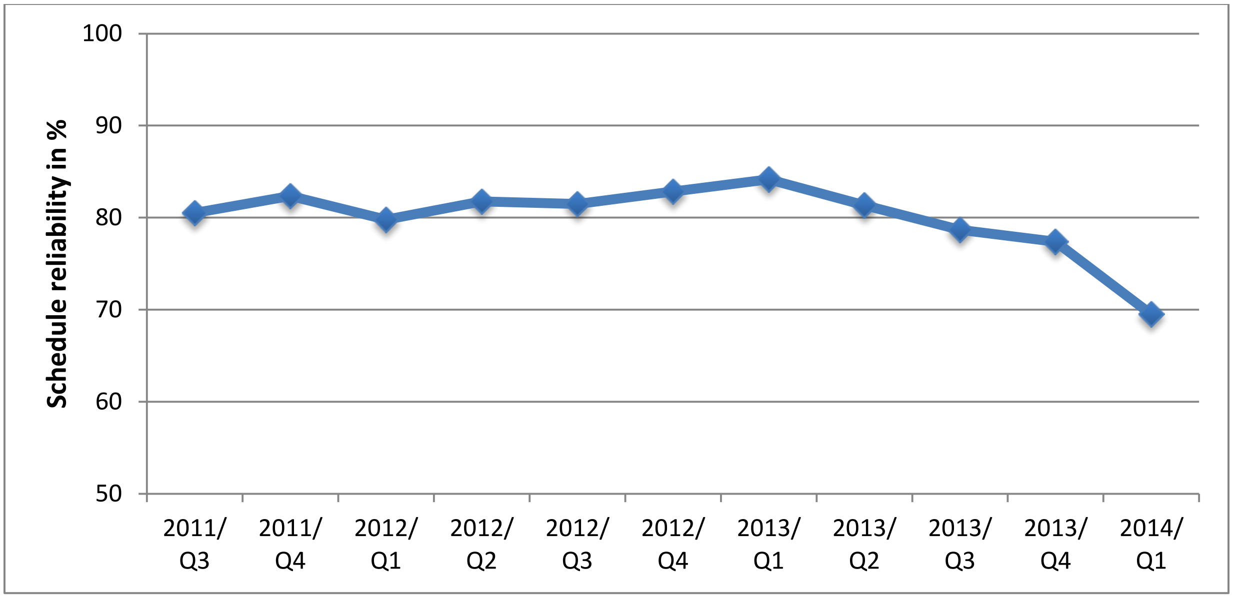


Figure 10, Schedule reliability after slow steaming from 2011 till 2014 (SeaIntel, 2014)

7.4.3 Conclusion

Comparing the period before slow steaming and the period after slow steaming, a significant difference in schedule reliability can be observed. No certainty concerning the causes of this change in reliability can be stated. However, by the implementation of slow steaming, buffer time on each leg increases significantly. Therefore increased ability to speed up as mentioned in section 7.3 in order to catch up on schedule could be an explaining factor for the change in reliability before and after slow steaming. Flexible speed, which can be implemented due to slow steaming, will always yield higher service reliability compared to fast steaming (Lee, 2013). It's also plausible that due to the better on-time performance of vessels, ports can achieve higher efficiency due to a strict birth planning. As mentioned by Notteboom, port congestion is one of the most important causes of schedule unreliability (Notteboom T. , 2006). So, the two most plausible explanations for the change in reliability are the extended ability to speed up and more efficient port handling due to better on-time performance of vessels. As mentioned before, a great improvement in schedule reliability is achieved by the top-20 shipping lines after the implementation of slow steaming. It should be noted that there are a few disturbances in this data which should be considered in taking a conclusion. The data before and after the implementation of slow steaming, is derived from two different sources. The two different sources seem to analyze the data on the same way, but a few deviations in calculations or interpretation could be present. Therefore a (small) bias in data could be possible. Second, the data only encounters the top-20 carriers on all trade lines. It's plausible that there is a great variance present in the reliability of each carrier separately. Further, other drivers of liners shipping aren't included in this data such as traffic volume index, major global route disruptions, etc. Nevertheless, besides these considerations it may be stated that generally the reliability of liner shipping is improved after the implementation of slow steaming. These results shows that the claim of shipping lines that reliability has been improved by the implementation of slow steaming might be true. In the next section of this thesis, a more in-depth analyze will be done.

7.5 Causes of service line (un)reliability

In this section the different causes of service line unreliability (schedule unreliability) will be discussed. Only delays which are related to vessel operations will be discussed. Notteboom acknowledges four main causes of delays which will be discussed: terminal operations, port access, maritime passages and chance (Notteboom T. , 2006). The different disruptions are shown in figure 11.

- Terminal operations

  Due to the rising worldwide trade and increasing size in vessels and port/terminal congestion or unexpected waiting times before berthing or before start loading/discharging, delays in port had become rather a rule than an exception. Port congestion can disrupt a vessel schedule completely which will result in schedule unreliability. Besides port congestion, port/terminal productivity is an important factor which can contributes to schedule (un)reliability. Productivity of a port is a factor which is considered to be an important design factor of a loop. Flexibility of a terminal is also taken in to account. A terminal which operates efficiently, flexible and have strict berth windows can be of great value in order to ensure reliability towards costumers of shipping lines (Notteboom, 2006). Therefore an ongoing trend of vertical integration of terminals into shipping lines is rising to ensure a reliable terminal at important ports of call.

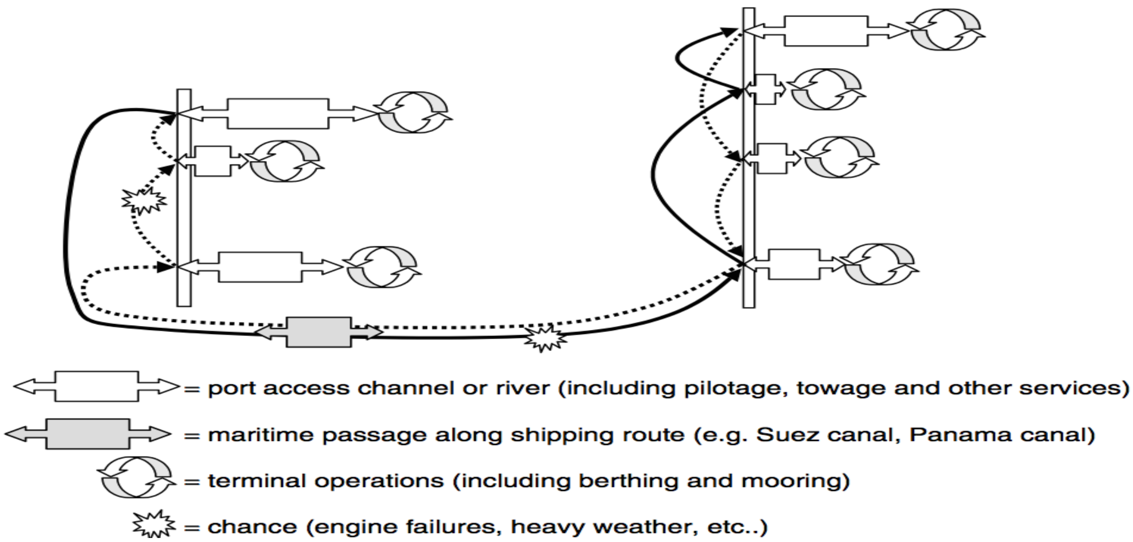


Figure 11, disruptions which can occur in a loop (Notteboom T. , 2006)

- Port access

  Major disruptions in port access can occur when a vessels wants to enter/exit a port of call. These disruptions range from unexpected waiting time due to pilotage or towage services to delays at sea locks or not able to access a port due to tidal windows. With the increasing vessel size port access becomes more relevant than ever before. Especially tidal windows are becoming a major concern of shipping lines. In Europe various ports such as Antwerp and Hamburg have constantly been deepening its maritime access to cope up with the growing draft of big vessels (Notteboom T. , 2006) . According to Notteboom, unexpected vessel waiting times in one port cascade throughout the whole loop" (Notteboom T. , 2006). So it's quite important to limit the port delays as much as possible

- Maritime passage

  Besides ports, maritime passages are also becoming a factor which should be considered in a vessel voyage. The most important passages are the Suez Canal and the Panama Canal. These canals have a maximal capacity and draft. The maximum draft of the Suez Canal is 20 meters. Because a maximum capacity of a certain number of ships and the narrow passage, vessels need to sail the passage in a convoy. These convoys depart each 12 hours, when a container vessel arrives late at the Canal, a vessel will have an additional waiting time of up to 12 hours. Shipping lines will reserve a place for their vessels to ensure passage of the canal. Due to slow steaming the ability to arrive on time for maritime passage may be considered as higher. There is room for vessels to catch up time by increasing speed.

- Chance

  Disturbances due to chance consist of unexpected waiting time due to weather circumstances, mechanical problems or waiting time at a bunkering site. Weather is a factor which can't be predicted but may cause serious schedule disruptions. According to Maersk, 42% of schedule disturbances on their shipping routes are caused by weather disruptions (Maersk, 2011). It should be noted that by slow steaming, more time on sea is spent and therefore the chance of any schedule disruption due to weather increases. According to Notteboom whom stated that in 2006 before the implementation of slow steaming, "the time buffers shipping lines build in their liner service schedules are typically very low. By the adaption of slow steaming, buffer time increased significantly as disruptions can be encountered by increasing steaming speed to catch up on the vessels schedule. It may be concluded that with the adaption of slow steaming, the increased reliability which is discussed previously in this thesis, may be addressed to the increasing buffer times and the easier adaption of schedule disruptions which is cause by chance.

7.6 Consequences of unreliability in liner service shipping

A logical and direct consequence of unreliability for shippers in liner shipping is the rise of inventory- and deprecation costs. An unreliable supply of goods can disrupt a supply chain which will cause a rise of costs (Vernimmen, 2007). An average cost of deprecation is difficult to set because the deprecation of a good is in direct relation with its value. If a shipping line is expected to be unreliable, a high safety stock should be maintained in order to cope with the unreliability. Due to the increasing safety stock it's made sure that any supply disruptions can be anticipated.

For shipping lines schedule reliability has it consequences as well. Shipping lines will have to have their vessels sail at faster speeds in order to recover any lost time. Rescheduling of vessels and therefore change in productivity of container handling will decrease the image and service level of a shipping line which comes at great costs (Smedts, 2011).

Concerning ports and terminals, schedule unreliability will cause vessels to miss their planned birthing window, which in their turn cause a disruption in the berthing schedule of a terminal or a port. This rescheduling of berthing windows and the stack of cargo which will increase terminal congestion comes at great costs for terminal operators. Therefore terminal operators also benefit from schedule reliability in liner shipping.

8. Case study: Reliability of Maersk

In this section the reliability of the largest shipping line worldwide and the leading shipping line concerning the implementation of slow steaming will be discussed with a case study. By using a case study the change in reliability due to slow steaming can be analyzed in a better fashion than analyzing the global liner reliability. Maersk is analyzed because this shipping line has implemented slow steaming as one of the first shipping lines in the world. Since July 2008, the average speed of the Maersk fleets had been decreased by 27% (Reinhardt, Casadesus-Masanell, & Nellemann, 2012). Due to the broad adaption of slow steaming in the fleet of Maersk, a plausible comparison between the reliability before and after the implementation of slow steaming can be done.

8.1 Global reliability of Maersk before and after implementation of slow steaming

By using data from SeaIntel and Drewry, the reliability levels of Maersk from 2006 till 2014 have been plotted in figure 12. A rising trend line in schedule reliability of Maersk can be derived. Especially the figures onwards 2008 when slow steaming was adopted are interesting. A sharp rise in schedule reliability which starts from 2008/ Q1 is shown. Besides a major decrease in 2009/ Q4 and 2010/ Q4 the average reliability rose significantly. By comparing the two years before slow steaming and the two years after slow steaming, it shows that the average reliability from 2006 till the end of 2007 amounts 62,3%[3] compared to a reliability level of 71,6%[4] from 2008 till the end of 2009. With this figures in mind it seems that the schedule reliability of Maersk has increased significantly since the implementation of slow steaming.

---

[3] Based on own calculations from SeaIntel data (2006-2007)

[4] Based on own calculations from SeaIntel data (2007-2008)

These figures are in line with the goals of Maersk because Maersk values schedule reliability as one of the most important services which can be offered to its customers (Maersk, 2012).

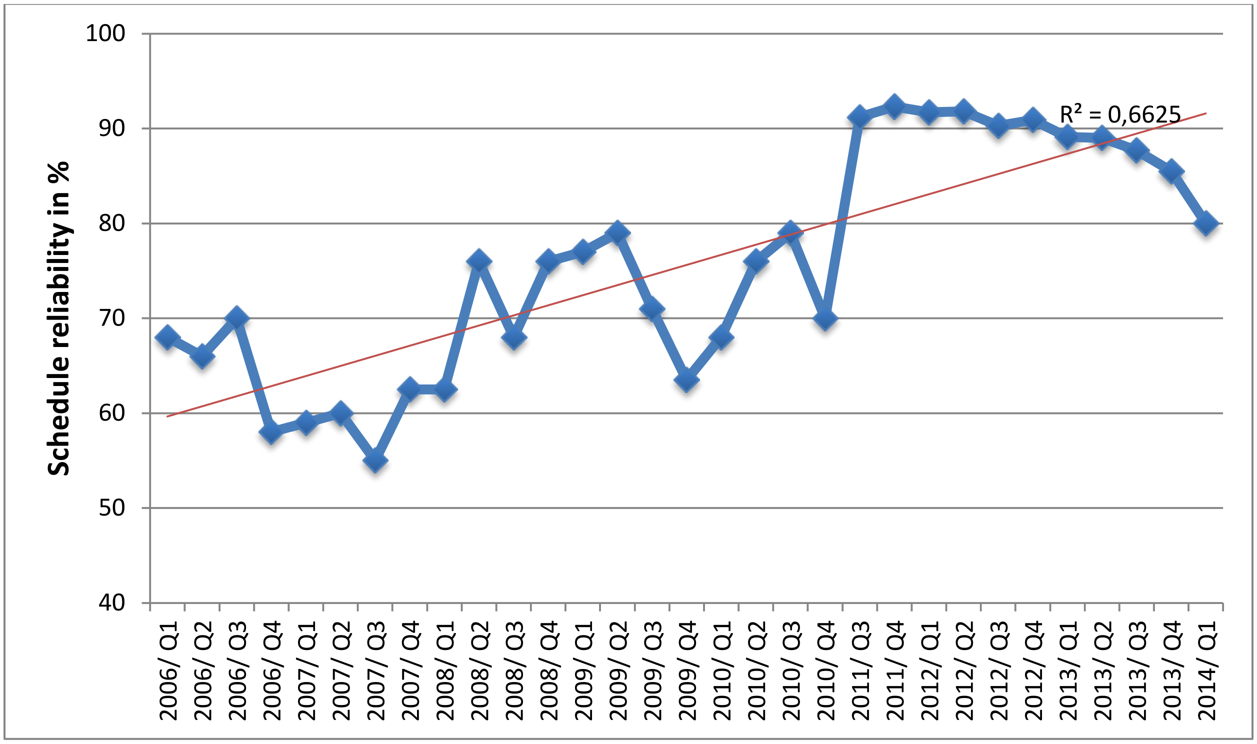


Figure 12, Maersk schedule reliability 2006-2014 (Seaintel/Drewry 2010)

8.2 Analyze of AE10 route

For this case study the reliability of the AE10 (Asia-Europe 10) route will be analyzed. The reason for choosing this particular line and route is because Maersk is the largest shipping line in the world and is considered by Drewry to maintain the highest schedule reliability in the industry (Drewry, 2014). By implementing slow steaming as one of the first shipping lines in the world, Maersk is considered to be a leading shipping line in terms of slow steaming throughout their vessel fleet. Additional, Maersk claims that due to slow steaming it can maintain higher schedule reliability. A shipping route between Europe and Asia is chosen because according to Cariou 74.8% of the vessels on this shipping route in implemented slow steaming in 2010 (Cariou, 2011) . It may be assumed that that figure is even higher nowadays.

The “Asia-Europe AE10” route consists of a loop between Asia and North-Europe (see figure 13).

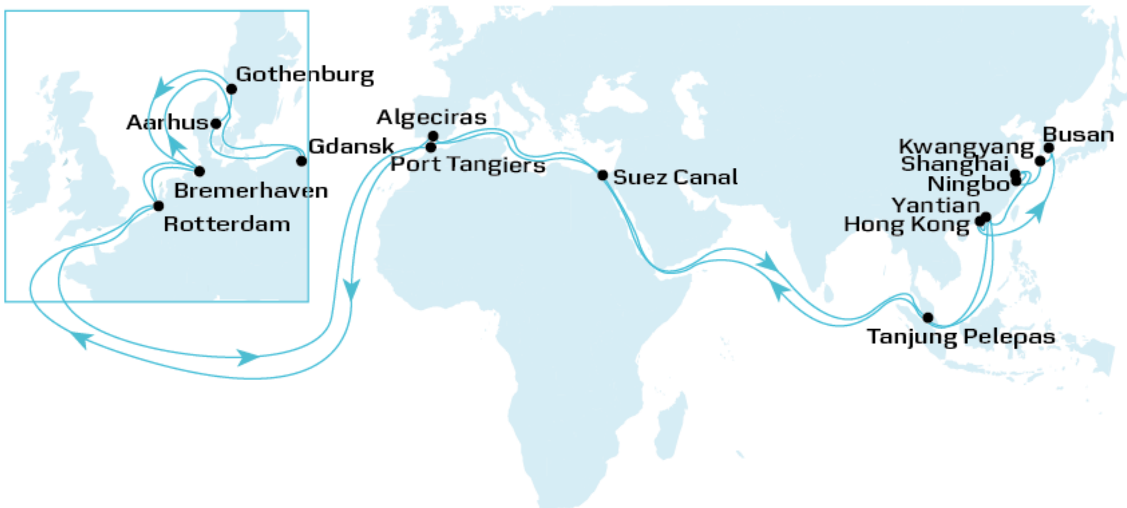


Figure 13, Maersk Europe Asia Line 10 (Maersk, 2014)

On this route Maersk deploys 15 vessels, which serves 19 ports on a weekly basis. The total time for one round-trip (loop) amounts 84 days (Maersk, 2014). On the basis of appendix A it shows that different vessels with different capacity are deployed on this route. The total TEU capacity of vessels amounts 265,740 TEU, calculations shows a mean of 17,716 TEU per vessel. This is route generally served by the so called E-class from Maersk. These vessels belong to the biggest containerships in the world. Therefore a huge capacity of TEU is available on this route provided by mainly Maersk.

8.3 Reliability of AE10 route

In this section the reliability figures of the AE10 route will be analyzed. In order to get some reference material, firstly the reliability off the top 20- carriers that operates on the Europe-Asia loop will be analyzed against the reliability of Maersk on this route. Thereafter the reliability of the A10 route of Maersk will be looked into.

8.3.1 Liner service reliability of Europe-Asia loop

The data which is used for the Europe-Asia loop is provided by SeaIntel. The received data starts in July 2011, no data from before the first implementation of slow steaming is available because before 2011 no data was obtained by SeaIntel concerning the reliability of vessels and routes. Thus, the difference in reliability after and before slow steaming cannot be measured. But it may be assumed that since 2011 a growing number of vessels are slow steaming. SeaIntel divides the reliability of the loop of the Europe-Asia routes in two different segments namely: eastbound and westbound. By calculation the average between eastbound and westbound the values of each month(s) are obtained. The “average of all carriers” contains the average of all the top-20 carriers which operates Europe-Asia loops. Concerning Maersk, the average of their 10 different Europe-Asia loops is used.

A rising trend line in the average reliability of Maersk can be derived from figure 14. Concerning the global average of all carriers, only a large increase in reliability occurs between March and December 2011. After this large increase, the reliability slightly decreases each month. No extensive research is done on these sudden large deviations. The deviations could be explained by the implementation of slow steaming at that time, but it seems unlikely that this is the only factors which caused the sudden increase in reliability as the change in reliability will be smoother. Despite the uncertainty of the sudden increase, it should be remarked that the overall reliability in 2011 till 2013 has increased. But a downward trend is present from December 2011. In the next section a more in-depth analyses will be done why the reliability of Maersk is significantly higher than the average of all carriers.

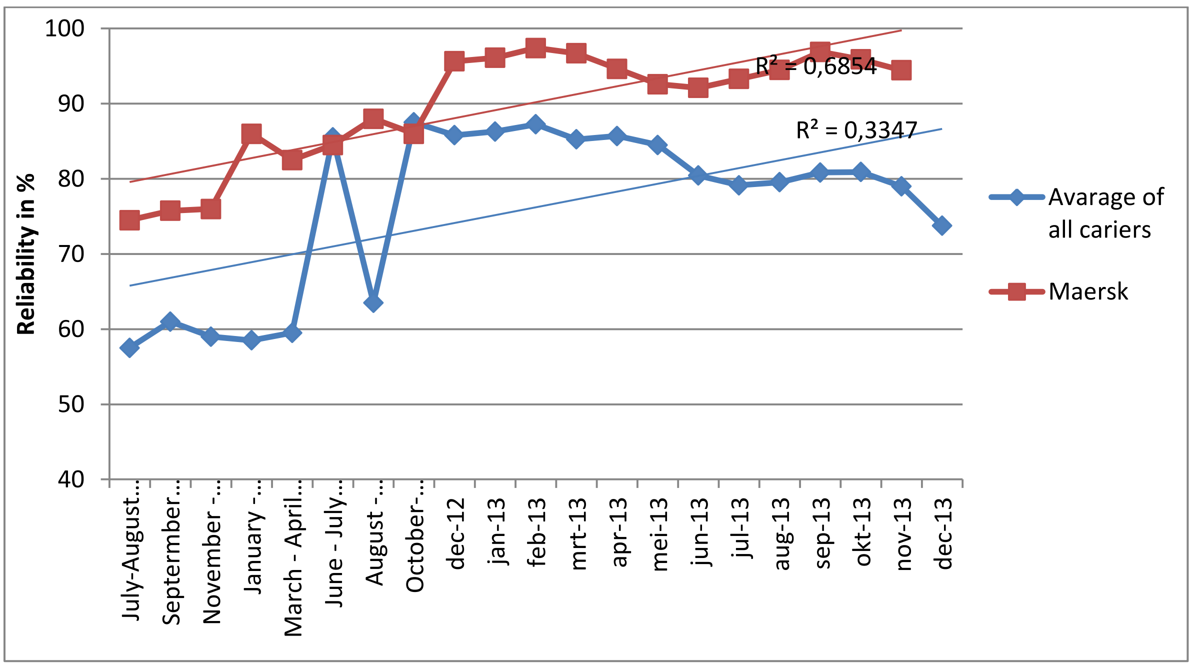


Figure 14, Schedule reliability Europe-Asia loop (SeaIntel, 2014)

8.3.2 Maersk AE10 reliability

The reliability of the AE10 route is divided in two different sections: Eastbound (Europe to Asia) and Westbound (Asia to Europe). This segmentation is very useful as different average speeds are applied on these legs. The speeds on the westbound legs are higher than the speeds on the eastbound legs, due to the fact that the most valuable goods move from Asia to Europe. On the eastbound legs a lot of empty TEU or low value cargo is transported. Therefore the inventory and depreciation costs are significantly lower, so lower speeds can be applied.

The reliability of the AE10 route can be found in appendix B, the graph can be found in figure 15. The data covers the reliability from September 2011 till January 2014. The average reliability of the AE10 route can be considered as very high, especially compared to the average Asia-Europe loop reliability of the top-20 carriers. The difference in reliability of the eastbound and westbound legs is significant till March 2013. From March 2013 the reliability of the two legs is roughly identical. It's remarkable that from March 2013 the reliability is roughly 100%.

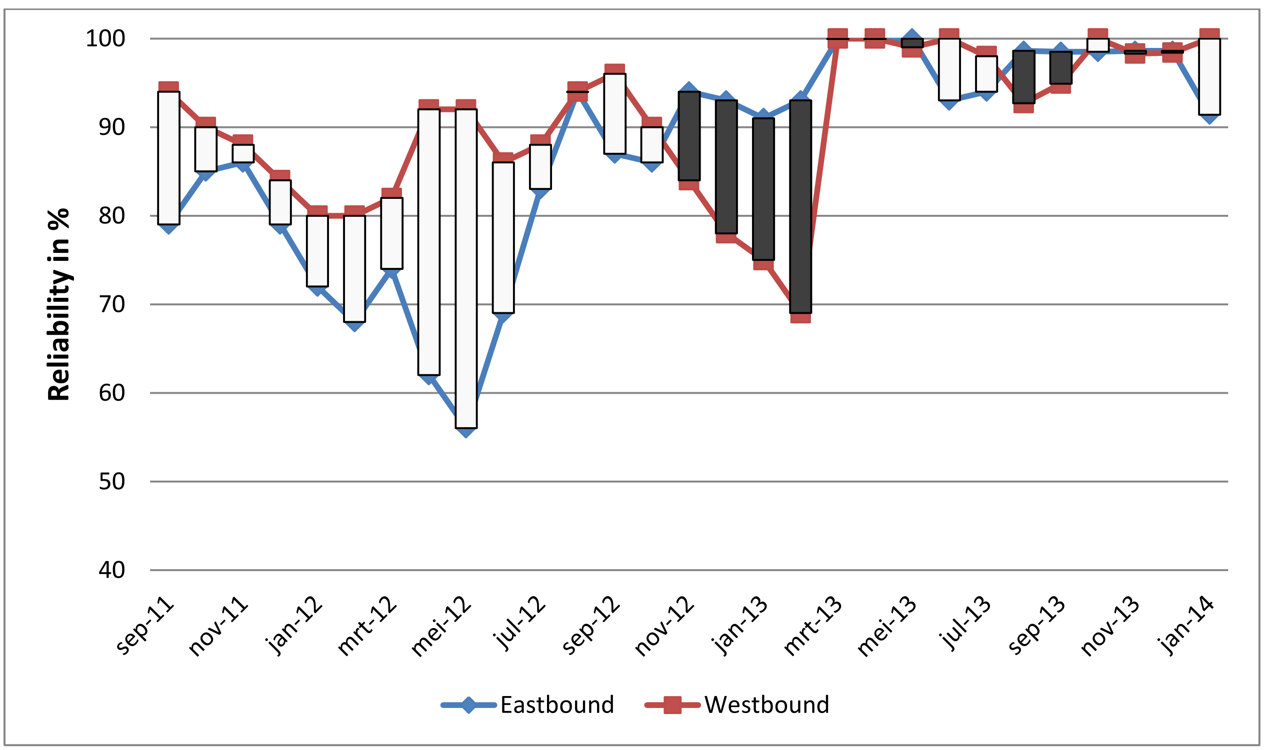


Figure 15, Reliability of AE10 loop from September 2011 till January 2014 (SeaIntel, 2014)

It may be stated that the AE10 is a very reliable loop, especially the past year. How is it possible that Maersk maintain such a high reliability of its AE10 loop? And can this be fed back due to slow steaming? As stated by Notteboom and by Maersk themselves, by the implementation of slow steaming, buffer time increased. Therefore it is possible to speed up their vessels in order to catch up time when any disruption in the schedule occurs. According to Notteboom, Maersk uses a significant high buffer time in their schedules compared to the industry standard (Notteboom T. , 2006).

The buffer time which is used by Maersk can be roughly be estimated. To obtain the used buffer time, a few calculations should be done. These calculations will be done by analyzing one particular vessel which operates the AE10 loop. The vessel which will be analyzed is called the "Emma Maersk". This vessel had a capacity of 14660 TEU, which is close to the average TEU per vessel which is used for the AE10 loop. Firstly, the schedule of the vessel should be retrieved.

Port of call	Arrival date	Arrival time	Departure date	Departure time	Port time	Distance
Busan	15-sep-14	17:00	16-sep-14	12:00	0,8	0
Kwangyang	16-sep-14	19:00	17-sep-14	12:00	0,7	91
Ningbo	18-sep-14	15:00	19-sep-14	14:00	1,0	474
Shanghai	20-sep-14	8:00	21-sep-14	9:00	1,0	163
Yantian	24-sep-14	6:00	24-sep-14	20:00	0,6	858
Tanjung Pelepas	27-sep-14	21:00	29-sep-14	3:00	1,2	1498
Suez Canal	10-okt-14	2:00	10-okt-14	17:00	0,6	5029
Algeciras	14-okt-14	20:00	15-okt-14	8:00	0,5	1966
Rotterdam	18-okt-14	7:30	18-okt-14	23:00	0,6	1141
Bremerhaven	19-okt-14	23:59	20-okt-14	22:00	0,9	262
Gdansk	22-okt-14	22:00	25-okt-14	17:00	2,8	870
Aarhus	27-okt-14	6:00	27-okt-14	22:00	0,7	427
Gothenburg	28-okt-14	7:00	29-okt-14	7:00	1,0	126
Bremerhaven	30-okt-14	22:00	1-nov-14	6:00	0,3	374
Rotterdam	2-nov-14	3:30	2-nov-14	23:00	0,8	262
Port Tangier	6-nov-14	23:00	8-nov-14	7:00	1,3	1386
Suez Canal	13-nov-14	19:00	14-nov-14	17:00	0,9	1987
Tanjung Pelepas	28-nov-14	3:00	29-nov-14	7:00	1,2	5029
Yantian	4-dec-14	0:01	5-dec-14	1:00	1,0	1498
Hong Kong	5-dec-14	10:00	5-dec-14	21:00	0,5	55
Busan	8-dec-14	17:00				1148

Figure 16, Sailing schedule Emma Maersk A10 loop (Maersk, 2014)

By using the vessel schedule the total port time at each port can be calculated. These values are needed to calculate the minimum required vessel speed. For the calculation of the minimum required vessel speed, the formula of Notteboom will be used which is discussed earlier.

The variables should be set first in order to calculate the minimum required vessels speed. The total distance of the AE10 loop amounts 24644 nautical mile; Total vessels which are deployed: 15 vessels; Frequency is set to once a week; Total time in port is set at 18,5 days. By using equation 3) the minimum average speed which should be sailed in order to complete the loop following the mentioned variables amounts 15,6 knots[5].

This speed can be definitely defined as slow steaming speed. However, it should be noted that for each leg different speeds are sailed according to the schedule of the AE10 loop. In figure 17 the different scheduled speeds which are sailed for each leg of the AE10 loop is shown.

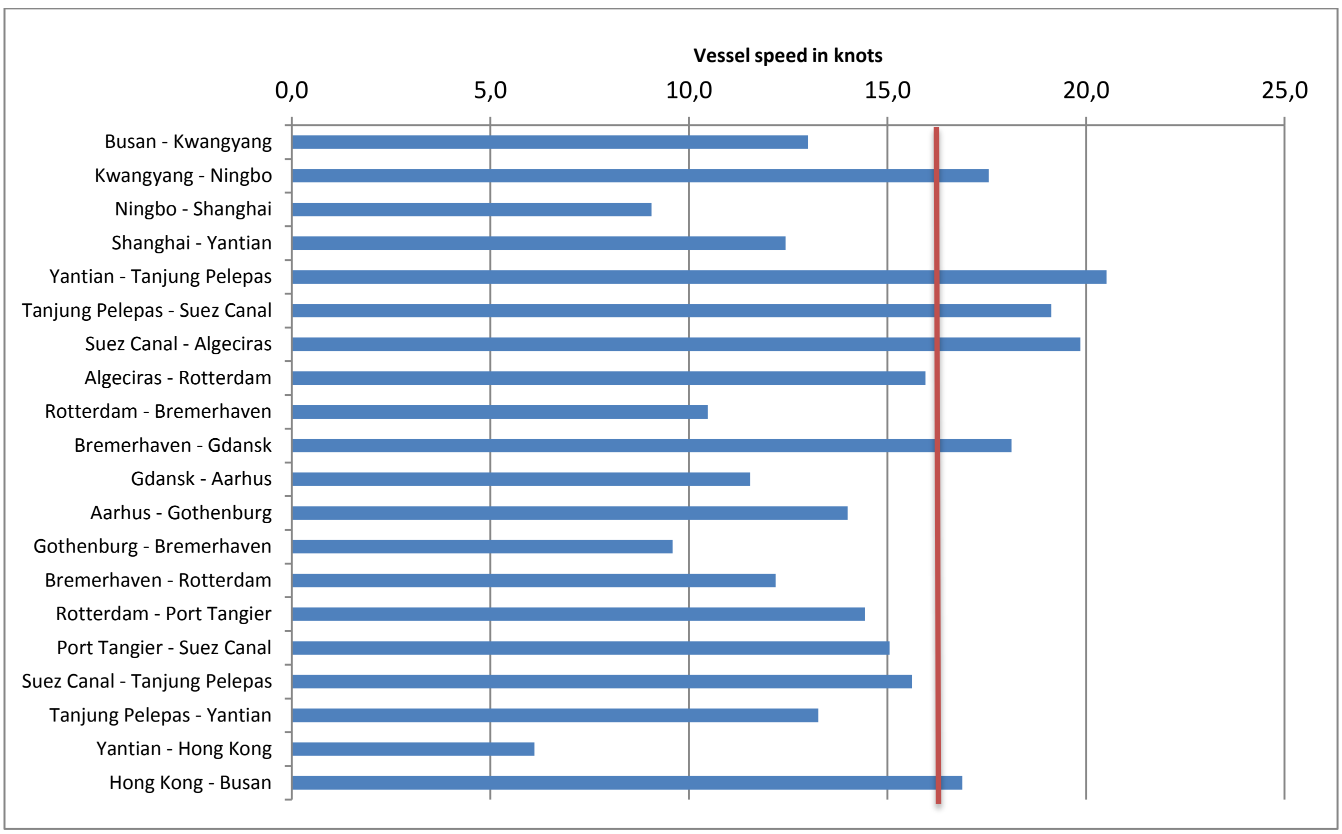


Figure 17, scheduled average speed on legs of AE10 loop (Own calculations)

[5] $84 = 18.5 + \frac{24644}{v*24} = 15.6$

Significant variation in speed which is sailed for each leg can be observed. The red line in figure 17 illustrates the average speed of 15,6 knots which is calculated. On a few legs, especially the long distance legs and the westbound legs, higher speeds are sailed. But on the most legs, scheduled speeds are below the average slow steaming sailing speed. This shows that Maersk schedules a considerable buffer time on the legs of the AE10 loop. By scheduling this buffer time, vessels can easily increase speed, even not higher than the standard slow steaming speed of 16 knots and still make up time for any schedule disruptions. The buffer time which is used by Maersk for its AE10 loop can be estimated by calculating the deviation of the time difference between scheduled vessel speed and the standard slow steaming speed of 16 knots. In figure 18 the deviations compared to the standard slow steaming speed of 16 knots on each leg of the AE10 loop can be derived. Figure 18 shows on which legs Maersk expects any disruptions which are indicated by positive values of deviation. Legs were Maersk expects no disruptions are indicated by negative values of deviation which means no or negative buffer time.

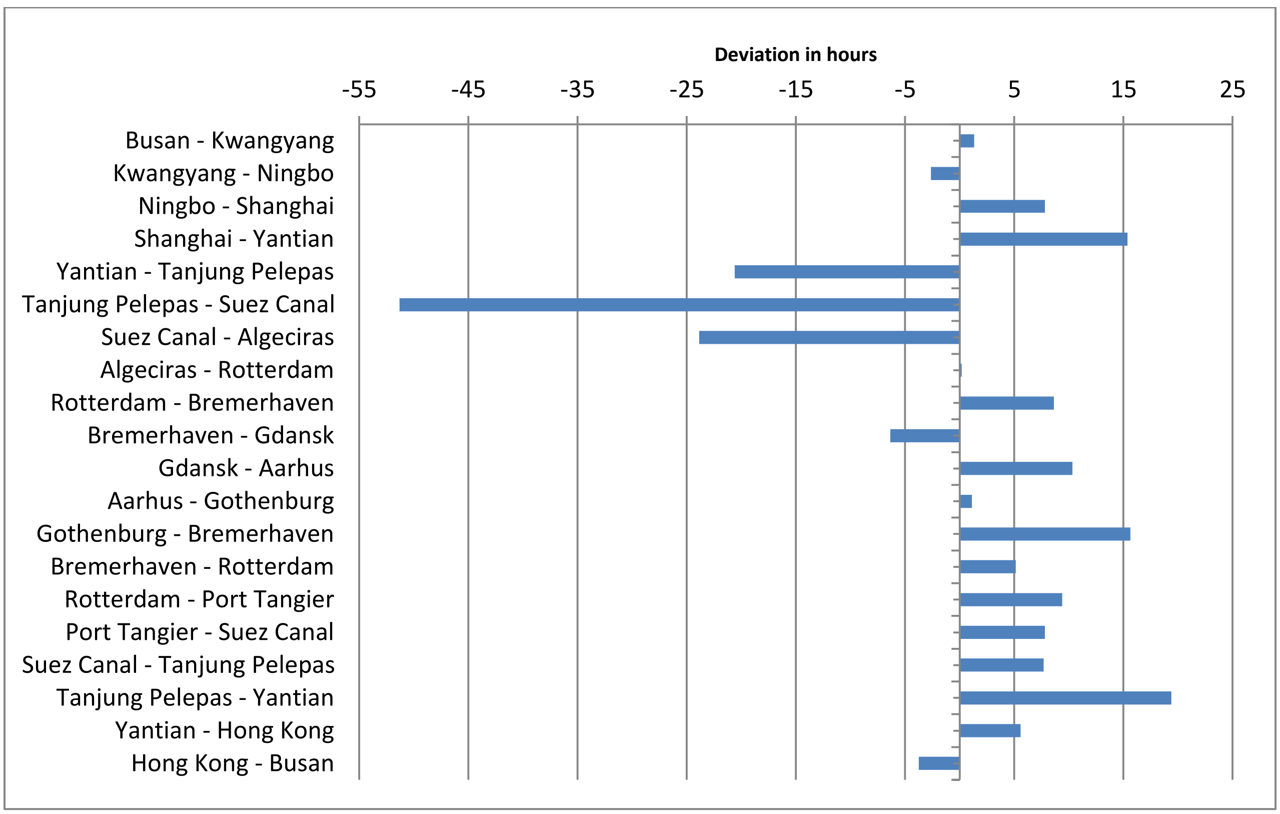


Figure 18, deviation between actual vessel speed and slow steaming speed of 16 knots (Own calculations)

Now that the schedule of the AE10 loop is discussed, a comparison with the actual service speed which is applied on the loop can be made. According to Drewry, the average service speed of the AE10 loop for the westbound leg amounts 20,1 knots. The service speed on the eastbound leg amounts 14,2 (Drewry, 2014). According to the schedule of Maersk the service speed on the westbound leg amounts 14,5 knots and the eastbound leg amounts 17,6 knots. This means that on the eastbound leg, nearly any increased vessel speed is applied on this leg. This could imply that that nearly any schedule disruptions occurs on this leg. In contradiction of the eastbound leg, the actual sailing speed on the westbound leg is significantly higher than the scheduled service speed. This implies that vessels increased speed in order to make up time which occurred due to any schedule disruptions. These findings are in line with the applied buffer time which is calculated before. The buffer time on the eastbound leg is significantly higher than on the westbound leg. So, on the eastbound leg, no increasing service speed needs to be applied in order to be on time.

8.3.3 Conclusion

The results of the analysis of the AE10 loop of Maersk are quite clear. The reliability is very high and has even achieved a reliability of nearly 100% in the last months of 2013. By discussing and analyzing the buffer time which is applied on the AE10 loop, it became clear that Maersk implements a significant buffer time. By comparing the scheduled and the actual speeds which are sailed, it becomes clear that Maersk speeds up on certain legs of the AE10 loop and manages to achieve a high on-time performance. This case study clarifies the main advantage in terms of increased buffer time due to slow steaming which implies high reliability. Maersk uses this buffer time in order to speed up and achieve high reliability for its customers. However, it should be noted that this case study doesn’t clarifies any increased reliability of other carriers or routes. As mentioned before, Maersk is the leading shipping line in the world with a modern fleet which can apply slow steaming and is known for their high reliability. Prices of Maersk are significantly higher than other carriers as mentioned by Notteboom. Also it should be noted that Maersk regards reliability as one of their main goals, other carries might value reliability less and therefore make less use of the increased ability due to slow steaming to achieve higher reliability.

9. Conclusion

Slow steaming is nowadays implemented industry wide in the container liner shipping industry. Shippers had to deal with the consequences of the increased transit time due to slow steaming which was initiated by shipping lines. With the implementation of slow steaming, shipping lines promises higher reliability to their customers in order to compensate the increased transit time. This thesis analyzed and researched that particular claim of shipping lines by answering the following research question;

Is the reliability of liner services improved due to slow steaming?

The first section of the thesis discussed what slow steaming is and what sort of effects it has on shippers and shipping lines. The main factors, which were mentioned included: the time factor, bunker costs, CO2 reduction and inventory costs of goods. Concluding, the most important factor and direct consequence of slow steaming is the increased transit time, increasing inventory costs and bunker costs reductions due to slower steaming speeds.

After this section the change in global liner shipping reliability was analyzed. Therefore the importance of reliability has been discussed. It became clear that since recent years a shift of focus of the shortest transit times to the highest reliability arose in the shipping line industry. Reliability is nowadays one the most important discussions in contract negotiations. Because of this importance of offering high reliability to its customers, different ways to achieve high reliability is discussed. Actions such as reshuffling the order of ports of call, cut and run, increasing vessel speed, cancelation of port and more efficient port handling.

The global reliability of the top-20 carriers before and after the implementation of slow steaming has been analyzed. A significant higher reliability after the implementation of slow steaming is observed than after the implementation of slow steaming. This difference can mainly be explained by the fact that the buffer time increases as steaming speed decreases. Due to the slower steaming speed, more time is available to speed up and to catch up on the vessels schedule which increases reliability. Due to the higher on-time performance of vessels, strict birth planning in ports can be exercised which causes a higher reliability due to efficient port handling. On a global level, it may be stated that the reliability of the top-20 carriers has increased compared to the period before slow steaming. However, due to the large dataset and great variations between different carriers, it's difficult to state that the increased reliability is solely due to slow steaming. Furthermore, due to a usage of two different datasets concerning the periods before and after the implementation of slow steaming, some bias may occur in the processing of the datasets.

In order to measure the change of reliability due to slow steaming more in depth, the AE10 route of Maersk was analyzed in a case study. Maersk is a leading player in the shipping line industry concerning the implementation of slow steaming on their fleet. By analyzing this particular loop from Asia to Europe, a trend in increasing reliability can be observed. Due to the lack of data from before the implementation of slow steaming, it's hard to compare this with a period before the implementation of slow steaming. However, it may be stated that since the start of the dataset in 2011, Maersk introduced the new so called E-class vessels on this particular loop. According to Maersk, all of the E-class vessels are slow steaming on their voyages. So, the increased reliability from the beginning of the dataset in 2011 till 2014 which is observed on the AE10 loop can be derived due to increasing slow steaming practices of Maersk on this particular loop. Due to slow steaming significant buffer times are present on the AE10 loop. As shown in own calculations, Maersk has a lot of buffer time implemented in their schedule in order to catch up if needed. Due to this fact, the high reliability levels are significantly higher than the competition. According to Notteboom, Maersk is one of the most expensive but reliable carriers in the industry, this due to the extensive buffer time which is implemented in their vessels schedule (Notteboom T. , 2006). However, it should be noted that Maersk regards reliability as one of their main goals; other carries might value reliability less and therefore make less use of the increased ability due to slow steaming to achieve higher reliability.

Concluding, the claim of shipping lines that reliability is improved due to slow steaming seems to be valid. This can be stated because the overall reliability before the implementation of slow steaming throughout the shipping industry is lower than the reliability after the implementation of slow steaming. The dataset ranges from 2006 till 2014 which is quite a long and reliable period of time. A sharp increase in the period 2008/2009 can be observed, which the time in which is slow steaming is implemented in the industry. However, the increase in reliability is quite small and significant differences in term of schedule reliability between different carriers and routes should occur and should be considered.

Acknowledgment

This thesis researched the reliability on a global level which included the top-20 carriers and a lot of different loops. Further research could be done on the reliability levels of individual carriers and routes compared to their percentage of vessels which practices slow steaming on these routes. As each shipping line operates on different terms and values reliability differently, a better picture than could be shaped if there is a change in reliability and if it’s caused by slow steaming or another factor.

Due to slow steaming, transit times increased and therefore the time on sea is longer. As stated by Maersk, weather is one of the main factors which cause disruptions in their schedule. Further research could be done on the increased chance of disruptions due to weather which arise due to longer time on sea. It could be so that the extra ability to catch up on schedule due to slow steaming is limited due to the increased chance of bad weather conditions.

An extensive research on the increased reliability on ports due to slow steaming could be interesting. As stated in different literature, port congestion is one of the main causes of schedule disruptions. The increased reliability due to the ability to maintain a strict birth planning schedule which is caused by slow steaming could be done with a quantitative research.

References

Bernal, S., Burr, C., & Johnsen, R. (1995). Competitor networks: international competitiveness through collaboration: The case of small freight forwarders in the High-Tech Forwarder Network. *International Journal of Entrepreneurial Behaviour & Research*, 239-253.

Bonney, J. (2012). *Drewry Forecasts rough seas for container lines*. Retrieved July 25, 2014, from The Journal of Commerce Online: http://www.joc.com/maritime-news/container-lines/drewry-forecasts-rough-seas-con- tainer-lines_20121010.html

Bonney, J., & Leach, P. (2010, February 1). *Slow Boat from China*. Retrieved July 25, 2014, from JOC: http://www.joc.com/maritime-news/slow-boat-china_20100201.html

Buhaug, O., & al., e. (2009). *Second IMO Greenhouse Gas Study.* London: International Maritime Organization.

Bunkerindex. (2014, July 26). *Bunker Prices Rotterdam*. Retrieved from Bunkerindex: http://www.bunkerindex.com/prices/portfreels_xmdo.php?port_id=637

Cariou, P. (2011). Is Slow Steaming a Sustainable means of reducing co2 emissions from container shipping? *Transport Research*, 260-264.

CENTRX, International, B., & University, S. J. (2013). *Managing your International Supply Chain, What Companies are saying about the impacts of slow steaming.*

Chung, C., & Chiang, C. (2011). The Critical Factors: An Evaluation of Schedule Reliability in Liner Shipping. *International Journal of Operations Research* , 3-9.

Cowie, A. (2007). *Cargo Accumulation.* New York: AIMU/IMUA Seminar.

Cullinane, K. P., & Khanna, M. (1999). Economies of scale in large container ships. *Journal of Transport Economics and policy*, 185-208.

Drewry. (2010). *Carrier Performance Insight.* London: Drewry.

Drewry. (2014). *Carrier Peformance Insight.* London: Drewry.

Fowkes, A. (2004). How highly does the freight transport industry value journey time reliability - and for what reasons? *International Journal of Logistics*, 33-43.

Ganeshan, R., & Harrison, T. (1995). *An Introduction to Supply Chain Management.*

Hummels, D. (2007). Transportation Costs and International Trade in the Second Era of Globalization. *Journal of Economic Perspectives*, 131-154.

Lee, C. (2013). *The Impact of Slow Ocean Steaming On Delivery Reliability and Fuel Consumption.* Hong Kong: The Hong Kong University of Science and Technology.

Maersk. (2011). *Terminal Partnering Project.* Shanghai: Maersk.

Maersk. (2012). *Slow Steaming, The Full Story.* Copenhagen: Maersk.

Maersk. (2014). *Asia - Europe (AE10) - Roundtrip*. Retrieved August 14, 2014, from Maersk Line: http://www.maerskline.com/en-us/shipping-services/routenet/maersk-line-network/asia-europe/ae10-roundtrip

Maersk. (2014). *BunkerAdjustment Factor Formula*. Retrieved July 25, 2014, from Maersk Line: http://baf.maerskline.com/AboutBAF.aspx?FromCountry=511&ToCountry=411&ContainerType=9

Maloni, M. (2013). Slow Steaming Impacts on Ocean Carriers and Shippers. *Maritime Economics & Logistics*, 151-171.

MAN. (2011). *Slow Steaming Practices in the Global Shipping Industry.* Munich: MAN PrimeSerc.

Mclean, A., & Biles, W. E. (2008). *A Simulation Approach to the Evaluation of Operational Costs and Performance in Liner Shipping Operations.* Winter: Simulation Conference.

Murphy, A. (2014). *Trade Route Intelligence & The Global Liner Shipping Outlook.* Shanghai: SeaIntel Maritime Analysis.

Nations, U. (2013). *Review Of Maritime Transport.* New York: United Nations.

Notteboom, T. (2006). The Time Factor in Liner Shipping Services. *Maritime Economics & Logistics*, 19-39.

Notteboom, T., & Carriou, P. (2009). *Fuel surcharge practices of container shipping lines: Is is about cost recovery or revenue making?* Copenhagen: International Association of Maritime Economists (IAME).

Notteboom, T., & Vernimmen, B. (2008). *The Impcat of Fuel Costs on Liner Service Design in Container Shipping.* Dalian: International Association of Maritime Economists (IAME).

Page, P. (2010). Reality shows. *Journal of Commerce*, 4.

Parameswaran, B. (2004). *The Liberalization of Maritime Transport Services.* Hamburg: Springer.

Psarafits, H., & Kontovas, C. (2009). Co2 Emmisions Statistics for the World Commercial Fleet. *WMU Journal of Maritime Affairs*, 1642-1654.

Reinhardt, F., Casadesus-Masanell, R., & Nellemann, F. (2012). *Maersk Line and the Future of Container Shipping.* Harvard: Harvard Business School.

Rodrigue, J. (2009). *The Geography of Transport Systems*. Retrieved July 25, 2014, from Hofstra: http://people.hofstra.edu/geotrans/eng/ch8en/conc8en/fuel_consumption_containerships.html

Ronen, D. (2011). The Effect Of Oil Price On Containership Speed and Fleet Size. *Journal of the Operational Research Society*, 211-216.

SeaIntel. (2012). *Global Liner Schedule Realiability.* Copenhagen: SeaIntel.

SeaIntel. (2014). *Global Liner Schedule Reliability.* London: SeaIntel.

Shukla, R. (2009). *Process of Developing and Integrating Skilled Workers.* New Delhi: Global India Publications Pvt Ltd.

Smedts, M. (2011). *Evaluating Performance in the Transportation Chain: the Effect of Schedule Reliability.* Eindhoven: TU Eindhoven.

Ting, E. (2007). *Liner Shipping Operations.* Taiwan: Department of Transportation and Navigation Science.

Vernimmen, B. (2007). Schedule Unreliability in Liner Shipping: Orgins and Consequences for the Hinterland Supply Chain. *Maritime Economics & Logistics*, 193-213.

WSC. (2008). *Liner Ship Design*. Retrieved July 25, 2014, from World Shipping Council: http://www.worldshipping.org/pressroom/news-archive

Wurst, S., & Cremon, M. (2003). *Supply Chain and Logistics in the Supply Chain and Logistics in the Maritime Indusrty - Dialogue on Future Scenarios.* Delft: Wondermar Workshop.

Appendices

Appendix A

Vessel	Capacity in TEU
Magleby Maersk	18270
Evelyn Maerk	15500
Mary Maersk	18270
Marstal Maersk	18270
Edith Maersk	15500
Elly Maersk	15500
Maersk M. Moller	18270
Matz Maersk	18270
Madison Maersk	18270
Maribo Maersk	18270
Marie Maersk	18270
Majectic Maersk	18270
Mayview Maersk	18270
Merete Maersk	18270
Mogens Maersk	18270
Total	265740
Mean	17716

(Maersk, 2014)

Appendix B

Maersk AE10 line reliability		
	Eastbound	Westbound
sep-11	79	94
okt-11	85	90
nov-11	86	88
dec-11	79	84
jan-12	72	80
feb-12	68	80
mrt-12	74	82
apr-12	62	92
mei-12	56	92
jun-12	69	86
jul-12	83	88
aug-12	94	94
sep-12	87	96
okt-12	86	90
nov-12	94	84
dec-12	93	78
jan-13	91	75
feb-13	93	69
mrt-13	100	100
apr-13	100	100
mei-13	100	99
jun-13	93	100
jul-13	94	98
aug-13	98,6	92,7
sep-13	98,5	94,9
okt-13	98,5	100
nov-13	98,6	98,3
dec-13	98,6	98,4
jan-14	91,4	100
Mean	87,0	90,5

(SeaIntel, 2014)